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PRESIDENT'S REPORT ISSUE 1962

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The Corporation

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Report of the President

One year ago I began my report to the Corporation by recalling some of the highlights of our first century. The events of the brilliant Centennial Celebration of the preceding April were still fresh in mind. But with the conclusion of those ceremonies there has remained no further desire to look back, no time to reflect upon the past. Every effort has been mobilized, every moment occupied in giving substance and reality to our plans for the future. And in this program for the opening of our second century the alumni, the Corporation, the faculty, and the administration of M.I.T. are making common cause.

In May, 1960, we made the first public announcement of our Second Century Program with a minimum goal of $66,000,000. Our purpose is to enhance the quality of education at M.I.T.; to create new facilities for research, to press forward in special fields of critical importance, and to relate research more closely to teaching; and to develop further the physical environment of our campus so that it may contribute more effectively to the life of each student.

Underlying this effort is a conviction that the progress of science and engineering increasingly will affect the destiny of our country and the world—that their influence upon ever-widening domains of human interest and endeavor will deepen and expand. In its spirit and in its objectives M.I.T. is moving completely in unison with the needs and conditions of the times. This favorable tide in our affairs is adding enormously to our opportunities. It brings also in the same measure new obligations.

But throughout this extraordinary period of change and growth M.I.T. must hold fast to its central mission: to send forth men and women of the highest professional competence, with the breadth of learning, the understanding, and the character to deal creatively with the increasingly complex problems of this modern technological society. Indeed, it will be through the quality of our graduates that we meet our ultimate obligations to research, to industry, and to government.

The Second Century Fund

The response from alumni and friends of the Institute, from industry and foundations to the appeal of the Second Century Fund was prompt and generous. On Alumni Day this past June eleventh John Wilson was able to report $60 million already committed to the Fund, of which more than $17 million had been pledged by industry, some $16 million from individual donors, over $18 million from foundations, and more than $8 million from the general alumni campaign.

This June, too, the class gifts established an all-time high, affording ample testimony of the confidence and loyalty of our alumni. The 40-year Class of 1922 led with a gift of $738,000, including $628,000 for the endowment of a professorship. The Classes of 1935 and 1921 followed with gifts of $641,656 and $589,003. To these were added gifts of $309,087 from the Class of 1910; $298,602 from 1911; $225,000 from 1912; $223,218 from 1920; $259,284 from 1936; and $269,000 from 1937—bringing the total for this memorable day to $3,552,850.

In the light of this progress a Fund of $66 million or more seems assured, and we anticipate a conclusion of all the intensive, highly organized phases of the campaign by the end of the present academic year. Despite this optimism, much remains to be done if all the goals of the original Program are to be achieved. We have been remarkably fortunate in the proportion of unrestricted grants and gifts. Yet many donors quite understandably have wished to direct their contributions towards specific projects. All of these are of the utmost importance to the Institute, but some fall outside the basic plan. Consequently, we distinguish between the Second Century *Program* and the *Fund.* As of the first of September we have some $3 million more in the Fund than in the Program itself, and painful decisions on priorities for the allocation of unrestricted funds may be ahead. From the outset this Program has been so tightly knit, so urgent in all its parts for the future of M.I.T., that it has been difficult to attach a higher importance to one project than to another. With the accumulated experience of some three years since the first formulation of the plan, we believe that events have demonstrated the validity of the original objectives. We hope most earnestly, therefore, that all the major projects of the Program will share in the ultimate success of the Fund.

I write these comments at the end of the summer in preparation for the annual meeting of the Corporation in October. The coming months will see a final, concerted effort to achieve our goals, and at the appropriate time there will be a full accounting of all that has been accomplished. There will be occasion then to express fittingly our gratitude to all who have made this achievement possible—to alumni for their continuing support and to the host of others who have been moved by the ideals and aspirations of M.I.T. and who have seen in this institution an ever-growing role of leadership and national service. Our thanks, too, will go to the hundreds of alumni and friends all over the country who have devoted time and energy unsparingly to the success of this undertaking.

All this will be said in due course by others than myself, eloquently I am sure, and certainly with deep sincerity. But even while we are yet in the final heat of effort, I should like here to record my personal tribute to those who have organized and led the campaign: to Alfred P. Sloan, Jr., the Honorary Chairman, for his unfailing faith in M.I.T. and for the wisdom of his counsel; to John J. Wilson, the General Chairman, who for more than two years at the sacrifice of his own affairs has dedicated himself with tremendous zeal to this great endeavor; to Walter J. Beadle, who has served with great skill and effectiveness as chairman of the committee on individual leadership gifts; to Mervin J. Kelly, whose personal leadership of corporate solicitation has brought about an unprecedented response from industry to M.I.T.'s special appeal. Through the splendid efforts of Earl P. Stevenson, Massachusetts business and industry has rallied to the support of the Institute. Philip H. Peters, with the help of Gregory Smith and Joseph Harrington, Jr., undertook and completed the immense task of general alumni solicitation, surpassing the original goal. This effort has raised the total alumni contributions to the Fund to more than $21 million.

I have reserved to the last a grateful word of appreciation to the man who has done most of all to assure the success of the Second

Century Fund. I know that I speak for the members of the Corporation, the faculty, and the alumni in acknowledging our profound indebtedness to Dr. James R. Killian, Jr., for his superb planning and organization, for the tireless energy that he is devoting to this task, and, as always, for his complete dedication to all that is good for M.I.T.

New Construction

Everyone associated with the Institute has begun to feel this past year the full impact of the Second Century Program. As new funds have become available the faculty and administration have become engrossed by the task of putting them to work effectively. Suddenly a great array of ideas that we have nurtured over a period of years has matured, and the projects are about to become realities. Consequently this is a time of intense planning and development, involving a multitude of decisions affecting both the academic and the material future of the Institute. I am confident that the response of M.I.T. to the many new gifts and grants will justify the generosity and expectations of all who have supported the Program.

The growth of the Institute over the past decade, our entry into new fields, and the consequent increases in students, faculty, and staff have created critical needs for additional space and facilities. In my report a year ago I outlined plans for new construction with an indication of the future development of the campus. The building program is now moving rapidly ahead. By mid-winter we shall have under way construction amounting to some $30 million, and although this figure includes projects beyond the objectives of the Second Century Program, such as a group of apartments for married students and the National Magnet Laboratory, it makes clear the scale of present activities.

I shall report here only briefly on the current state of the new buildings:

Green Center for the Earth Sciences. This twenty-story tower, located on the East Campus, will provide 126,000 square feet gross for geology, geophysics, meteorology, oceanography, and for the newly emerging and related fields of space and planetary science. The construction, which was started in December, encountered serious foundation problems; but these have been overcome, and the building has begun to rise. It will be completed next year.

Residence for Women. On Alumni Day this past June we had the pleasure of revealing that Mrs. Stanley McCormick, an alumna of the Class of 1904, was the anonymous donor who has made this residence possible with a very generous gift of more than $2,000,000. Our first on-campus dormitory for women, it will provide superb accommodations for 116 residents, with additional guest rooms and lounges for women students living off campus. Progress has been rapid, and we hope that the house will be ready for occupancy in the fall of 1963.

Center for Materials Science and Engineering. Currently our largest single project and the first in our new North Campus development, this Center will add approximately 160,000 square feet gross to our facilities for research and teaching in the broad field of materials. It will provide common central facilities for the support of studies involving nearly every department of science and engineering. Since my last report the funding for this Center has been completed and the architectural design approved; the final plans will be ready for bidding this fall.

Center for the Life Sciences. A magnificent anonymous gift of $2,100,000 from another alumnus this year has enabled us to proceed with our plans for a major addition to the Dorrance Laboratories. We have also received a grant of $2,129,082 from the National Institutes of Health for this Center. Extending eastward from Dorrance, this new building of approximately 132,000 square feet will more than double the space now available to the Departments of Biology and of Nutrition, Food Science and Technology. The addition, which will provide for research laboratories in such areas as molecular biology, genetics, biophysics, and nutrition, will also include seminar rooms, animal quarters, and other special facilities. Detailed planning is nearly complete, and we expect to start construction during the coming year.

Student Center. A preliminary plan for the Center has been approved and the architect authorized to complete final plans with a view to starting construction during 1963. Later in the present report I shall comment at greater length on this project and its importance for our future program.

Married Student Apartments. This is a self-amortizing project financed by a $3,000,000 loan under the Federal government's college housing program. Located at the western end of the campus on the site of the former Westgate apartments, these permanent facilities will accommodate 210 students and their families. The new complex will be dominated by a sixteen-story tower containing ninety efficiency and sixty one-bedroom apartments. Around this high-rise building will be four three-story garden-type units containing a total of sixty two-bedroom apartments. Construction was begun this past January, and the apartments should be ready for the fall of 1963.

Burton House Dining Room. With the completion of the dining room and its supporting facilities for the 560 residents of Burton-Conner House in the summer of 1961, this dormitory was operated for the first time as a self-contained unit during the past year. The dining room, an addition of contemporary design at the rear of the House, is used not only for meals but also for meetings and a variety of social events. We are indebted to the Alumni Fund for an initial contribution of $300,000 towards this project and for other substantial grants to a continuing program of renovation in all our residential facilities.

Psychology Building. A year ago I reported on the establishment of a Psychology Section in the School of Humanities and Social Science and on the acquisition of a three-story building on Ames Street, opposite Senior House, to provide such necessary facilities as research and teaching laboratories, seminar rooms, and animal quarters. The reconstruction of this building of approximately 36,000 square feet is now essentially complete, and it will be available this fall.

Radiochemistry Laboratory. A grant from the National Science Foundation has been augmented with Second Century Fund support to provide 13,000 square feet for additional research in the field of radiochemistry. Located next to the Nuclear Reactor on Albany Street, this new laboratory will also be ready this fall.

Cyclotron. The M.I.T. Cyclotron was first put into service in 1940, and we are now rebuilding it to extend its useful life. The reconstruction will provide for a wider range of experiments and for other improvements, including better resolution of the beam. This modernization is part of a long-range plan for the continued development of our research in low-energy particle physics.

National Magnet Laboratory. The establishment of a laboratory at M.I.T. for research involving high magnetic fields was reported just a year ago. The new Laboratory building on Albany Street is now finished, and we anticipate that by late fall the installation of an eight-megawatt motor generator power supply and an extensive water cooling system drawing from the Charles River will be completed. Soon thereafter the first experimental 250,000 gauss magnet will be ready for testing. The Office of Scientific Research of the Air Force is the sponsor, and construction costs are estimated at $6 million.

It is appropriate to record here also that the Cambridge Electron Accelerator, a joint undertaking of Harvard and M.I.T. with the support of the Atomic Energy Commission, is now in operation. On March 7, 1962, the first beam was produced with an energy of 2.2 billion electron volts—itself a new high for electron accelerators— and in August the design energy of 6 Bev. was attained. This now becomes a major national resource that should have an important influence upon the further development of high-energy particle physics. The initial construction cost amounted to $11.6 million, and the estimated budget for operations and instrumentation during the coming year is of the order of $5 million. This seems modest as compared with an expected $114 million for the construction costs of the Stanford linear accelerator now being built in Palo Alto. Nevertheless, the scale of such facilities as the C.E.A. and the Magnet Laboratory, their relation to the progress of modern science, and the inevitable involvement of the Federal government clearly reveal the complexity of some of the problems that confront the contemporary university.

A View on Teaching

Even a summary account of such a building program is impressive, and the temptation to elaborate is almost irresistible, for here we have very tangible evidence of progress, of great activity, of things happening. But stones and bricks and mortar have no isolated meaning of their own—they serve merely to support the intellectual purposes of the institution. And it is about more subtle developments affecting education, research, and the student at M.I.T. that I wish now to report.

The most difficult, the most basic problems in education have been generated within the past few decades by a vast expansion of the frontiers of science and by the explosive rapidity that has marked this advance. So much has been said of late on the revolutionary nature of this contemporary development that further comment may seem trite and redundant. Yet the fact remains that man is currently accumulating knowledge—and with it material power—at a phenomenal rate, indeed faster than he is able to digest and control. We have not yet begun to understand the consequences of this great outpouring for our society as a whole. Since we can see only vaguely the shape of things to come, it is difficult to design a plan of education appropriate for the future. Clearly science must play a more important role in the primary and secondary school and in the total development of a liberal education. We have only begun in this country to think seriously about how this objective may be accomplished.

At the professional level, the education of the scientist, the engineer, or the doctor presents an array of problems that are, if possible, even more complex and elusive. Somehow, the mounting mass of essential new material must be incorporated into the total body of instruction. But we have gone far beyond the point where the process can be simply additive if the student is not to be overwhelmed. Consequently, the faculties of every leading professional school are almost constantly engaged in the task of synthesizing new materials with the old, of re-evaluating and revising curricula. The increasingly abstract and mathematical character of modern science presents us with another perplexing problem. How are we to develop the physical insight, the perspective and understanding of natural phenomena that are quite as essential as a high order of mathematical ability, not simply for the engineer but for the scientist as well? The laboratory takes on new importance, and along with—or rather as a part of—the revision of curricula we are faced with the need for a sweeping renewal and development of our experimental facilities. And finally, there is the problem of balance: how to proportion properly the time and effort allotted to physics, chemistry, and mathematics, to professional studies, to the social sciences and the humanities.

The object of these endeavors is, of course, the student himself. Notwithstanding the glamorous appeal of research and the publicity that is frequently associated with it, there exists currently at M.I.T. a deep and sincere concern for the welfare of the undergraduate. There are, throughout the Institute, innumerable projects undertaken by individual members or by groups of the faculty for improvement in the process of teaching as well as for development of the curriculum. I consider it a primary responsibility of heads of departments to bring such projects to the attention of the Academic Council so that others may benefit from them and so that those involved may be encouraged and supported in their efforts.

We are, in short, both as a faculty and as an administration, conscious of our obligations for teaching as well as research and eager to fulfill them. We are aware also that for many undergraduates the transition from the methods and perspective of the secondary school to the life of an institution such as M.I.T. is difficult and often painful. It takes time and experience to understand that the first purpose of a university is to provide the resources and opportunities for education, with the ultimate responsibility for learning falling primarily upon the individual student himself. Our own great task, as I have commented in another report, is to convey to the student a feeling for the freshness, the relevance, and the importance of his subject; to excite him, to capture his mind and enthusiasm; and to help him develop a consuming interest in his chosen field. This is the context, it seems to me, within which we should endeavor to maintain at M.I.T. a tradition of fine teaching.

Engineering Education

Current developments in the School of Engineering provide abundant illustrations of the foregoing remarks. In his own annual report Dean Gordon S. Brown gives a more complete account of the progress of the past year, and I shall draw here only upon a few examples.

The accelerating tempo of technological change has had certainly a larger impact upon engineering than upon any other great profession. In the light of wholly new conditions we have been engaged for the past two years in a massive effort to reconstruct the curriculum, to infuse fresh vitality into the materials of teaching, and to develop a plan of engineering education completely attuned both to the advances in science and the contemporary requirements of industry. For the support of this effort the October, 1959, grant of $9 million from the Ford Foundation has been indispensable.

Within recent months the engineering faculty has prepared several dozen new texts, sets of notes, and laboratory manuals. There have been fresh syntheses of core courses in such broad areas as materials, communications, and energy conversion; and a number of entirely new subjects are being offered, demonstrating again the problems of keeping pace with an expanding technology.

In all this work of revision and in the development of new subject matter the influence of contemporary advances in basic physics and chemistry is apparent, as is also an increasing reliance upon the methods of higher mathematics. But there has also been a consuming concern for what Dean Brown calls the purposefulness of engineering, for proper attention to the ideas of cost, reliability, and the empirical judgments that often determine design.

One of our most difficult problems in mapping out a new plan of engineering education is indeed that of establishing proper balance between theory and application. The Departments of Civil, Mechanical, and Chemical Engineering and of Aeronautics and Astronautics have been particularly active in the exploration of new approaches to the teaching of design. Thus, by way of example, the Department of Chemical Engineering introduced this past fall a new subject on Process Design comprising a set of projects representing genuine engineering situations. Each entailed elements of theory, analysis, optimization, and the formation of an engineering judgment.

A year ago I wrote of extensive plans under the Ford grant for the reconstruction of undergraduate laboratories. This work has gone ahead rapidly, and we have undertaken new efforts to convert existing laboratories into more effective teaching facilities. One may observe throughout all this new development a predominating emphasis upon the engineering point of view. Much ingenuity has been shown in the construction of new apparatus for teaching. Novel devices and new approaches have been invented to facilitate learning by experiment. The experiments themselves have become more sophisticated. Typically they are going deeper into a subject and demanding a more mature analysis and understanding than the traditional experiment designed to illustrate in isolation some physical principle or particular mode of application.

Throughout the School there is growing support for the project-type laboratory in which students carry out a small piece of authentic research. For example, the Department of Aeronautics and Astronautics now requires all undergraduates to take project laboratory subjects in which they accept responsibility for designing on their own initiative experiments that cut across the boundaries of several conventional disciplines. Our students have shown the ability to deal effectively with programs of this kind.

The educational merit of the project approach is clear. By requiring independence of action it develops the student's initiative and self-reliance. It lays a firm foundation for more advanced work and leads to an early appreciation of the proper relationships between theory and experiment in an engineering environment. Small projects are frequently followed by longer ones that are in themselves authentic engineering problems, and increasingly the student is drawn into research itself.

Last year I reported on a plan to create an Engineering Projects Laboratory in the Department of Mechanical Engineering. Construction of this laboratory has been completed, and four previously unrelated laboratories have been merged into a single interdisciplinary unit under the direction of Professor Robert W. Mann. The result is a superb new facility in which teaching and research are carried on together. This past year every junior in mechanical engineering was introduced to a new laboratory subject which involved programs of sponsored research. During the fall term each student undertook four or five intensive laboratory investigations, while in the spring students worked in small groups with a faculty supervisor on a specific research project. The laboratory was also used during the year for seven other undergraduate subjects and for senior theses. Concurrently, and often collaboratively, some seventy graduate students and thirty members of the faculty carried on twenty research projects in the laboratory.

To give the Engineering Projects Laboratory further strength, particularly in its interdepartmental aspects, we plan next year to move the Electronic Systems Laboratory of the Department of Electrical Engineering into contiguous space. Then undergraduate and graduate subjects in control systems for both mechanical and electrical engineering students, together with faculty research, will occupy neighboring laboratories and share common equipment and instrumentation.

All this is a splendid demonstration of a more intimate mingling of graduate and undergraduate students in our teaching laboratories and of student participation in research. I might cite numerous other examples that indicate a growing movement throughout the School of Engineering to couple graduate and undergraduate teaching with research. This development is based on the conviction that here is a powerful way of imparting to the student in his early years an insight into the nature of engineering, an understanding of the professional qualities and motivations that distinguish the engineer from the scientist, and—by no means least important—a feeling of active participation in the intellectual life of the institution.

In support of these ideas we determined this year to double the funds originally provided for the laboratory program. Our initial plan under the Ford Foundation engineering grant was to apply $1,500,000 for the redevelopment—both physical and philosophical—of *undergraduate* laboratory instruction. In view of the promising results already achieved we are, with Foundation approval, reallocating $1,500,000 from the grant for further renovation of laboratories, including graduate facilities wherever their usefulness can be extended to the undergraduate program.

There is every indication that these developments are having a marked impact on engineering education throughout the country. Because of its size and because of the excellence of its faculty, M.I.T.'s School of Engineering has traditionally played a leading role in the United States. In view of the current and urgent national desire to strengthen engineering education, and because of the magnificent opportunities provided by the Ford Foundation grant, the M.I.T. faculty now has a special obligation towards its colleagues at other institutions. We are endeavoring to keep them in touch with developments here in a variety of ways—through visiting and exchange professorships, by special publications and notes, through summer fellowships, in educational conferences, by the normal professional channels, and in informal ways as well. Many of these exchanges are through collaborative enterprises and mutually profitable.

Through a number of grants the Institute has had other opportunities to serve the broad interests of engineering teaching. I cite a few by way of illustration. Last summer, with Ford Foundation support, we underwrote in part the attendance of a number of engineering teachers at some of our Special Summer Programs, which are designed to give professional men and women opportunities to review recent advances in their own fields. The response of those who attended was enthusiastic, and a later grant has extended the program for a three-year period. With this support, 110 teachers of engineering from 68 institutions enrolled in 25 of these programs this summer.

This year the School of Engineering sponsored two special summer programs in engineering education. One of these was a course in Experimental Solid-State Physics which represented an entirely new venture in technical education for the college teacher. Its objective was to describe and demonstrate a wide variety of experiments that have been developed at M.I.T. to illustrate theory in this field of physics that has now been incorporated into engineering education. The larger aim of the course was to help others establish comparable laboratory courses in their own schools.

The second was given by members of the Division of Design and Graphics with National Science Foundation support. It consisted of an intensive two-week review of undergraduate teaching in graphics and engineering design in the Department of Mechanical Engineering. This seminar placed special emphasis on the educational philosophy of the program and included enough detail to give the participants the capability of adapting various aspects of our curriculum to their own programs. Applications for this conference far exceeded our capacity, and we were able to select a representative group of some 75 outstanding engineering teachers on a national basis.

Besides these activities on our own campus, M.I.T. is playing a leading role in several inter-institutional efforts. I single out for special mention two substantial programs which have been established on the initiative of our faculty. The first is the National Committee for Fluid Mechanics Films, to which I referred last year and of which Professor Ascher Shapiro is Chairman. This Committee, composed of teachers from twenty cooperating schools, now has completed two half-hour films on experimental phenomena in fluid mechanics, has another six in production, and will produce about six more during the coming year.

The second project, also initiated at M.I.T., is the Semiconductor Electronics Education Committee. Under the chairmanship of Professor Campbell L. Searle, this group has brought together representatives from twenty academic institutions and industrial research laboratories to create an improved course in semiconductor electronics at the undergraduate level. In scope the course will range from solid-state physics through devices into circuit applications. The Committee has produced part of an experimental text which was taught on a trial basis last year at Iowa State University and the University of California (Berkeley) as well as at M.I.T. This material is now being revised and extended to cover a full one-year course; the Committee is also developing a number of novel experiments, including some in kit form, and a program of films.

The interest in motion-picture demonstrations and other teaching tools brought to these national programs by members of our faculty reflects the lively experimentation at the Institute with teaching aids. A year ago I reviewed a variety of such aids—demonstration apparatus, home laboratory kits, teaching machines—being developed on this campus. These experiments continue.

The home laboratory kits afford a good example. The electronics laboratory kit, which I described last year and which gives the student the means to construct in his dormitory a number of simple electronic circuits, underwent further development. Over 250 students used these kits this year, and they have begun to attract attention and interest from engineering schools across the country. This kit is being modified for use by the Semiconductor Electronics Committee, and other departments are adapting the technique to their own purposes. For example, in the Laboratory on the Mechanical Behavior of Materials, Professor Frank A. McClintock made available to his students this past year kits of materials—wire, rubber, silicone putty, plasticine, chalk, polyethylene—with which they could experiment to substantiate the results of homework problems.

Other Educational Developments

In these comments on teaching I have focused on engineering education because it is here that the Second Century Fund has had an early and powerful influence. But there are comparable activities—if on a lesser scale—in other areas of the Institute.

Thus the School of Industrial Management introduced a number of unusual techniques and methods and extended others to add interest and vigor to its educational program. Among these were the continued development and testing of the M.I.T. marketing game; the application of group dynamics principles to "sensitivity training" for arriving Sloan Fellows and for newly appointed M.I.T. Fellows in Africa; the increasing use of tutorials; and experimentation with programmed instruction in accounting, statistics, and other fields.

The effort to employ our laboratories to better advantage for teaching is widespread. For example, during the spring term a group of junior students in Experimental Atomic Physics were given projects outside their regular laboratory. These experiments were located in one or another of the many different laboratories devoted to experimental physics at M.I.T. Each was related to the work of a particular laboratory and each supervised by a member of the faculty in that laboratory. A difficult double dose of advanced theory and sophisticated techniques, the subject gave these students a firsthand view of professional research in a number of branches of physics.

The Department of Architecture, to cite another example, has joined with the Department of Civil Engineering in establishing a laboratory for structural models, the first of its kind in the United States. Through a Second Century Fund grant from the Perini Memorial Foundation, the laboratory is developing more effective facilities for the analysis of structural models, particularly those of modern design and materials. The laboratory will offer students in both departments an excellent opportunity to relate to physical measurements the theory developed in subjects in design.

This past August we suffered a most grievous loss in the death of Professor Francis L. Friedman, who was instrumental in the establishment of the Science Teaching Center at M.I.T. and who since 1960 had given it leadership and direction. The Institute is deeply committed to the idea of the Center, and we propose to carry on its work. Professor Jerrold R. Zacharias has indicated his willingness to serve as Director until a successor to Francis Friedman has been appointed.

The concept of our Science Teaching Center was derived originally from the example of the Physical Sciences Study Committee, whose work over the past several years has had such a profound influence on the teaching of science in secondary schools. The general intent of the present Center is to contribute to the improvement of education in science at the college and university level. The initial activities have been concentrated in the area of physics, and the main goal has been the creation of new material to strengthen introductory courses and to incorporate the ideas of modern physics in elementary instruction. The project has a national objective and draws not only upon M.I.T. but also upon visiting faculty from other institutions. One of the principal virtues of such an undertaking is the opportunity for a free exchange of ideas among a variety of individuals seriously concerned with the technical problems of education. The national character of our program has found recognition and generous support in the form of grants from the Charles F. Kettering Foundation, the Shell Companies Foundation, the Victoria Foundation, and the National Science Foundation.

Finally, I should like to report briefly on two further developments that relate more broadly to undergraduate education at M.I.T.

This year we experimented for the first time with a program of freshman seminars. Small groups of students—five or six on the average—pursued a wide range of subjects outside the formal curriculum under the guidance of a professor. In total, over the two terms, 494 students enrolled in 90 seminars. Designed to fire the interest and imagination of an undergraduate at the outset of his academic career, these seminars afforded freshmen exceptional opportunities to meet senior members of the faculty in a close and informal relationship. The methods of teaching varied from group to group, but there was a substantial amount of experimental work in research laboratories. On the basis of a single year's trial, it is hardly possible to assess the significance or even the long-range feasibility of this seminar program. It has proved to be a valuable experiment, and we shall continue it during the coming year.

In March the Committee on Educational Policy established two strong working groups of the faculty to carry out an intensive study of undergraduate affairs.

Under the guidance of Dean Wadleigh one group will examine the non-curricular aspects of student life and student-faculty relationships. The investigation will concentrate on the following four areas with a view to ascertaining their present influence on the total educational experience:

1. Admissions, financial aid, academic counseling, and academic performance.
2. The residence system and general environment.
3. Activities, athletics, and student government.
4. Morale, attitude, health, and personal counseling.

A special committee on curricular matters under the chairmanship of Professor Zacharias will study the present undergraduate program and the future curricular needs of M.I.T. The first goal will be to obtain a clear understanding of the basic educational objectives and content of each of the core subjects which form the present General Institute Requirements. The interrelationships among these objectives and opportunities for achieving greater coherence in the overall program will be explored in depth. The group will also review the present structure of undergraduate education from the point of view of the pace of subject presentation, the magnitude and diversity of a student's academic load, and the degree of scheduling flexibility. It will explore new methods for teaching subjects with very large enrollments and the possibility and desirability of allowing greater time for independent study programs. In all of these areas an effort will be made to correlate curricular problems with the environmental factors which are being studied by the groups working with Dean Wadleigh.

Biology, Chemistry, Physics, Mathematics, the Humanities, and the Schools of Engineering and of Industrial Management are represented through members of the Committee, but the final responsibility for curricular changes remains, of course, with the departments concerned.

These studies can have enormous import for M.I.T. over the coming decade. As the Committee on Educational Policy points out, we are engaging upon this project with no preconceptions of necessary changes nor with the expectation that it will reveal a simple, over-all solution for the complex problems of undergraduate education. But we may hope for a factual assessment of our present situation and thus arrive at a clear definition of major problems. We may also count on these studies to generate new ideas for the development of our present program, to encourage experimentation, and to focus the attention of both faculty and students upon our future needs.

Interdepartmental Centers

I began the present report with a restatement of the goals of our Second Century Program. These are, in fact, identical with the main objectives of M.I.T. itself. The first is to enhance the quality and to add to the opportunities for education. The preceding pages have given an abridged account of recent developments relating directly to this part of our mission. Our second goal has been to create new facilities for research, to develop special fields of critical importance, and to relate research more closely to teaching. A substantial part of the Second Century Fund will be allocated to the construction of five interdepartmental centers: Aeronautics and Astronautics, the Communication Sciences, the Earth Sciences, the Life Sciences, and Materials Science and Engineering. Progress on these plans for construction has been described earlier in this report. In each area, moreover, there have been notable contributions to research.

A faculty committee under the chairmanship of Professor John C. Slater has taken primary responsibility for planning the facilities in the new Center for Materials. These include a new Cooperative Computing Laboratory on the third floor of Building 10 completed this year and equipped with an I.B.M. 709 computer. In April the Center published its first annual report, reviewing briefly the whole spectrum of research in materials at the Institute. The record is most impressive, and this document conveys a clearer insight into the idea and the constitution of a major interdepartmental center than can possibly be derived from any secondhand description.

The report gives short accounts of research currently in progress in eleven departments of the Schools of Engineering and Science—Aeronautics and Astronautics, Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, Metallurgy, Nuclear Engineering, Biology, Chemistry, Geology and Geophysics, and Physics. There are included also reports of associated work in the field of materials in the National Magnet Laboratory, Lincoln Laboratory, and Instrumentation Laboratory.

In the President's Report for 1959 I commented at some length upon the forces that have led to the formation of interdepartmental centers at M.I.T., their plan of operation, and their probable influence upon the future organizational development of the Institute. The concept is described concisely in an introductory statement to the current report issued by the Center for Materials: "We conceive the Center to be a federation of many individual projects, each consisting of a professor or a few closely associated professors, with their graduate students, postdoctoral research workers, and so on. In conformity with university traditions, these individual projects are essentially autonomous, determining their own programs and to a large extent handling their own business, and the Center is a coordinating body whose main function is to pass information back and forth, as well as to supply the convenience of central facilities which are too large for any one project to handle by itself."

Nearly 700 people have contributed to the research reported this year by the Center for Materials—115 members of the faculty, 126 postdoctoral and senior research staff members, 400 graduate students, and 51 technicians and junior staff members. These are in fact the members of our academic community whose special interests lie approximately in the fields of chemical and solid-state physics, molecular science and molecular engineering, metallurgy and materials science, and materials engineering. The Center is largely a product of their need for closer alliance, of a desire to resolve at least in part the problems of overlapping fields, and of the need to share in the exceedingly costly shops, libraries, and experimental facilities that are an inescapable part of modern research. The central administration will be occupied with the management of these facilities, with the tasks related to funding, and with the encouragement of interchange and collaboration. There is no thought of a highly focused, centrally organized program of research.

The arguments in support of an academic federation within a university in certain broad, new fields of research are extremely persuasive. Our experience at M.I.T. over the past fifteen years with interdepartmental organizations of this kind has been highly successful, and I have the impression that the Institute has carried their development further than any other American university. Nevertheless, there are thoughtful members of our faculty who view the influence of such large research centers upon the ultimate character of M.I.T. with misgivings.

Contrary to the laws of thermodynamics, human social systems tend to increase in their degree of organization. We may start out with the concept of an autonomous federation, an association of independent scholars whose chief interest is the development of their students. But may not the magnitude of the effort overwhelm us and seriously reduce the individual freedom of thought and action that is the essence of a university? Can we cope with the demands of projects, reports, and deadlines without increasing and tightening administrative restraints? Will the centers tend inevitably to develop more highly directed programs and assume as a consequence some of the characteristics of large industrial research organizations? What, finally, will be the long-range effect upon the departmental structure and the responsibility for formal teaching?

These are serious and searching questions. During the past winter the Faculty Council devoted several of its meetings to an examination of the issues and debated the several points of view. There is, I believe, a wide awareness among members of our faculty that these dangers are real. The interdepartmental centers at M.I.T. have been generated spontaneously as a device for dealing effectively with the exceedingly difficult organizational problems of contemporary science and engineering They have thus far clearly proved their worth. But it is also apparent that an immoderate growth in these directions, or a shift in point of view with respect to their administration, might have a major impact upon the character of this institution. The faculty itself will be the most seriously affected by imbalances among fields of concentrated effort or in the relative emphasis placed upon teaching and research and upon graduate and undergraduate activity. I hope, therefore, that the faculty will take very seriously its responsibilities for sharing in the formulation of academic and administrative policies that will shape the future of M.I.T.

To these remarks upon the development of large centers I should like to add one further comment. I see no evidence that the traditional departmental structure is about to wither away. Individual departments may in time disappear, or be combined with others, or break off in new groups, as Chemical Engineering was once a division of the Department of Chemistry, Electrical Engineering a part of Physics, and Aeronautical grew out of Mechanical Engineering. It is conceivable—though not predicted—that the new fields of materials, of communication sciences, of energy conversion, may be themselves some day represented by formal departments. So there will be changes, but the basic organizational structure of departments and schools seems entirely sound and healthy. Moreover, there has never been, to my knowledge, a period of greater cooperation among departments, particularly within the School of Engineering, or a time when information flowed more freely back and forth across departmental lines. One might give countless examples of small interdepartmental projects for teaching or research. The Engineering Projects Laboratory described earlier in this report provides one case in point. And finally, although the plans for new centers loom very large in our recent discussions, it must be remembered that there is at M.I.T. a vast amount of research still carried on within the confines of a department, by an individual professor with a few students, after the manner of every academic institution. Our principal safeguard against fears of excessive "bigness" in research will be found by constantly protecting and cultivating this aspect of our academic life.

The Life Sciences

It is precisely because these isolated, initially modest research projects often succeed brilliantly that we are repeatedly confronted with our most difficult decisions on growth and expansion. An important discovery suddenly opens wide a whole new horizon, a vast new field of enterprise. One can hardly withdraw. Here lies the future. This is the nature of engineering and the sciences—social and physical. It is a problem that is somewhat less acute for the fields of classical scholarship. And it explains to some degree the dynamic quality of these issues at M.I.T.

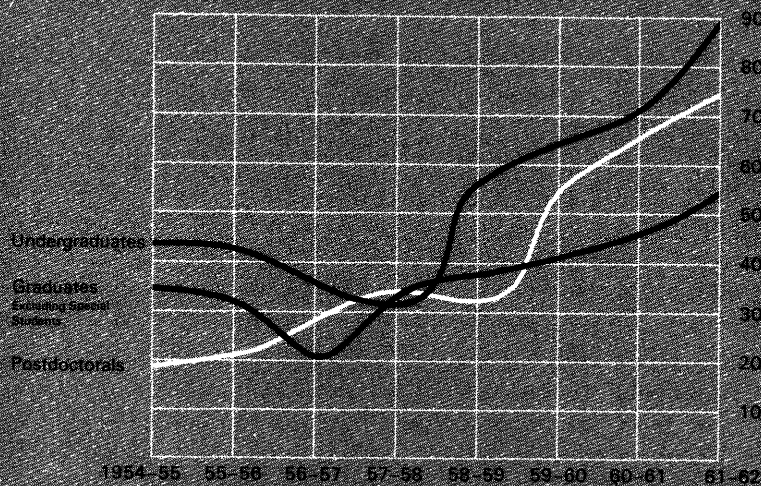
The recent development of the life sciences at the Institute provides a rather dramatic illustration. Our initial investments in this area go back many years, to Prescott and Sedgwick and before; yet for a long time support was meager and our interests highly specialized. Now there are compelling reasons to add the biological sciences and their applications to our principal fields of activity. They are clearly entering into one of the most interesting and productive periods in the entire history of science. They have a direct and powerful bearing on matters that affect human welfare—on medicine, on food and nutrition, and on our understanding of the basic processes of life and disease. And finally, progress in the life sciences is drawing increasingly upon just those resources that we have so abundantly available at M.I.T.—upon physics, chemistry, mathematics, and the several fields of engineering.

Within the past few years we have taken a number of decisive actions to expand and to add new strength to the Departments of Biology and of Nutrition and Food Science. We are most fortunate in the strong leadership of both departments, in their established quality, and in the outstanding men we have recently added to our faculty in these fields. We have undertaken many new research programs and have introduced new subjects, including this year an undergraduate core curriculum in the life sciences. The new building adjoining the Dorrance Laboratories will provide facilities and space for which there is already a most urgent demand.

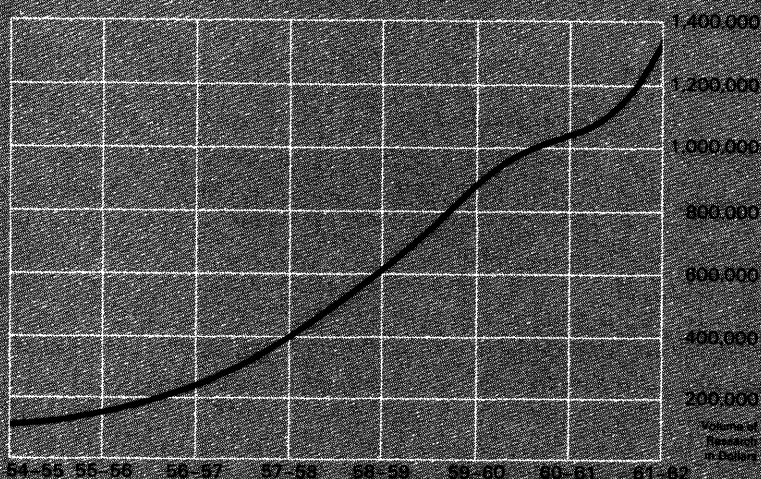
The effect of these measures is reflected now in a rapid rise in enrollment and in the volume of research. The graphs on the following page show for the Department of Biology the increases in the three categories of undergraduate, graduate, and postdoctoral students and the growth of sponsored research from a level of $106,700 in 1955 to $1,347,000 in 1962. The Department of Nutrition and Food Science anticipates a doubling in both student enrollment and in the volume of research this fall.

Although our interests in the manifold fields of the life sciences have been vastly expanded, they are nonetheless limited and

Enrollment in Biology, 1954 to 1962



Research Support in Biology, 1954 to 1962



shaped by the character of M.I.T. as a whole. In biology, for example, the focus of research is on the modern quantitative fields—biophysics, biochemistry, physiology, microbiology, communication physiology, molecular biology, embryology, genetics. Relations with the medical schools and research hospitals of Boston are close, and much of our research is directed toward medical problems, such as bacterial and virus diseases, the origin of cancer, or the chemistry of tissues involved in the healing of wounds, arthritis, and hardening of the arteries. These interests, together with the new teaching program, have had a notable influence upon undergraduates. This year thirty-five members of the class of 1962 have indicated their intention of going on to the study of medicine, and many others will do graduate work in the life sciences.

In its own area, the Department of Nutrition and Food Science is moving vigorously into a broad new range of activities. M.I.T. has been a pioneer in the fields of biochemical engineering, industrial microbiology, and food chemistry and processing, and this work continues. But we are now giving increased attention to the fields of nutrition and food science, and we have added to the activities of the Department this past year new programs in nutritional biochemistry, clinical nutrition, and food toxicology. The Department is concerned with the relation of stress and infection to nutritional requirements; with the problems of synthetic foods; and with the exceedingly important questions that relate to food additives—intentional and unintentional, as may occur through the use of insecticides, for example—and their toxic properties. The relationship of these studies to medical and other applications is clear, and the Department is actively encouraging a variety of broad interdisciplinary activities.

There is also much active collaboration between biologists and other groups within the Institute. An outstanding example of this interlocking of research interests occurs in the field of communication physiology and in the related studies on information theory developed in the Center for Communication Sciences. The fundamental processes and the underlying theory of communication seem similar in both man and machine, and there are useful comparisons to be made between the nervous system and the electronic system. Consequently, the Center for Communication Sciences has fostered an effective collaboration among electrical engineers, mathematicians, physicists, physiologists, and psychologists. Other groups outside the Center are doing related work. For example, the Neurology Group of the Electronic Systems

Laboratory is applying servo-analysis techniques to biological and neurological systems. Feedback control in human systems in particular is being studied experimentally with specially developed equipment.

Throughout the School of Engineering there is a multitude of projects bearing on the life sciences. There is a group of mechanical engineers, for example, interested in engineering problems relating to surgery and to medical therapy. In the Department of Metallurgy, Professor Antoine M. Gaudin this year applied the technique of froth flotation, used in refining mineral ores, to the separation of bacteria from other materials. The Department of Chemical Engineering is conducting jointly with the Department of Biology studies aimed at learning more about the structural differences in the important DNA molecules through observations of their hydrodynamic responses. This research is employing an incredibly sensitive viscometer which was invented in the Instrumentation Laboratory and which is also being used in studies of some of the fundamental properties of blood and blood plasma.

Planetary and Space Science

I have remarked earlier upon the ease and frequency with which working partnerships and alliances are formed among members of our faculty. These associations are for the most part informal and unorganized; they extend beyond research to teaching, and in their strength they give new meaning to the ancient idea of the community of scholars. These alliances arise from the mutual interests of individual professors, and it is only out of clusters of such relationships that the larger laboratories and centers are formed. One may find many such groups in different stages of development throughout the Institute.

The way in which new groups appear and the process by which an institution enters new fields and thereby expands its activities is well illustrated by the formation this past year of an *ad hoc* Committee on Planetary and Space Science known as COMPASS. It began with a series of lunch-time discussions stimulated by recent developments in space physics and the imminent prospects of planetary explorations. These meetings within recent months have brought together members of the Departments of Mathematics, Physics, Meteorology, and Geology and Geophysics. Electrical Engineering and Aeronautics and Astronautics have also been represented. Thus we have here a bridge already forming between two other centers of research—the Earth Sciences and Astronautics.

Admittedly there is a certain amount of arbitrariness in defining just what constitutes "Planetary and Space Science." In a brochure drawn up for the guidance of students at M.I.T., the COMPASS group has attempted a definition by listing partially the basic areas of study that enter into the new synthesis. The list is long, but I think it worth quoting here as a concrete example of how each major advance into a fresh field of science or engineering is supported by an entire constellation of older subjects. In this particular instance, planetary and space science includes the study of cosmology, formation and evolution of stars, abundance of the elements, stellar magnetism, radio astronomy, cosmic rays; solar activity, solar magnetism; structure of the solar system, planetary spectra, structure and formation of planetary atmospheres, dynamics of planetary atmospheres, planetary interiors, interplanetary space; figure, internal constitution, rotation, age, gravitational field, and magnetic field of the earth; structure and formation of the lower atmosphere and oceans, dynamics of the lower atmosphere, dynamical oceanography, solar-terrestrial relations.

It is of interest to observe that essentially all these studies affect the environment and condition of man upon our own planet, and the relation of space science, astrophysics, and the investigation of other planets to the earth sciences is plain.

As the Committee points out, no single university, and *a fortiori* no individual school or department, covers all these topics to an extent and depth commensurate with the highest level of undergraduate and graduate instruction and research. Nevertheless, the total existing resources of M.I.T., including those of the Lincoln and Instrumentation Laboratories, offer extraordinary opportunities for study and research in many of the areas listed above. To encourage an interest on the part of students, the Committee has outlined a program of study that ranges from the undergraduate to the postdoctoral level. It includes twenty-eight possible subject choices that will be offered this coming fall by six different departments. The program is highly selective and is designed merely to suggest to the student a coherent plan of study that may be related to his own special needs. The brochure prepared by the COMPASS group reveals an imposing amount of research currently in progress in these same fields, and members of the Committee will advise students on special reading courses and on the selection of thesis topics. The whole effort demonstrates precisely how the evolving interests of the faculty continuously reshape the teaching program, the readiness to experiment and innovate, and a freedom from departmental restraints.

An Environment for Education

I turn now to the third of our three main goals for the further development of M.I.T.—the creation of a physical environment about this campus that will contribute in a maximum way to the personal life of each student and to his total educational experience. This is a subject—as members of our Corporation are aware—upon which I feel most strongly. No one who enjoys any association with M.I.T. can fail to take pride in our high academic standing, in the enormous productivity of our research laboratories, and in the public services that the faculty of this institution render to the community and to the nation. I trust that the preceding pages of this report will have conveyed a sense of the current vitality and forward movement of the Institute. But the men and women themselves who graduate from M.I.T. are by far the most valuable product that we have to give to our country or to the world. They are, in fact, the essential reason for our being, and we shall be judged not only by the quality of their intellectual discipline but equally by the firmness of their moral fibre, by their attitudes towards the whole of learning, by the manner in which they speak and act, and by their understanding of the obligations of a citizen.

There is no single, simple way by which such ideas can be imparted to the student. Certainly it isn't done alone by lectures upon ethics, or character, or the duties of citizenship. But it is accomplished in the subtle way of example, of association with a faculty that the student respects, of an undergraduate experience of several years in an environment that is in every way conducive to the highest values that shape the lives of cultivated men and women.

A former student myself at the Institute, and at a time when life on this campus was far more austere than at present, I understand the tradition of rigor and simple surroundings and appreciate its worth. But as a resident I have also ample opportunity to observe at firsthand the influence of our urban setting, the pressure under which our students work, their need for more ample facilities for study, for reading, for a better social life, and for simple relaxation.

Earlier I reported on the study initiated by the Committee on Educational Policy in collaboration with Dean Wadleigh on the non-curricular aspects of student life. I believe it essential that the recommendations of this group be given the most serious consideration.

The proposed Student Center is in my judgment the most important single uncompleted objective of the Second Century Program. There is as yet no major gift on hand designated specifically for the Center, but we are pressing ahead with the plans. Professor Eduardo F. Catalano of our Department of Architecture has undertaken the design and has worked most effectively with committees of students and faculty in determining the facilities that will best meet the present and future needs of this community. Out of that study has come an excellent proposal for a building to supplement Walker Memorial, which we have long since outgrown. For the first time in many years there will be adequate provision for meeting rooms and offices for student activities; a variety of recreational facilities including lounges, a small library and reading room; several dining rooms; a hall for lectures, dances, or banquets; and space for a number of essential commercial services which are seriously lacking in the neighborhood of the Institute. A location for the Center has been chosen on the West Campus, south of the du Pont Athletic building, where it will form with Kresge Auditorium and the Chapel an architectural unit around a central plaza.

The response of students to facilities of this kind and their meaning in the life of the M.I.T. community are admirably illustrated by our experience of the past seven years with the auditorium and the Chapel.

The Chapel has become the focus of a number of religious programs at the Institute involving lectures, seminars, and counseling. At least thirteen formal services are conducted each week, and there are now fourteen clergymen—ministers, priests, a rabbi—who spend a part or all of their time working with students. A former residence on Memorial Drive near the Graduate House and adjacent to the Non-Resident Student Center has been converted to provide study and conference rooms.

Since the completion of the auditorium in 1955, there has been year by year an impressive increase in the use of the building. The large auditorium, the Little Theater, the rehearsal rooms are booked months in advance, and we have long since passed the limit of our ability to accommodate all those who would like to schedule evening or week-end events.

During the past year, for example, the auditorium was the scene of twenty-eight concerts presented by both M.I.T. groups and by distinguished visiting artists. On one week end alone this spring there was a Festival of Music which included a program of Ives and Copland, Bach and Bruckner by the Choral Society; a performance of Tchaikovsky's *Fifth Symphony* by the M.I.T. Symphony Orchestra; and the presentation of Randall Thompson's *Testament of Freedom* by the Concert Band and the Glee Club under the direction of the composer.

There was also opera and dance and a regular series of organ recitals. There were films and lectures, including this year the fourth Karl Taylor Compton program and the Lincoln Laboratory Decennial Lectures. These two series alone presented seventeen separate lectures and panels and brought to this campus a number of unusually distinguished visitors. There were thirty-six evenings of theater, ranging from student musical comedy through standard works to experimental productions. These programs of drama, and of music also, provide our students with exceptional opportunities to participate actively in many phases of the performing arts.

There is yet another aspect of extracurricular life at M.I.T. that has developed in a highly satisfactory manner and about which not enough is known. This is our athletic program.

It is a program that is in many respects unique. It is supported entirely through academic funds. There are no gate receipts, and we draw no vast crowds. But there is on this campus much athletic competition in the finest amateur tradition. And our teams do like to win. In fact, this year teams in more than half of the eighteen intercollegiate sports in which we participate enjoyed winning seasons. The basketball team concluded its season with a fifteen-game undefeated streak; the wrestling team placed second in the New England championships; and the rifle team was first in New England for the second consecutive year. In crew, the varsity heavies returned both the Karl Taylor Compton and the Admiral Edward L. Cochrane Cups to the Institute; and the varsity lightweight crew competed for the Thames Challenge Cup in the annual Henley Regatta in England.

Even more significant is the vigor of intramural competition, which has been greatly strengthened in recent years by the expansion of facilities—the acquisition of the Armory, the construction of the new du Pont Center and of the skating rink. Fifteen sports are now played at the intramural level, and last winter there were eighty teams competing in basketball and hockey alone. Approximately two-thirds of our students participated in some phase of these activities.

This whole intramural program is managed principally by the students themselves with only occasional advice and assistance from the athletic staff. In addition to these organized activities, there are student clubs that sponsor teams in such sports as rugby, cricket, and water polo. And there is finally the individual recreational use—for tennis, swimming, sailing—of the athletic facilities. All told, this broad student-oriented athletic program contributes most importantly in its own way to life at M.I.T.

I have attempted in this report merely to identify the main currents of movement at M.I.T. and the ideas that affect our planning. The separate reports from the several schools and administrative offices will provide much of the missing detail. However, I have hoped also to make clear how the Second Century Program is interwoven with our plans and how it supports our efforts to translate plans into tangible reality.

The Second Century Fund will have a profound influence upon the future of the Institute. We have set our sights high, and the immediate cost in hard dollars is correspondingly large. But the true significance of this program is much more than a matter of dollars. It has had a very large part in stimulating the faculty and administration to take stock, to re-examine, and to formulate more clearly and sharply our principal objectives. It has brought alumni in every part of the country into closer touch with their institution. And it has been a means to present to the public—to industry, to foundations, to individuals—a clearer view of the role of M.I.T. and of its contributions to our national life.

Now, even before our immediate goals are fully realized, we must begin to look further ahead. The development of a living institution is not an effort to be terminated at the end of a particular campaign. In reporting upon the progress of the Institute, the temptation to emphasize change and innovation is almost irresistible. Yet it is also misleading; for the accent upon what is new and different seems to imply a rejection of the past and so, to a degree, distorts the truth. M.I.T. was, in fact, founded upon an original set of ideas that over the years have continued to prove sound and that have imparted to the Institute its particular quality and character. Our entire history may be described simply as the amplification and fulfillment of those ideas in the context of contemporary society. And because we live in a very different kind of world from that of Rogers, or Maclaurin, or even of Karl Compton, we are also becoming a very different kind of institution.

As the horizons of science and engineering expand, there will open before us almost limitless opportunities for the development of new fields. There is a readiness to innovate at M.I.T. and a flexibility of administration that allows us to take quick advantage of special situations. But we must not let this freedom, this openness of mind, lead us into ways of expediency. One of the particular merits of the Second Century Program has been that it has fixed our attention upon certain well-defined objectives. We need to maintain that focus and to keep before us the elements of a plan and a philosophy. We need constantly to renew and fortify that plan. It must at all times represent our best thinking about the future of M.I.T.

J. A. STRATTON

Statistics of the Year

The following paragraphs report briefly on various aspects of the Institute's activities and operations during the 1961-62 year.

REGISTRATION

In 1961-62 student enrollment was 6,454 as compared with 6,289 in 1960-61. We estimate that enrollment this fall will be about 6,650. Married students in 1961-62 accounted for about 44 per cent of the graduate enrollment and 4 per cent of the undergraduate. There were 168 women enrolled, 84 of whom were graduate students.

Enrollment in the Graduate School was 2,892, including 150 officers from the United States armed services.

Students who entered M.I.T. last year held degrees from 285 other colleges and universities, 171 American and 114 foreign. The foreign student population was 793, representing some 12 per cent of the total student body. These students were citizens of 72 different countries.

Degrees awarded by the Institute in 1961-62, in the various categories, were as follows: 794 Bachelor's degrees, 628 Master's degrees, 86 Engineer degrees, and 224 Doctoral degrees—a total for all categories of 1,732.

PLACEMENT

More than 450 employers visited the Placement Bureau between October 16, 1961, and April 27, 1962, and some 1,350 students met employers' representatives in 6,840 interviews. The average offer to this year's graduating seniors was $582 per month; to Master's candidates, $690; and to Doctoral candidates, $925. The corresponding averages last year were $550, $650, and $850 per month.

STUDENT AID

This year 1,722 undergraduates, or nearly 50 per cent of those enrolled, received $1,450,200 in scholarship aid and $533,068 in loans. These two categories of direct aid totaled $1,983,268, a gain of 6.5 per cent over the year before.

Undergraduate earnings in term-time jobs this year amounted to $938,800. Thus, through scholarships, loans, and campus employment, $2,922,068 was made available to undergraduates during 1961-62.

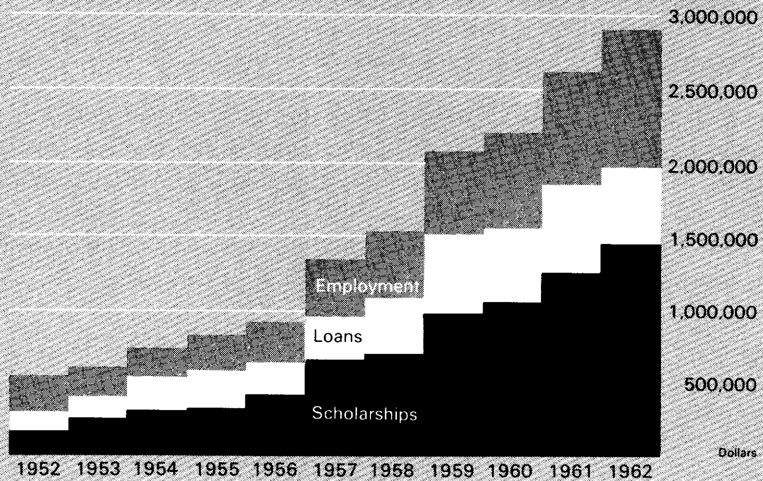
For the third successive year we also experienced a substantial increase in undergraduate scholarship endowment through gifts and bequests. This year the endowment increase was $1,750,000, or a gain of more than twenty per cent. Total scholarship endowment is now $10,236,000.

Graduate students this year received $309,474 in staff awards, $182,725 in loans, $147,863 in scholarships, and $709,067 in fellowships, for a total of $1,349,129. The corresponding figures for last year were $356,020, $165,535, $73,650, and $686,821, respectively, for a total of $1,282,026.

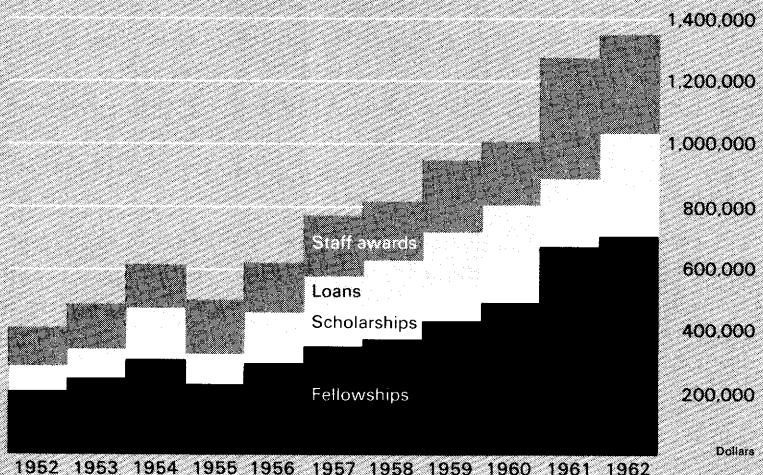
In addition, 69 students received $29,350 under the Installment Credit Plan, which extends payment of a portion of tuition over a ten-year period.

The graphs on the following page show the history of recent increases in financial aid to undergraduate and graduate students at the Institute.

Financial Aid to Undergraduate Students, 1952 to 1962



Financial Aid to Graduate Students, 1952 to 1962



FINANCES

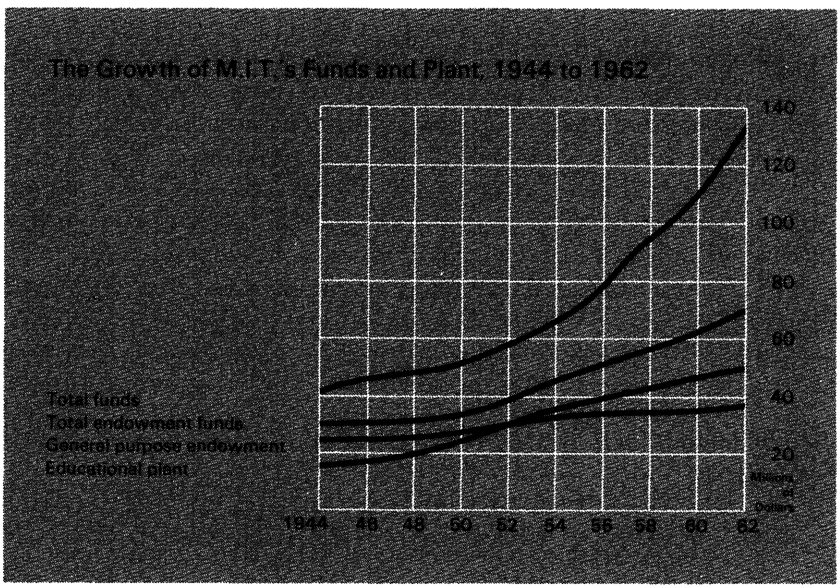
During the year 1961-62 the Institute's academic expenses—excluding the expenses of departmental and interdepartmental research and of the Lincoln Laboratory, Instrumentation Laboratory, and Operations Evaluation Group—amounted to $31,033,000. This compares to academic expenses of $29,889,000 in the preceding year.

For the fourth year the Faculty Salary Adjustment Fund was applied to teaching salaries, and the Industrial Liaison Program continues to contribute substantially to operating revenues.

Departmental and interdepartmental research expenditures increased from $20,314,000 to $24,621,000; and the combined operations of the Lincoln Laboratory, the Instrumentation Laboratory, and the Operations Evaluation Group rose from $56,996,000 to $66,472,000.

The Institute's investments at the end of the fiscal year had a book value of $132,719,000 and a market value of $186,721,000. Endowment and other funds increased this year from $122,657,000 to $134,875,000, and the educational plant assets increased from $49,-269,000 to $51,856,000.

The rate of income earned last year on the funds sharing in the general investments was 6.44 per cent on the average book value,



compared to 6.29 per cent in 1960-61. The total income on the general and special investments was $6,581,000, compared to $5,957,000 in the previous year.

GIFTS

Gifts in 1961-62 amounted to $17,691,000, compared to $14,584,000 the year before. As reported separately by the Treasurer, this total includes gifts for faculty salaries in the humanities, for the Class of 1922 endowed professorship, for the improvement of engineering education, for the earth sciences, for basic research, for the women's residence, and for student aid as well as undesignated contributions received during the year for the Second Century Fund. It also includes $414,473 reported by the Alumni Fund, but it does not include Second Century Fund pledges payable over a period of years.

During the year the Institute received two gifts totalling $1,000,000 towards additional facilities for chemistry.

Corporations and their foundations continue to be a principal source of support of the Second Century Fund. Some 600 companies have now made gifts and pledges to the Fund. Many have chosen to assist M.I.T. through increased participation in the Industrial Liaison Program or through the newly established Industrial Associates Program.

Foundations, as noted earlier, have given $18 million to the Institute since the start of the Second Century Fund campaign. These contributions have come from some 75 foundations, including many which have made grants to M.I.T. for the first time.

Individual gifts of alumni and friends have been the largest single source of contributions to the Fund. Of the nine gifts to the Fund of $1 million and above, five have come from individuals.

This summary can do no more than highlight the extraordinary response by alumni, friends, foundations, and corporations to M.I.T. and its special opportunities for leadership. A complete account will be given at the conclusion of the campaign.

Personnel Changes as of October 1, 1962

CORPORATION

TERM EXPIRATIONS

THOMAS J. WATSON, JR.
Special Term Member

CHARLES A. CHAYNE
Alumni Term Member

THEODORE T. MILLER
Alumni Term Member

CLARENCE L. A. WYND
Alumni Term Member, and President of the Alumni Association

ELECTIONS

CECIL H. GREEN
Life Member

HORACE W. MCCURDY
Life Member

JOHN J. WILSON
Life Member

LUIS A. FERRE
Special Term Member

WILLIAM B. MURPHY
Special Term Member

EDWARD M. PURCELL
Special Term Member

THEODORE A. MANGELSDORF
Alumni Term Member

FRANK R. MILLIKEN
Alumni Term Member

D. REID WEEDON, JR.
Alumni Term Member

WILLIAM L. TAGGART, JR.
President of the Alumni Association

FACULTY

DEATHS

LYMAN M. DAWES
Assistant Professor Emeritus

RALPH R. LAWRENCE
Professor Emeritus

WALTER R. MACCORNACK
Professor Emeritus

SAMUEL C. PRESCOTT
Professor Emeritus

ROBERT S. WILLIAMS
Professor Emeritus

FRANCIS L. FRIEDMAN
Professor of Physics

HOWARD F. TAYLOR
Professor of Foundry Metallurgy

JEROME A. URAM
Assistant Professor of Food Toxicology

RETIREMENTS *(with the title of Professor Emeritus)*

Professors:

JOHN CHIPMAN
Metallurgy (Head of the Department)

JAMES HOLT
Mechanical Engineering

FREDERICK H. NORTON
Metallurgy

CARL L. SVENSON
Mechanical Engineer

CARLTON E. TUCKER
Electrical Engineering

Associate Professor:

NICHOLAS A. MILAS
Chemistry

RESIGNATIONS OF PROFESSORS

ROGER W. BROWN
Economics and Social Science

CHARLES H. NORRIS
Civil Engineering

JOHN B. RAWLS
Humanities

ELI SHAPIRO
Industrial Management

WALTER H. STOCKMAYER
Chemistry

GERALD B. WHITHAM
Mathematics

RESIGNATIONS OF ASSOCIATE PROFESSORS

ALBERT BUSH-BROWN
Architecture

MELVILLE CLARK, JR.
Nuclear Engineering

Myron J. Gordon
Industrial Management

Major Robert A. Ireland, Jr.
Military Science

John McCarthy
Electrical Engineering

Major Charles M. Shadle
Military Science

Maurice E. Shank
Mechanical Engineering

Captain Robert C. Shoemaker
Air Science

RESIGNATIONS OF ASSISTANT PROFESSORS

Gordon E. Agar
Metallurgy

William R. Alcorn
Chemical Engineering

Elie J. Baghdady
Electrical Engineering

Corrado Baglioni
Biology

Lawrence W. Barss
Humanities

Jose M. Borrego-Larralde
Electrical Engineering

Stuart E. Dreyfus
Industrial Management

Daniel F. Fairbanks
Chemical Engineering

Stephen J. Gendzier
Modern Languages

Sheldon Gruber
Electrical Engineering

Chadwick J. Haberstroh
Industrial Management

Charles F. Hoffman, Jr.
Humanities

Stephen H. Hymer
Economics and Social Science

Thomas M. Lodahl
Industrial Management

Perry L. McCarty
Civil Engineering

Kenneth G. McCracken
Physics

Richard B. Maffei
Industrial Management

Laurence W. Martin
Economics and Social Science

William F. Massy
Industrial Management

Anthony M. Mlikotin
Modern Languages

Charles R. Niehaus
Humanities

David C. Pridmore-Brown
Mechanical Engineering

Venkatachari Ramakrishna
Metallurgy

Ronald E. Rosensweig
Chemical Engineering

James W. Ross, Jr.
Chemistry

Lawrence A. Shepard
Metallurgy

Alexander Sotir
Athletics

James B. Stone
Humanities

James M. Symons
Civil Engineering

Seth P. Tillman
Economics and Social Science

Michael A. Wallach
Economics and Social Science

Martin Wohl
Civil Engineering

CHANGES OF APPOINTMENT

Secor D. Browne
Assistant Professor of Flight Transportation and of Russian

William W. Buechner
Head of the Department of Physics

Morris Cohen
Ford Professor of Materials Science and Engineering

Jacob P. Den Hartog
Professor of Mechanical Engineering (Departments of Mechanical Engineering and of Naval Architecture and Marine Engineering)

Albert G. H. Dietz
Professor of Building Engineering (Departments of Civil Engineering and of Architecture)

Robert M. Fano
Ford Professor of Engineering

Nathaniel H. Frank
Professor of Physics (from Head of the Department)

Raymond Hide
Professor of Geophysics and Physics

Arthur R. Kantrowitz
Visiting Institute Professor

Thomas B. King
Acting Head of the Department of Metallurgy

Douglas M. McGregor
Sloan Fellows Professor of Industrial Management

Harold S. Mickley
Ford Professor of Engineering

Charles L. Miller
Professor and Head of the Department of Civil Engineering

Rene H. Miller
H. N. Slater Professor of Flight Transportation

Marvin L. Minsky
Associate Professor of Electrical Engineering

William W. Seifert
Assistant Dean of the School of Engineering

Ascher H. Shapiro
Ford Professor of Engineering

Arthur L. Singer, Jr.
Assistant Dean of the School of Industrial Management and of the School of Humanities and Social Science

Arthur R. von Hippel
Institute Professor

David C. White
Ford Professor of Engineering

John Wulff
Class of 1922 Professor of Metallurgy

John M. Wynne
Associate Dean of the School of Industrial Management

PROMOTIONS TO PROFESSOR

Stanley Backer
Mechanical Engineering

Sanborn C. Brown
Physics

Dayton E. Carritt
Geology and Geophysics

Alfred D. Chandler, Jr.
Humanities

Philip L. de Bruyn
Metallurgy

David J. Epstein
Electrical Engineering

Frederick D. Greene, II
Chemistry

Hermann A. Haus
Electrical Engineering

Daniel M. Holland
Industrial Management

David A. Huffman
Electrical Engineering

William D. Kingery
Metallurgy

Edwin Kuh
Industrial Management, and Economics and Social Science

Edward N. Lorenz
Meteorology

Erik L. Mollo-Christensen
Aeronautics and Astronautics

Alexander Smakula
Electrical Engineering

Leon Trilling
Aeronautics and Astronautics

John S. Waugh
Chemistry

Robert C. Wood
Economics and Social Science

PROMOTIONS TO ASSOCIATE PROFESSOR

Klaus Biemann
Chemistry

William F. Brace
Geology and Geophysics

Captain Leo Brachtenbach
Air Science

P. L. Thibaut Brian
Chemical Engineering

George A. Brown
Mechanical Engineering

ROBERT L. COBLE
Metallurgy

ALFRED R. COOPER, JR.
Metallurgy

PAUL H. COOTNER
Industrial Management

JAMES E. DARNELL
Biology

JOHN DUGUNDJI
Aeronautics and Astronautics

FRANKLIN M. FISHER
Economics and Social Science

HERBERT F. GOODWIN
Industrial Management

LEE GRODZINS
Physics

EDWARD HERBERT
Biology

KENNETH M. HOFFMAN
Mathematics

NORMAN N. HOLLAND
Humanities

RONALD A. HOWARD
Electrical Engineering and Industrial Management

WILLIAM D. JACKSON
Electrical Engineering

JACK L. KERREBROCK
Aeronautics and Astronautics

THEODORE R. MADDEN
Geology and Geophysics

WINSTON R. MARKEY
Aeronautics and Astronautics

RONALD MELZACK
Economics and Social Science

PERRY A. MILES
Electrical Engineering

GEORGE S. REICHENBACH
Mechanical Engineering

PHILLIPS W. ROBBINS
Biology

GIAN-CARLO ROTA
Mathematics

CAPTAIN DAVID A. SENA
Air Science

DIETMAR SEYFERTH
Chemistry

STEPHEN M. SIMPSON, JR.
Geology and Geophysics

DAVID A. THOMAS
Metallurgy

PROMOTIONS TO ASSISTANT PROFESSOR

JOHN G. BARRY
Athletics

FORBES T. BROWN
Mechanical Engineering

ALVIN W. DRAKE
Electrical Engineering

WARD D. GETTY
Electrical Engineering

JOHN M. HEINZ
Electrical Engineering

RICHARD Y. KAIN
Electrical Engineering

HARRY B. LEE, JR.
Electrical Engineering

RICHARD H. LEMMER
Physics

GONZALO S. LEON
Mechanical Engineering

ROBERT D. LOGCHER
Civil Engineering

DANIEL H. MARCUS
Mechanical Engineering

RICHARD I. MATELES
Nutrition, Food Science and Technology

JAMES R. MELCHER
Electrical Engineering

TRENCHARD MORE, JR.
Electrical Engineering

ADEL F. SAROFIM
Chemical Engineering

JOSEPH J. SCHIFFER
Architecture

WALTER C. SCHWAB
Electrical Engineering

BRADBURY SEASHOLES
Economics and Social Science

BARRY B. SPACKS
Humanities

DONALD E. TROXEL
Electrical Engineering

BRUCE D. WEDLOCK
Electrical Engineering

WILLIAM H. YOUNGREN
Humanities

APPOINTMENTS AS PROFESSOR

HORACIO CAMINOS
Architecture

RICHARD M. DOUGLAS
Humanities, and Head of the Department[1]

HARRY C. GATOS
Metallurgy and Electrical Engineering

BERTRAM KOSTANT
Mathematics

CAPTAIN LEWIS E. LARSON, JR.
Naval Science, and Head of the Department

FRANCO MODIGLIANI
Industrial Management

CAPTAIN WILLIAM M. NICHOLSON
Naval Architecture and Marine Engineering

RONALD F. PROBSTEIN
Mechanical Engineering

ROBERT A. SMITH
Physics, and Director of the Center for Materials Science and Engineering

APPOINTMENTS AS ASSOCIATE PROFESSOR

JOSEPH ALTMAN
Economics and Social Science

PIERRE E. CONNER, JR.
Mathematics

FERNANDO J. CORBATO
Electrical Engineering

RICHARD S. ECKAUS
Economics

WILLIAM M. EVAN
Industrial Management

MAURICE S. FOX
Biology

LEO FRIEDMAN
Nutrition, Food Science and Technology

MAJOR PAUL L. GURNEE
Military Science

JOHN W. KANWISHER
Geology and Geophysics

[1] Effective in February, 1963.

JOHN D. C. LITTLE
Industrial Management

PAUL M. NEWBERNE
Nutrition, Food Science and Technology

CAPTAIN HIRAM J. THOMAS
Military Science

GEORGE WOLF
Nutrition, Food Science and Technology

APPOINTMENTS AS ASSISTANT PROFESSOR

ARNOLD E. AMSTUTZ
Industrial Management

DAVID E. BERLEW
Industrial Management

ERNEST F. BISBEE
Civil Engineering

WILLIAM W. CARLTON
Nutrition, Food Science and Technology

FRED CHERNOW
Electrical Engineering

STEPHAN L. CHOROVER
Economics and Social Science

JEROME J. CONNOR, JR.
Civil Engineering

LARRY B. EVANS
Chemical Engineering

LEONARD J. FEIN
Economics and Social Science

RONALD B. GOLDNER
Electrical Engineering

NORMAN D. HAM
Aeronautics and Astronautics

WILLIAM H. HEISER
Mechanical Engineering

JAMES S. HEKIMIAN
Industrial Management

FREDERIC L. HOLMES
Humanities

ROY KAPLOW
Metallurgy

GORDON M. KAUFMAN
Industrial Management

JAMES L. KINSEY
Chemistry

MARC A. KOLPIN
Aeronautics and Astronautics

EDWARD M. KROKOSKY
Civil Engineering

David D. Lanning
Nuclear Engineering
James A. Larrimore
Nuclear Engineering
Lawrence M. Lidsky
Nuclear Engineering
James R. McCord, III
Chemical Engineering
Ronald T. McLaughlin
Civil Engineering
Thomas R. Meadowcroft
Metallurgy
Jan Miel
Modern Languages
Simon C. Moss
Metallurgy
J. Daniel Nyhart
Industrial Management
Martin S. Osman
Electrical Engineering
Clive H. Perry
Physics
David K. Roe
Chemistry
Ralph R. Rumer, Jr.
Civil Engineering
John S. Saloma, III
Economics and Social Science
Herbert D. Saltzstein
Industrial Management, and Economics and Social Science
John D. Sherman
Chemical Engineering
Robert E. Stickney
Mechanical Engineering
W. Gilbert Strang
Mathematics
Wolf R. Vieth
Chemical Engineering
Wayne A. Wickelgren
Economics and Social Science
August F. Witt
Metallurgy
Gerald N. Wogan
Nutrition, Food Science and Technology
John H. Wood
Physics
Laurence R. Young
Aeronautics and Astronautics

APPOINTMENTS AS VISITING PROFESSOR

Louis H. Ahrens
Geology and Geophysics
Michael P. Banton
Economics and Social Science
William Bollay
Aeronautics and Astronautics
John F. Brock
Nutrition, Food Science and Technology
Norman H. Brooks
Civil Engineering
Gerald E. Brown
Physics
John P. T. Byhouwer
Architecture
Benjamin H. De Mott
Humanities
Shmuel N. Eisenstadt
Economics
Arnt Eliassen
Meteorology
Murray Gell-Mann
Physics
Marvin L. Goldberger
Physics
John E. Gordon
Nutrition, Food Science and Technology
Richard Held
Economics and Social Science
Franklyn D. Holzman
Economics and Social Science
Howard M. Jones
Humanities
Jerzy Kurylowicz
Modern Languages
Solomon B. Levine
Economics and Social Science
Mario Perez de Arce
Architecture
Alban H. Phillips
Economics and Social Science
Massoud T. Simnad
Nuclear Engineering and Metallurgy
Bengt G. D. Stromgren
Institute Professor

LODEWIJK WOLTJER
Mathematics

G. DAVID N. WORSWICK
Economics and Social Science

LOTFI A. ZADEH
Electrical Engineering

APPOINTMENTS AS VISITING ASSOCIATE PROFESSOR

GUILLERMO ARROYAVE
Nutrition, Food Science and Technology

HAROLD BILLETT
Mechanical Engineering

ROBERT J. BOUTHILET
Nutrition, Food Science and Technology

CHU-I CHANG
Electrical Engineering

JOHN COCKE
Electrical Engineering

STEVEN J. FENVES
Civil Engineering

THOMAS P. HUGHES
Humanities

THOMAS J. LEWIS
Electrical Engineering

LIONELLO A. LOMBARDI
Industrial Management

CHARLES W. LOVELL, JR.
Civil Engineering

BERNARD W. MARTIN
Mechanical Engineering

EDMUND S. PHELPS
Economics and Social Science

MICHAEL O. RABIN
Mathematics

A. DANIEL RUBENSTEIN
Nutrition, Food Science and Technology

ROBERT L. SCHIFFMAN
Civil Engineering

NATHANIEL S. SCHNEIDER
Chemical Engineering

HAROLD Y. WACHMAN
Aeronautics and Astronautics

APPOINTMENTS AS VISITING ASSISTANT PROFESSOR

JOHN B. CALDWELL
Naval Architecture and Marine Engineering

MICHAEL LITT
Biology

DAISUKE NAKADA
Biology

W. FORREST STINESPRING
Mathematics

ADMINISTRATION

APPOINTMENTS

LLOYD BECKETT
Industrial Liaison Officer

CARROLL G. BOWEN
Director of the M.I.T. Press

JAMES A. CARRIG
Manager of Records Processing

WILLIAM J. DUGGAN
Manager of Data Processing

JACK H. FRAILEY
Special Assistant to the Provost

JOHN M. GALLAGHER
Assistant Auditor

DANIEL J. HOLLAND
Industrial Liaison Officer

PHILIP J. ROBINSON
Industrial Liaison Officer

JOHN R. ROGERS
Assistant Bursar

RICHARD L. SNYDER
Associate Director of Libraries

RETIREMENT

HAROLD E. LOBDELL
Executive Vice President of the Alumni Association

RESIGNATIONS

STUART H. COWEN
Assistant Director of the Division of Sponsored Research

WILLARD W. DICKERSON
Assistant Director of Admissions

WINSTON R. HINDLE
Acting Director of the Industrial Liaison Office

JAMES MCCLYMONT
Industrial Liaison Officer

RYBURN M. ROSS
Associate Director of Libraries

PROMOTIONS AND CHANGES

CAPTAIN EDWARD S. ARENTZEN
Administrative Officer in Physics

D. HUGH DAREN
Director of the Educational Council and Associate Director of Admissions

JAMES H. EACKER
Administrative Officer in Mechanical Engineering

RICHARD B. FINN, JR.
Acting Director of the Industrial Liaison Office

PETER P. GIL
Director of Executive Development Programs, School of Industrial Management

THADDEUS W. KOWILCIK
Assistant Accounting Officer

FREDERICK G. LEHMANN
Secretary of the Alumni Association

RICHARD A. MAY
Accounting Officer for Payrolls

DONALD P. SEVERANCE
Executive Vice President and Treasurer of the Alumni Association

VOLTA W. TORREY
Publisher and Editor of *The Technology Review*

ROBERT K. WEATHERALL
Associate Director of Admissions

School of Architecture and Planning

The professions of architecture and planning are going through a period of immense activity. Large-scale developments, urban renewals, industrial parks, and new suburbs are being built throughout the land. The more gifted architects and planners are in such demand and their rewards in money and satisfaction are so great that it is becoming increasingly difficult to find superior professionals willing to dedicate themselves to teaching. In this respect, our School has been more fortunate than others, particularly this year in inducing Professor Horacio Caminos to come to us. He brings a great reputation both as teacher and as designer and will be a major addition to our permanent full-time staff. In spite of recent losses, our staff still ranks with the best in the country. We take particular pride in this fact, since all theories of architectural education come to little unless the teacher brings to his teaching, passion, inspired skill, and—even more importantly—a background of practical and creative experience which he must not lose through inactivity.

However, it must be recorded that the profession at large believes that our schools are not doing all that needs be done in training young men. Some of its members claim that design and theory are still being taught in the same manner as they were in the past, in spite of the fact that a real revolution has occurred in the art and technique of building and planning. Very recently the Managing Editor of *Architectural Forum* wrote to the Ford Foundation as follows: "Both as a practicing architect and as a journalist who interviews many young people who have recently graduated from architectural schools, I have long noticed a profound dissatisfaction among young people in our architectural schools—a dissatisfaction which is largely due, I think, to the fact that their training seems to be too theoretical and there is too little practical application of architectural theories. A secondary source of dissatisfaction can probably be found in the present state of architecture itself: many students are confused by various seemingly contradictory concepts being advocated by leading practitioners." The American Institute of Architects in its outline for what is called "comprehensive architectural services" states that the architect must be prepared to include additional services such as operation programming, land assembly, and financial programming.

Obviously a school cannot undertake to emphasize practicality at the expense of theory or risk producing narrow specialists. Yet even realizing that the arguments advanced by lay critics are seldom enlightened by thoughtful analysis or by knowledge of how the young mind acquires the ability to think, schools should not ignore criticism; we must continually reexamine methods to see that the proper goals are clearly kept in sight.

The formalization of architectural education during the past century into professional schools like that at M.I.T. has developed a pedagogy that seeks to give the student a maturing experience in design based on case studies of many different types of building situations pursued over a period of several years. By encountering all of these diverse problems one after the other and by constant practice accompanied by criticism, the student acquires his most important professional qualification, a design method. He can apply this method to any situation that he may meet; and if its principle is sufficiently basic, his work will be reasonably adequate.

But it takes a long time to develop self-sufficiency in design. In the meantime the beginner will experience many frustrations and will often find the criticism irksome because it points out deficiencies that become obvious when attention is drawn to them. The reason the beginner has to flounder in this field is that architectural design does not consist of a number of orderly sequential steps; it is more like the simultaneous consideration of a vast number of factors, each of which will influence the result and the combination of which makes every problem in some way different from every other problem. Moreover, even if one could accurately define these factors in a given case, there would still be no undisputed best way to react to them. This reaction varies with the mentality of designers.

The most important factors effecting design are the increasing intensification of urban development and the increasingly more industrialized technology of construction. To secure the educational advantages of experiences broadly shared among the professional groups requires a structure that allows flexibility to avoid completely separate curricular "tracks." These tracks tend to insulate professionals too early from the subject-matter of allied disciplines. The desired flexibility can only be assured if there are several levels on which each subject-matter realm may be approached. For instance, a city planner may wish a one-term subject to acquaint himself with the broad aspects of the behavior of static structures. An architect will require perhaps four terms of the study of structures, but with emphasis on generality and quality; whereas the student who is to become a structures consultant will need still more, especially if we include time for the acquisition of the mathematical insights necessary to a more analytical view of the field. In a properly coordinated school, these subjects will all be taught by one group of faculty members, although some teachers will feel more at home in some presentations than in others.

Professor Lawrence B. Anderson, in consultation with Professor Albert G. H. Dietz of the Department of Civil Engineering, this past year prepared a memorandum which attempts a tentative answer to the ideas expressed above, in what he calls a "school of planning arts." Such a school would be based on the recognition of the fact that the three fields of city planning, architecture, and building technology have become well established as separate professions but that all of them are concerned with giving workable and culturally significant form to the physical environment. Increasingly, it is realized that this task is a collaborative process in which each profession must learn to adapt its own role to complement the work of others. The fact that these professions deal with the same materials and have similar goals has not been sufficiently emphasized in education.

City planning has been busy coordinating the applicable sectors of sociology, statistics, transportation, land economics, legislation, and public administration and developing the theory and practice of professional action. It now needs to go beyond policy and controls and to strengthen its ability to deal creatively with physical reality. This positive approach is essential in the light of the urban expansion foreseeable all over the world.

Architecture carries the heaviest burden of aesthetic problems and has experienced an aesthetic revolution, accompanied, perhaps caused by, a technological revolution. Architecture had to give up leadership in technological development when this expanded into the new fields of applied science. In the effort to keep the attitude of objectivity required for over-all design, the architect lost his authority in many of the details; left to himself, he is too often a poor builder.

The potentiality of the field of building technology to improve the quality of environment depends upon redefinition and a new surge of creative thinking. The engineering and construction of buildings and other environmental structures today are carried out through the often unrelated activities of a variety of consultants and entrepreneurs: structural, mechanical, electrical, and sanitary engineers, materials technologists, acousticians, and construction managers. Architectural structures present problems in all these fields, sometimes not of overwhelming interest when considered separately; but the components when put together can make very challenging problems indeed. Thus the combination of materials technology with construction management can attack the problems of standardization and modularization; the mechanical, electrical, and sanitary considerations ought to be combined, because the creative possibility here is the integration of all building services in an over-all system that neatly matches the structural system.

The "school of planning arts" would attempt an educational grouping at M.I.T. of these three fields, with the objective of providing a much closer linkage for mutual reinforcement than has so far been attained. This school should function like a small undergraduate college having a special orientation and branching out into three graduate professional schools. Candidates for study in such a school would need to show excellence in verbal understanding and communication; mathematical and scientific aptitude and achievement; knowledge and talent in the visual arts; the urge to construct; and ability to organize and lead.

Transfer students demonstrating good educational backgrounds in other colleges would be admitted, under controls to insure capabilities equivalent to those of native M.I.T. stock. Planning and architecture need to keep open their recruitment from liberal arts colleges, and building technology would need transfers from schools of engineering. Transfers into or out of other M.I.T. courses would also be facilitated as much as possible without unnecessary loss of time. Undergraduate areas of instruction would include at least the following study areas: history of the visual arts, architecture and city development, drawing, basic design, mechanics, strength of materials, structures, earth construction and site development, materials technology, building construction, acoustics, architectural design, land economics, public planning policy, sociology, and housing.

The baccalaureate degrees available would be not only the S.B. but also the A.B. (not presently conferred at M.I.T.)—the S.B. for a program predominantly scientific-technological, the A.B. for one predominantly humanistic-aesthetic. Within these two broad categories, many combinations would be possible. Planning, architecture, and building technology would each have sequences leading to professional degrees at the graduate level, into which would be admitted students having completed the undergraduate program or its equivalent with high achievement. Some latitude should be allowed within each field for the student to weight his studies in one direction or another, including subjects normally within the professional sequence or in another department of the school.

We believe that M.I.T. is capable of providing both the breadth of education needed to give its students an over-all grasp of the planning arts and the training in depth needed to master the various aspects of the field. Some of this is already well established; some is on a piecemeal and fragmentary basis. Much better integration is possible, but integration means cutting across a good many traditional lines and welding together disciplines now diverse and not coordinated. Specifically, it means cutting across the lines of architecture, engineering, science, and management. Some areas should be common for all students in the field; others should provide specialization, depending upon the aims of the student—whether he is inclined toward social analysis, visual factors, engineering, or construction.

We realize that there are great administrative difficulties to be overcome before such integration becomes possible. For instance, to set up a separate faculty of building technology either in the School of Engineering or the School of Architecture and Planning would deprive the Department of Civil Engineering of strength and lead to duplication. Heating, ventilating, and air conditioning; mechanical and electrical building services; and illumination are areas traditionally the concern of the Departments of Mechanical and Electrical Engineering, respectively. Their present remoteness and scattering would constitute a problem in the education of all professionals concerned with the design and construction of buildings. Furthermore, building technology is now subject to engineering accreditation which focuses on the bachelor's degree. Even if this factor is discounted, modification that would make the S.B. any less of an engineer would be undesirable. The optimum pre-engineering course as laid out for building technology is very close to the present S.B. in civil engineering except that it includes graphics, a two-term subject in project-planning, and the possibility of some electives in architecture and planning.

In spite of the obvious difficulties, we wish to place these thoughts on the record and urge that further study be given to them in the years to come. In the meantime, Professor Charles L. Miller, head of the Department of Civil Engineering, has shown his sympathy with our goals and has suggested ways and means within present administrative lines to strengthen architecture at M.I.T. He has recommended as a first step that effective with the academic year 1962-63 students in architecture and those in civil engineering take the same first subject in structures, Structural Analysis and Design (1.511 and 1.512), and he has followed this suggestion with a proposal, which has been adopted, that Professor Dietz have an appointment jointly in the Departments of Civil Engineering and Architecture.

Policy on Transfer and Superior Students

During the year, the architectural faculty has reviewed the policy of accelerating the time spent in Architectural Design by transfer students with degrees by allowing them to do independent projects during the summer to present as advanced standing examinations for credit for one term of Architectural Design. The faculty decided to continue such a policy with the transfer students with substantial credits and to extend the same privilege to "other superior students," meaning those whom the faculty designates as able to advance more rapidly without loss of content and quality—the termination of the third year being the appropriate time for such students to consider whether it is in their interest to make the application.

Proposed Program of Exhibitions

The faculty, through the exhibitions committee, has recommended that there be as a pilot program a series of three to five exhibitions a year sponsored by the Department of Architecture. The subject matter for these exhibitions would be selected particularly with a view of its value for architectural students. The Department, through the committee, would plan, design, and execute all exhibits; but in the beginning, use might be made of traveling exhibits that are of interest. At least once each year there should be an exhibition of student work selected by the committee. The exhibitions would be held in the Exhibition Room unless their character gave them a much wider interest, when a more central location would be sought. This activity should be conducted in cooperation with a student exhibition committee which would assist the faculty committee and suggest subjects for exhibition. It is hoped that about $3,000 of Second Century Program funds can be devoted to realizing this program.

Curriculum

A joint design program at the graduate level between the Departments of Architecture and of City and Regional Planning was inaugurated under Professor Kevin A. Lynch with the assistance of Professor Donald S. Appleyard during the past year. The program included a new fall term collaborative design workshop with graduate students in architecture and a pioneering spring term workshop for five advanced planning students. The latter dealt with physical and visual form at the metropolitan scale, taking a sector of the Washington region as a case study. It was aided by the National Capital Planning Commission.

Administration of the master's thesis program for architectural students was revised so as to terminate in July rather than in August and to direct the subjects into two specific channels, the use of concrete in architecture and the planning of new settlements. Visiting critics were appointed to assist in this program. Those participating for concrete were A. J. Harris of London, Howard Simpson of Cambridge, and Giulio Pizzetti of Italy. Professor J. T. P. Byhower, Head of the School of Landscape Architecture at Wageningen, Holland, and Professor Appleyard took part in the planning projects. A third group was also organized around the use of prefabrication for housing in developing countries, supported by the work in Carl Koch's subject on The Industrialized House. This reorganization will be evaluated to determine plans for the coming year.

The faculty of the Department of Architecture continued an intensive review of the curriculum. For the coming year, with the cooperation of the Graphics Division of the Department of Mechanical Engineering, a special section of freshman graphics for architects will be presented. As mentioned before, discussions were also held with members of the faculty of the Department of Civil Engineering to improve joint efforts in the area of structures, materials, and construction.

New course work was offered in regional planning with Professor John R. P. Friedmann and in transportation problems with Professor Aaron Fleisher. Courses in planning law and in urban sociology were again taught by temporary one-term visiting lecturers. There remain gaps in the permanent staff resources.

Recruitment and Scholarships

The Department of Architecture has experienced difficulties in its graduate admissions because of growing competition between schools and the general inadequacy of its scholarship resources. Last year admission was offered to forty candidates, of whom twenty did not accept; scholarships were offered to eight students and were declined by five. Of $16,500 in scholarships offered, $8,800 was declined. Of the twenty students who cancelled, seventeen had also applied to one or more other schools. These schools, and the number of times each was mentioned, are Harvard, 12; Pennsylvania, 7; Columbia, 6; Yale, 5; Princeton, 3; and Cornell, Pratt, Rice, and California, one each.

In the Department of City and Regional Planning, the enrollment of graduate students has risen slightly in number and quality, with a shift toward the doctoral from the master's program. The faculty has been enlarged and strengthened. The course offerings have been revised and increased. Looking to the future, the Department plans and hopes for further growth in order to develop the number and capacity of its graduates to cope with the urban environment of this and other countries. The Department considers the M.I.T. environment to be favorable for improving both the scientific knowledge and professional skill of city and regional planning.

Enrollment in 1961-62 was 27 master's candidates in the fall, 25 in the spring; 11 doctoral candidates in the fall, 12 in the spring; and 5 special students in the fall, 3 in the spring. Eight master's degrees and the Department's first Doctor of Philosophy degree (to Professor Bernard J. Frieden) were awarded. The teaching staff numbered 16 (full-time equivalent of 8) in the fall and 12 (full-time equivalent of 6½) in the spring; the ratio of students to staff, on a full-time equivalent basis, was 5:1 in the fall and 6:1 in the spring. Full-time enrollment was up a little from last year; the staff-student ratio was improved.

Students in the Department of City Planning continue to receive more than their numerical share of the few national fellowships available, a credit to their quality and to M.I.T.'s standing. Last year 2 of the 10 national fellows under the Sears-Roebuck Foundation program were here; for next year we will have 4 of the 16. Also for next year, the new Lasker Fellowship Trust has awarded 3 of its 19 grants to M.I.T. (but we will receive none of the 3 Pittsburgh Plate Glass awards). Thus for both last year and next year, M.I.T. has won about 20 per cent of these awards with an enrollment of less than 10 per cent of the country's graduate planning students. Aid from M.I.T. itself, however, continues at a very low rate compared to the need. Last year only four of our students had scholarships or fellowships, and five had staff tuition awards through teaching appointments. For next year these numbers will be six and two; the six is thanks only to a special advance of four scholarships from prospective Second Century Fund moneys. Counting all sources of help, including the above and foreign and U.S. government fellowships, for both last year and next year only 50 per cent of our graduate students will be receiving any kind of grant. Most of the others are forced into both heavy borrowing and part-time work which cuts severely into their academic opportunity; and several this year are dropping out prematurely, with only a hope of return after a year or two of full-time earning. The need for more, and more generous, financial aid remains acute. A brighter note is that three of our Ph.D. candidates are taking one-year leaves to study abroad under Fulbright grants next year. In spite of drop-outs, applications for entrance have been numerous and of good quality, and we expect an enrollment next year of nearly 50, a 25 per cent increase over last year and 100 per cent over five years ago. There will be 22 incoming M.C.P. candidates, including three with M.I.T. undergraduate degrees. Of the Ph.D. candidates, five are from our own M.C.P. program.

Faculty

The appointment of Horacio Caminos to be Professor of Architectural Design and the appointment of Professor Dietz to serve jointly in architecture and civil engineering have been mentioned. Professor Albert Bush-Brown resigned effective July 1, 1962, as Associate Professor of Architectural History and Executive Officer of the Department of Architecture to become President of the Rhode Island School of Design. A replacement has not yet been proposed.

Visiting Bemis Professors in architectural design during the year were Halldor Gunnløgsoon of the Danish Royal Academy of Fine Arts in Copenhagen, and Mario Perez de Arce of the Universidad Catolica of Santiago, Chile. New members in the Department of City and Regional Planning this year include Professor John Friedmann, whose special experience is in economic and regional planning in the United States and in developing countries, and Professor Bernard J. Frieden, who in addition to joining our staff was appointed Editor of the *Journal* of the American Institute of Planners for the coming three years. Manfredi Nicoletti will study urban development patterns in the United States as a Sloan Postdoctoral Fellow.

All the members of the faculty have been active in professional society affairs and in professional consultation, mainly to government. For example, Professor Frederick J. Adams has been working with the Puerto Rico Industrial Development Commission on an island-wide plan for sites for manufacturing; Professor Lloyd Rodwin is advising the Turkish government on regional development; Professor Kevin A. Lynch played a major part in the plans for Boston's waterfront development; Professor Charles Abrams is aiding the State of California to formulate a housing program.

Professor Rodwin continued as Chairman of the Faculty Committee of the Joint Center for Urban Studies of M.I.T. and Harvard and as a member of the M.I.T. Political Science Section.

Research

The M.I.T.-Harvard Joint Center for Urban Studies continues as the focus of research in the Department of City Planning. Professors Fleisher and Abrams have devoted substantial time to their own projects at the Joint Center. The Guayana Region project in Venezuela has involved Professors Appleyard and Friedmann as well as Professor

Rodwin; it is under the full-time direction of Visiting Professor Norman William, Jr. Special summer research is also being supported for Professor Adams. This involvement of almost the entire faculty is the most direct impact of the Joint Center upon the Department, feeding as it does new material and stimulation into the teaching. Students have also benefitted from a number of symposia arranged by the Center and from research opportunities.

The Perini Foundation has granted $250,000 for support of the Laboratory for Model Testing, and plans are under way for the active participation of the Department of Architecture in the work of this Laboratory.

The project for the design of a traveling exhibition for the United States Information Agency on "World Science and the United States" was completed by Professors Gyorgy Kepes and Maurice K. Smith.

Under a grant from the Educational Facilities Laboratories, Professor Marvin E. Goody and Joseph Schiffer, with the collaboration of members of the faculty of the Department of Civil Engineering, completed a full-scale mock-up of a classroom unit for a modular school based on a new form of repeating structural modules. It is hoped that this building can be tested by occupancy and that an industrial firm will wish to produce additional units for use elsewhere.

PIETRO BELLUSCHI

School of Engineering

This report of activities in the School of Engineering elaborates on topics discussed in the reports of 1960 and of 1961, wherein many of the issues that confront engineering education were set forth and the course that M.I.T. has charted toward a new level of excellence was outlined. The reasons for strengthening the scientific foundations of the subjects taught in the engineering curricula were cited, the importance of the laboratory in the education of engineers was stressed, and the efforts to develop a new role for the laboratory through the establishment of facilities which would afford students an experience of an authentic engineering character were enumerated. The need to achieve an interdisciplinary character in much of the teaching and research and the related emerging role of interdisciplinary Research Centers were given prominent mention.

As these matters are broadly appraised, two overriding issues come sharply into focus, namely: (a) the need to inject the purposefulness of an engineering viewpoint into an educational program which must be so strongly science-based that, to the traditionally practical engineer, it could look like science; and (b) the importance that must be attached to establishing an environment wherein teaching and research in engineering achieve a degree of coupling and mutual reinforcement far stronger and more interdisciplinary than ever before.

Efforts made thus far toward realization of this science-based engineering viewpoint and toward the mutual reinforcement of teaching and research make it clear that we must achieve a widespread regrouping of faculty, provide new space and facilities for their research, and evolve wholly new kinds of educational laboratories for undergraduate and graduate teaching. The continually growing need for men who have continued their education through to the doctoral degree demands that we accelerate our efforts to improve the facilities and support for our graduate students without lessening our determination to provide the best engineering education for undergraduates. These requirements raise issues that transcend the confines of any single department and even the confines of the Engineering School as a whole. To a degree hardly foreseen three or four years ago, the issues weave throughout the many schools and departments at M.I.T. The problems they raise are taxing the human, the intellectual, the financial, and the physical resources of the entire M.I.T. community in a multitude of new ways. The successful culmination of the Institute's Second Century Fund is a matter of crucial importance.

The Changing Character of Engineering

Today's engineering practice and engineering education both differ greatly from those of only a few decades ago. Up to about the time of World War II, engineering practice embraced a spectrum of technology that was relatively well defined. We could point to such specific projects as the building of the Brooklyn Bridge or the development of our vast systems of transportation, electric power, or wire-telephone communication. The role of the engineer was at that time widely understood, and the technology on which most of his work was based had been relatively stable for a quarter century or more. Engineering education, in the main, was geared to preparing a young man for a perpetuation of that era.

Engineers are still employed in carrying out assignments such as the design and building of a bridge, an aircraft, or a communications system, but under the accelerating tempo of scientific discovery, an avalanche of new technology has appeared and the demands on performance of all modern machines and systems have been upgraded to a very high degree. A rapidly growing segment of the engineering profession is engaged in research and development on projects which necessitate designing in advance of currently demonstrated feasibility in areas that often do not achieve practical fruition for a decade or more. Many engineering fields which are today growing most rapidly and contributing most significantly to broadening the base of industry were unknown fifteen years ago. The science on which they are based has now become of greater interest to the engineer than to the scientist. Engineers in these fields frequently work side by side with scientists, often accelerating science to bring it abreast of the desired engineering application. Indeed, the intrinsic capabilities of the scientists and the engineers of whom we here speak are frequently essentially the same, but the engineer is uniquely oriented toward a useful end objective. And finally, a growing number of scientists and engineers are engaged more and more in administrative, management, or advisory functions either for government or for industry. The vision and forthrightness with which they operate is directly related to the degree to which they have a profound understanding of—in contrast to detailed working familiarity with—the most important recent advances in science and their engineering applicability.

As a consequence of these trends, engineering leadership now demands creative innovation within a mixture of disciplines far more diverse and at a much higher level of scientific sophistication than was expected of the pre-World-War-II engineer. Furthermore, the doctrine of engineering education now widely held is that it should prepare a man so that throughout most of his professional lifetime he can play a leading role in forging a changing technology. It is expected to prepare him to cope with kinds of scientific knowledge and with technical demands that today cannot be foreseen.

A SPECTRUM OF ENGINEERING

Without proposing any succinct designations, it is helpful to subdivide engineers into the following four main categories:

(a) Those expert in assembling, operating, and maintaining the complicated machines and engineering works of a modern society. These engineers, in a sense, may be considered the *custodians* of technology. Their work requires considerable competence in mathematics, physics, and related sciences but not to the depth required by engineers in the categories that follow. These people comprise the largest group of engineers, and for them a bachelor's degree of a terminal character from an engineering college is ideal preparation for a career.

(b) Those who can conceive, design, and build new systems of engineering works by an orderly, creative, *ingenious arrangement* of the knowledge of their day. These are the men in a technical society who, with their supporting technicians, actually "get the work done." In addition to being highly intellectual and creative innovators, they must be highly knowledgeable about up-to-date science and must also be sensitive to engineering feasibility and to economic considerations.

(c) Those engaged in research and development where the primary effort is directed toward creative and original syntheses calling for the interpretation of recent findings of science—both abstract and physical—for possible practical applications. These engineers frequently work as scientists or with scientists in pushing forward the boundaries of scientific knowledge as they open up new engineering frontiers. They may be thought of as *composers* of new technology in contrast with the creative arrangers in (b) above.

(d) Those engaged in activities which draw constantly on a technological background but who must *interpret* and apply technology in those interface areas where the physical sciences interact with such fields as industrial management, political science, or the life sciences. These engineers do not require a working familiarity with science to the depth that is needed for those in categories (b) or (c). To be effective, however, they must have profound appreciation of the more important scientific and engineering concepts which have become so essential to modern engineering.

The above spectrum of categories of engineering work occurs throughout the traditional disciplines such as civil, electrical, and aeronautical engineering. They are stated here to bring into focus the range of characteristics of engineering in an expanding technological society rather than to propose abandonment of the traditional departmental framework. It is within the traditional disciplines that one observes most readily the purposefulness and the sense of reality that distinguish the role of the engineer from that of the scientist.

There are many reasons to suspect that at least a part of the change currently taking place in engineering education as a whole stems from the recognition of this expanding base of engineering, of the perhaps arbitrary categories of engineering work function mentioned above, and of the strong bonds between engineering and science. It is important for members of the engineering profession to be articulate in giving expression to these matters in ways that students in secondary schools who are potential engineers can understand. Unfortunately, many youths do not see those broad challenges in engineering and often undertake programs of study poorly suited to their talents. Some are attracted to engineering by the accounts of activities of a few spectacular achievements that receive prominent mention in the press but, upon graduation, find themselves in situations which afford little outlet for the powerful training they had received. These young people frequently become disenchanted with engineering as a whole, although the fault may be only that they are employed in the wrong job category. Their disenchantment often contributes to the general state of confusion about the role of engineering and the opportunities for challenging careers as engineers in modern society.

The Expanding Role of Engineering at M.I.T.

Efforts this past year to reshape our activities so as to provide new laboratories, new facilities, new curricula, and new doctrines bring more clearly into focus the impact of factors enumerated in the 1960-61 report; namely,

> " . . . (a) the great cost of refurbishing space, removing obsolete machines, and purchasing new instruments and experimental facilities; (b) the complexities introduced by the need to plan laboratories for both teaching and research; (c) the wide spectrum of engineering disciplines embraced by the teaching and research of M.I.T.'s School of Engineering; and (d) the need to change the character and substance of theory courses hand-in-hand with laboratory courses."

Problems of great complexity exist in sequencing the construction of buildings for the new research centers, in the acquisition of new capital facilities, and in coupling day-to-day teaching with new scientific discoveries and with new research activities in the various departments and schools. An efficient utilization of the creative energies of the faculty now depends more on the development of a long-range plan for regrouping of professors, their facilities, and their students into new interdisciplinary federations—*science and engineering together*—than on any other single factor. This regrouping involves, on the one hand, the physical relocation of the research and teaching facilities of a hundred or more professors and, on the other hand, the restructuring of many programs of teaching and research. Many existing teaching and research facilities must be abandoned and many new ones conceived, developed, and made operable. Many administrative activities that now occupy space within the central school buildings must in the process be relocated. This restructuring will involve expenditures of approximately a million dollars solely for refurbishing space in the existing buildings of the School, in addition to the expenditures for new capital facilities.

The magnitude of the complexities are further emphasized as one examines the reports of the departments as they appear this year. The breadth of technology embraced by the activities of the faculty and the vigor with which they are being pursued are most impressive. Never before has the faculty been engaged in so many teaching activities of an interdepartmental nature. Never before has there been evidence of so many programs where the faculty was breaking new ground and advancing the frontiers. Never before has the ratio of doctoral degrees to the total graduate degrees in engineering been so high. For the School as a whole, 436 Bachelor's, 462 Master's, 86 Engineer and 111 Doctor's degrees were awarded during the year 1961-62. The total in engineering was 1,095, out of an M.I.T. total of 1,732. The number of predoctoral students now enrolled indicates that during the next several years the number of doctoral degrees in engineering awarded by M.I.T. will increase substantially. During the year 1961-62 M.I.T. conferred ten percent or more of all the doctorates in engineering in the United States.

Our faculty is striving to advance the frontiers in areas where the exploitation of science is the key to progress. It is not surprising, therefore, that their viewpoints on curricula and research in engineering are tending further and further away from concepts and practices geared to the immediate present. As one reads the departmental reports on the new curricula developments and reflects on the research being conducted by the various departments in the School, he sees that the bulk of the activities focus on science and its potential exploitation with but modest concern for present-day hardware. The point that must not be missed is that as the time between discovery of knowledge and its practical use is reduced, it more and more becomes the responsibility of engineers to codify and describe facets of basic knowledge that are essential in engineering but not necessarily essential in science. This in turn necessitates the career involvement of many engineers in experiments and investigations of a highly scientific character.

As the scope of engineering expands it becomes clear that engineering schools must develop curricula along several paths rather than attempt to press all graduates out of essentially the same mold. Since no school has the capability for providing a truly excellent education for all categories of engineers, each must consider carefully what role it can uniquely fulfill. The School of Engineering at M.I.T. regards its principal mission to provide excellence in programs that prepare engineering majors for careers in a kind of work that would fall within the categories (b) and (c) above, and to give strong support to other schools at M.I.T. in programs that would equip these students for careers in work that falls within category (d) above.

Steps Toward Our Goals

During the past two and one half years, substantial progress has been made toward the achievement of many of our goals. From the resources provided by the grant* of $9 million received from the Ford Foundation in October, 1959, we have initiated closer coupling between undergraduate and graduate teaching and research, have made five appointments to the endowed professorships, have appointed 38 postdoctoral teaching interns, have made substantial curriculum changes, and have refurbished a number of undergraduate laboratories.

ACHIEVING GREATER INTERACTION BETWEEN UNDERGRADUATE AND GRADUATE EDUCATION

Last April we approached the Ford Foundation with a proposal to broaden the scope of the program initiated by their grant of October, 1959, by the reallocation of funds so that we could support developments at the graduate level as well as at the undergraduate level. Our original proposal had placed primary emphasis on the urgent needs to strengthen undergraduate education. This was an essential first step for the reasons discussed at length in the Report of the School for the year 1959-60. Our proposal to the Foundation of last April stemmed from the realization that as we moved to strengthen undergraduate curricula and to modify the role of the laboratory, we were tending to become so preoccupied with undergraduate education that it could have become something apart from graduate education. But

* The scope of this grant was outlined in the Report of the School for 1959-60.

countering this was our desire to confront undergraduates with some of the subtleties of real engineering by associating them with graduate student and faculty research. Then as we incorporated in undergraduate teaching many topics which formerly were thought to be exclusively of graduate calibre, we were confronted with the need to recreate our graduate teaching. It became essential, therefore, to erase the tendency to stratify undergraduate and graduate activities and to accept the single task of strengthening the whole program of study in engineering from the early undergraduate years through to the final graduate years.

Toward the close of this academic year our proposal received favorable action, and our faculty was presented a challenge of a wholly new magnitude. But because the broadening of the scope of the program and the reallocation of funding by doubling the funds previously allotted for laboratory refurbishing and facilities and halving the funds previously allotted for curriculum development received approval so near the close of the academic year, it is premature at this juncture to give a detailed statement of specific moves.

THE STRENGTHENING OF FACULTY UNDER THE FORD FOUNDATION GRANT FORD PROFESSORSHIPS

In October, 1959, the Ford Foundation endowed seven chairs to strengthen our faculty in important newly emerging domains in engineering. The stipulation that the fields of specialization of the occupants of the chairs be in newly emerging domains sharply limited the number of qualified applicants. After an exhaustive survey of the better candidates in industry and in education who were both qualified and available, the first five appointments were made this spring to members of our own faculty. As Ford Professors, each will continue to hold his own department affiliation and status but will be particularly concerned with interdisciplinary teaching and research activities in his respective field. The recipients of these chairs are:

Dr. Morris Cohen, Department of Metallurgy, Ford Professor of Materials Science and Engineering—a distinguished physical metallurgist and a key contributor to the development of materials science curricula.

Dr. Robert M. Fano, Department of Electrical Engineering, Ford Professor of Engineering—an authority on the processing and transmission of information and a key contributor to the development of new interdisciplinary curricula.

Dr. Harold S. Mickley, Department of Chemical Engineering, Ford Professor of Engineering—an authority on mass transfer and continuum mechanics and a key contributor to the development of a more generalized program of study in the continuum behavior of matter designed to provide an integrated presentation of thermodynamic processes and rate processes.

Dr. Ascher H. Shapiro, Department of Mechanical Engineering, Ford Professor of Engineering—an authority on fluid dynamics and thermodynamics, a pioneer in establishing fluid dynamics as a basic discipline in a wide range of technologies from hydraulics to plasma dynamics, a national leader in the production of educational films on fluid dynamics.

Dr. David C. White, Department of Electrical Engineering, Ford Professor of Engineering—an authority on energy processing and a pioneer in the development of new curricula in energy conversion involving the concepts of electromagnetic theory, analytical mechanics, and the interaction of fields and matter.

POSTDOCTORAL TEACHING INTERNSHIPS

During the year 1960-61 seven men held the appointment of Ford Postdoctoral Fellow and, simultaneously, that of either assistant professor or instructor. Last year we had 21 Fellows, and 38 have been appointed for the year 1962-63. These appointments are limited to a two-year tenure and are awarded to young men who show unusual professional promise, who recently achieved the Doctor's degree, and who indicate a genuine interest in teaching careers.

This program has not been in operation long enough to indicate the extent to which it will help augment the supply of engineering teachers. Of the seven Fellows who have completed their two-year tenure, five are now on the staff at M.I.T. Deans and department heads in other institutions show considerable interest in recruiting new professors from this program, but there is a tendency for the Fellows to restrict their interest to those institutions where they can engage in both teaching and research. This situation may ultimately demonstrate that any formal program to prepare first-rate teachers of engineering must also include ways to establish them in research in the institution that ultimately procures their services. Since these people are rarely well known professionally, their ability to procure research sponsorship or grants in a national competition is limited. It may prove essential, therefore, to provide each young professor who begins his long-term career in a smaller institution a nominal amount of research support over which he has complete control for the initial year or two of his appointment.

PREDOCTORAL LOAN PROGRAM

In the fall of 1959 the Ford Foundation awarded $150,000 to M.I.T. and seven other institutions for a new kind of Predoctoral Fellowship-Loan Program. Our funds were fully committed by the spring of 1962 by awards to a total of 31 Fellows, 18 of whom will be provided support for one or more additional terms. In February, 1962, grants to continue and broaden the loan portion of the Predoctoral Forgivable-Loan Program were awarded to M.I.T. and a number of other institutions.

The 1959 program stipulated that awards be made to students who had obtained the Master's degree or its equivalent. After appraising the program for two years, we recommended that the Foundation authorize awards to first-year Master's degree candidates, because at M.I.T., and probably elsewhere, the availability of support for the first year of graduate study is crucial to the question of whether many promising students will continue with graduate study or enter industry immediately following the Bachelor's degree. We believe that if the first year of graduate study is made more attractive, vis-a-vis an industrial job, the probability of many more good people entering teaching is substantially increased. More attention should be given to this issue.

Our recent experience indicates that the program initiated in February, 1962, will fill an important gap in the spectrum of assistance available to graduate students in engineering. The loans provide support much needed by the older students, several of whom are married and have families. They are attractive to many students just beginning their doctoral programs. The upper limit of the loan is now $10,000 and is forgiven at up to 20 percent or $1,000 per year if the student enters a teaching career. The flexibility has enabled us to assist a number of students with long-term financial need as well as those who were confronted with extraordinary short-run expenses which otherwise would have interrupted or terminated their programs.

FACULTY REGROUPING

During the year the Engineering Council and various members of the faculty have considered ways in which a number of units of the School, both graduate and undergraduate, could be regrouped to achieve greater effectiveness. Many activities, whose optimal operation calls for close association, are now widely separated—sometimes nearly as far as from one corner of the campus to the other. But with the emergence of the research centers, the construction of new buildings, and the broadened nature of professional work, it becomes essential to re-examine all existing space allocations and requirements —not in the light of a single department or laboratory but, rather, in the light of the Institute as a whole. While we can hope that this action, if taken wisely, can strengthen the activities of both faculty and students, the planning and implementation become orders of magnitude more difficult and more expensive than when carried on piecemeal.

The degree to which the effectiveness of our activities in the expanding field of energy conversion is curtailed by insufficient and inappropriate space graphically illustrates the problem. Professors from five engineering departments and from the Department of Physics are now forced to operate almost as independent units. But as their work advances, its success depends more and more on their ability to interrelate the most up-to-date understanding of such disciplines as fluid dynamics, electromagnetic theory, and plasma physics and on their accessibility to increasingly expensive and complex facilities. Both faculty and students are seeking a unity and a mutually supporting relationship that their present scattered activities do not provide. One move which is already under way to strengthen this group is to abandon much of the equipment previously in the Sloan Automotive Laboratory, Building 31, and to assign the released space to students and professors in the Departments of Aeronautics and Astronautics, Electrical Engineering, and Mechanical Engineering whose interests and activities in energy conversion interact.

Another urgent problem concerns the Electronic Systems Laboratory (E.S.L.), formerly the Servomechanisms Laboratory, of the

Department of Electrical Engineering. The desirability of bringing the faculty and students in this Laboratory into closer association with their counterparts in the Department of Mechanical Engineering has been evident for over a decade, but space limitations within each department seemed to preclude this possibility. With the completion of the new Engineering Projects Laboratory in the Department of Mechanical Engineering, greater latitude in the arrangement of activities became possible. Simultaneously, the relocation of E.S.L. has become mandatory in order that the building now occupied by that group can be razed to service construction of the new Center for Materials Science and Engineering, scheduled for occupancy early in 1964. Consequently, plans are currently under way to relocate E.S.L. among elements of the new Engineering Projects Laboratory and thereby to establish an environment in which these two groups can begin to federate their technical activities.

Still another problem involves the need to bring about a greater consolidation of the Civil Engineering Department and to bring elements of the Department into closer proximity with related activities in the Departments of Mechanical Engineering and Naval Architecture and Marine Engineering, and also with those activities in the School of Architecture and Planning which relate to materials and structures. The solution of this problem will require relocation of a number of administrative activities, such as the Comptroller's Accounting Office, the Educational Council, the Student Placement Office, the Student Personnel Office, the Alumni Association, and the office of *The Technology Review*. These activities are now located throughout the main buildings in ways that seriously fragment Civil Engineering.

In another area the Mechanical Engineering Department feels that its program in materials and materials processing has been seriously weakened because its extensive metals processing laboratories are located at some distance from the major related activities of the Department. Attempts are currently under way to achieve an arrangement whereby these activities can be relocated along with other activities from the Departments of Civil Engineering and Mechanical Engineering to achieve a high degree of intellectual and physical unity in the areas of materials and materials processing.

The Department of Electrical Engineering, whose students currently comprise about 40 per cent of the School, has educational and research activities spread all the way from Building 3 to remote sections of Building 20. Its undergraduate laboratory instruction involving some 500 student contacts per week in the vital area of circuits is now confined to cramped quarters on the fourth floor of Building 10. For the efficient conduct of teaching in this laboratory there is urgent need for frequent interaction with professors doing original experimental work in electronics and electronic circuits. Only Professor Harold E. Edgerton has his laboratory close to the electronic circuits teaching laboratory; all other faculty involved in experimental activities in the area of electronic circuits are associated with the Research Laboratory of Electronics located in the Compton Laboratory or in Building 20. To facilitate more efficient interaction of senior faculty in undergraduate laboratory teaching and because the long-range plan of the Institute envisions construction within three to four years of a Center for Communication Sciences close to the Compton Laboratory, detailed consideration is being given to the ultimate allocation of several floors of Building 24 to the Electrical Engineering Department. Building 24 is adjacent to the Compton Laboratory. In it could be located many of the educational laboratories of the Department as well as its headquarters.

If this move to Building 24 becomes feasible for the Electrical Engineering Department, it will in turn permit a more efficient utilization of its space in Building 10 for work in molecular engineering, because Building 10 will be contiguous with the Center for Materials Science and Engineering. The move to Building 24 will also permit extension of the Department's activities in plasma research in ways that will couple more efficiently with the activities that are being established in the Sloan Automotive Laboratory, which will be renamed the Sloan Engineering Research Laboratories.

The above are merely examples of the current problems to which the Engineering Council and the School of Engineering faculty, together with the Institute's administration, are addressing themselves as part of the expanding nature of engineering and technology at M.I.T.

Support of Graduate Education

An analysis of the funding of the expenses of graduate students in engineering at M.I.T. shows that in excess of 1,200 out of a total of 1,600 receive either tuition or a stipend or both. A large number of these students hold junior staff appointments as research assistants, teaching assistants, or instructors. Others hold fellowships granted through government agencies, the military, or industry, foreign as well as domestic.

RESEARCH ASSISTANTSHIPS

The funding of support for the approximately 450 graduate students who are research assistants is a matter that deserves mention. It is accomplished through the medium of a sponsored research project procured at the expense of considerable effort on the part of a professor who prepares a comprehensive proposal for submission to one of twelve or more different agencies—governmental, industrial, or private. The student is employed on the project as a colleague of the professor, and widespread agreement exists that a research assistant achieves a first-rate educational experience.

Funds for most of the sponsored research now undertaken in engineering colleges come from the federal government. In most instances government agencies grant contracts for periods of only one year, even though the life span of the project may be several years and most students require support for several years. During the six-month period, January 1, 1962, through June 30, 1962, professors in the School of Engineering prepared and submitted approximately 160 separate proposals to approximately 15 different agencies. Approximately 90 per cent of the agencies were governmental; 53 per cent of the proposals were for one-year support and 17 per cent for less than one year. Only 28 per cent were for support from one to three years.

One should not infer from these remarks that the sole purpose of sponsored research in universities is to fund graduate student education, even though many students could not afford graduate study without this aid. Of equal importance is the fact that it provides perhaps the only way to assure the enhancement and continued development of faculty competence and the strengthening of an institution's facilities. Only when an undergraduate educational program is developed in close association with forward looking research and graduate teaching is it assured of being up-to-date, and for engineering it is essential that this research provide an opportunity to bring onto the campus authentic problems that bear on frontier engineering topics. Furthermore, the existence of a flourishing research program on an educational campus has become the key factor in attracting faculty of the necessary professional capability and promise. Finally, university research programs offer a very good way of carrying out work which must be done to assure the continued technological progress of the nation.

The magnitude of faculty time and effort that must be allocated to procuring funds for this research and graduate student aid is cause for considerable concern. A proposal for support is an entrance into a national competition—as it must be when federal funds are involved—and since it must treat technical material of an advanced kind with great skill and persuasiveness, the preparation of proposals on the year-to-year basis is clearly a major burden.

The competition itself is also severe because professors as individuals find themselves in competition with industrial or national research laboratories when they seek funds. When they are called upon to show proof why their research is of sufficiently advanced character to justify federal money in open competition, they frequently find themselves in conflict with many well established criteria whose validity are essentially educational. There is latent here an issue of great national importance concerning the role of the university in advancing knowledge for its own sake vis-a-vis meeting a specific immediate goal of a government agency. The point that is not given the recognition it deserves is that, whenever a nation puts a significant percentage of its research investment into educational institutions that have intimate intellectual association with the youth of the next generation, it does several things at once, namely:

1) Strengthens the educational potential of a nation which in the final analysis may be the nation's most potent secret weapon.

2) Obtains the benefit of an environment that is virile and inherently self-generative and devoid of the restrictions which come from narrowly conceived objectives.

3) Educates the next generation of engineers at a level of sophistication and with a forward-looking vision commensurate with an expanding technology.

As many directors of industrial or governmental research laboratories will attest, continued viability of a large enterprise is extremely difficult to achieve. Often these laboratories show great promise for a decade or so and then appear to atrophy. They are seldom environments where young inquiring minds are encouraged to probe strange territory. In general, their sources of fresh new viewpoints are dependent upon a large turnover of people or an expansion in size. But research done in close association with the graduate student who is free to challenge accepted doctrines, who is encouraged to think freely and expansively and to undertake new ventures, benefits from many subtle factors which tend to keep the environment virile and viable.

Many persons in government and education support the doctrine that, to supply the number of highly trained, creative engineers presently needed, the dominant need is for funds to increase the national programs of fellowship support. But this action could easily result in the number of students running ahead of their educational supply lines—namely, the faculty and facilities which are needed to conduct strong programs of education. Surveys have shown that few schools, without additional facilities, can increase the number of graduate students, and rarely are these the stronger schools. The question might well be asked whether the kind of graduate education that they propose to furnish measures up to the demands of tomorrow's era. Almost without exception the strong schools plead for funds to procure additional space and to retool their research and teaching facilities so that they can move ahead with the difficult task of educating young men to meet the demands of a future era. There is presently an urgent need for a major reassessment of the premises on which graduate education is supported. Balance must be achieved between support for the student stipend and tuition and support for facilities, space, and time for professors whose research is key to the ultimate success of a strong program of teaching.

The National Science Foundation and certain other government agencies have sensed these situations for some time and have acted most wisely in their allocation of funds for the support of university on-campus research. The November, 1960, report of the President's Scientific Advisory Committee, entitled *Scientific Progress, the Universities and the Federal Government,* makes many important and constructive recommendations which, if instituted, should alleviate many of these difficulties. Nevertheless, our faculties in engineering face a major problem in continually funding their research programs to the degree that will support a large number of research assistants and graduate fellowship students and permit them to do the kind of research that is compatible with an evolving strong program of education, both undergraduate and graduate.

TEACHING ASSISTANTSHIPS

One other way whereby M.I.T. and its faculty contribute extensively to the funding of graduate education is by offering appointments as instructors and teaching assistants. During the academic year 1961-62, the School supported approximately 60 instructors and 140 teaching assistants. These appointments provide a student with a unique opportunity to test his command of the knowledge which he has acquired either in the classroom or laboratory through the demanding experience of communicating it to other students in class, in tutorials, or in the laboratory. It is not uncommon for instructors or teaching assistants at M.I.T. to teach graduate subjects. In fact, the challenge and rewards from teaching have now become so well recognized that a significant fraction of the predoctoral students who are research assistants request an opportunity to teach as part of their professional development. Likewise, in order to provide opportunity for teaching assistants to move ahead rapidly with their thesis research, the process of transferring a student from a teaching to a research assistantship is made very simple. Students are encouraged to transfer from one status to the other in order to derive the maximum benefit for their over-all programs.

Items of Current Interest

UNDERGRADUATE SEMINARS

The program of Undergraduate Seminars initiated last year for that third of the freshman class who elected it was an unqualified success from all points of view. The students gained a unique experience through active partnership with professors either in their laboratories or in small discussion groups working on problems characteristic of engineering. A total of 262 students were enrolled during the year in the 25 seminars offered by engineering professors—more than half of all the seminars that were offered. The program will be continued on an increased scale during the year 1962-63.

NEW PUBLICATION

This spring a new publication, *Engineering Notes*, was established as a partial solution to a major problem: that of transmitting to staff, students, alumni, professors in sister institutions, and the industrial community a current picture of our goals and programs. In spite of the already large number of M.I.T. publications, there is need for one specifically oriented toward informing the many people interested in educational trends within the School. The first issue discussed the content and goals of certain new subjects of instruction and gave a digest of texts or class notes currently in preparation. Another gave a brief summary of a number of the new ventures in laboratory teaching. Among the topics planned for the coming year in *Engineering Notes* are new research-teaching facilities, the role of teaching aids and computers, and some of the educational philosophy underlying these developments.

SPECIAL SUMMER PROGRAMS

Recognizing the need for closer collaboration between technical education and industry and the unusual opportunity afforded by its professional and geographical circumstances, the Massachusetts Institute of Technology in recent years has been shifting the accent of its summer activities. Greater emphasis is now given to its Special Summer Programs—a series of short intensive courses on timely scientific and technical topics. Here the Institute makes available, in a form permitting the participation of busy industrial and professional people, summaries of recent advances in many technical areas. The activity, initially conceived as an experiment, has now fully demonstrated its merit and takes its place as a principal purpose of the Institute's Summer Session. Nineteen programs were offered by Engineering School professors during the summer of 1962.

The problem that industry faces in bringing its personnel into contact with concepts and practices in new technologies has its parallel in the problem faced by many educational institutions in keeping faculties abreast of modern engineering. In many schools there is little opportunity for professors to conduct research or to work with graduate students. It appears that M.I.T. can make a major contribution by establishing programs wherein professors from these schools periodically may observe or participate either in research or in new experiments in teaching. These professors should then be in a position to translate their experience in fruitful ways on their local campuses.

Under an experiment conducted during the Summer Session of 1961, the School furnished a modest degree of financial assistance for professors from several institutions to attend Special Summer Programs of their choice. The funds were furnished from the portion of the 1959 grant from the Ford Foundation designated for extramural faculty development. The enthusiasm with which these visitors appraised their experiences led us to submit to the Ford Foundation a proposal to enlarge and extend the scope of the activity. Last February we received a grant of $150,000 for a three-year program. It is estimated that during the summer of 1962 about 140 professors will participate in 25 different programs. Of these, about 120 will attend one or more of the regular one- or two-week Special Summer Programs, and 16 will attend a five-week course on Experimental Solid-State Physics offered by Professor Arthur C. Smith and his colleagues in the Electrical Engineering Department. This latter program had its origin in a new graduate laboratory subject developed by the Department two years ago. The purpose of the summer program is to provide a broad experience in experimental solid-state physics and thereby enable the participants, all from other academic institutions, to strengthen their own programs.

Plans have also been made to present during late August a conference on Engineering Design and Graphics Education in which staff from the Department of Mechanical Engineering, under the leadership of Professor Robert W. Mann, will summarize the Department's educational program in the area of design for a group of approximately 75 participants from other engineering schools. This program will be sponsored by the National Science Foundation.

During the summer of 1963 we shall continue to assist professors from other institutions to attend the Special Summer Programs, and we hope to increase the number of programs concerned specifically with engineering instruction. It is now clear from these experiences that M.I.T. can play a major role in helping engineering professors from many other institutions gain an insight into recent experimental activities in research and teaching. It is clear that, if this type of activity is expanded and the financial support for professors is increased, a significant contribution is possible.

INVOLVEMENT IN OVERSEAS EDUCATION

The Kanpur Indo-American Program. The report of last year mentioned that the Indian Government had solicited the cooperation of American educational institutions in the establishment of a new

Indian Institute of Technology at Kanpur. This activity has now reached the stage where the program can be regarded as operational. Financial support from the United States Government has been furnished through the Agency for International Development (AID). A consortium of American institutions is operating under contract from Educational Services Incorporated which in turn negotiated a single contract with AID. The consortium comprises California Institute of Technology, Carnegie Institute of Technology, Case Institute of Technology, Massachusetts Institute of Technology, Ohio State University, Princeton University, Purdue University, University of California, University of Michigan, and Educational Services Incorporated.

The Indian Institute of Technology initiated operations on a modest scale in 1960 with faculty made up primarily of junior staff and with about 100 first-year students. Construction of laboratories, classrooms, and residential buildings on a site of 1,200 acres located just outside the city of Kanpur is now under way. The task of building the human, intellectual, and physical resources which collectively define a first-class institution is now the responsibility of the U.S. consortium working in partnership with the Indian Government.

Professor Norman C. Dahl of our Department of Mechanical Engineering was appointed Program Leader. He and his family took up residence in Kanpur in January, 1962. By September, 1962, he will be joined by Professor Robert L. Halfman of our Department of Aeronautics and Astronautics. We are pleased that M.I.T. has taken such a key role in the establishment of this important new project.

The Inter-American Program in Civil Engineering. Involvement by faculty and students in the Civil Engineering Department in overseas professional work has reached the stage where a grant of $250,000 from the Carnegie Corporation of New York was awarded for what may become a pioneer program of Inter-American activity. The program is unique in that it will involve upper-class and graduate students and professors from M.I.T. working in collaboration with professors and students from selected institutions in South America on unsolved civil engineering problems of technical, social, and economic importance. During the summer of 1962, Professors Charles L. Miller and Frederick McGarry of the Department of Civil Engineering visited selected institutions in Caracas, Venezuela, and Bogotá, Colombia, to arrange the initial details of next year's plan of action.

Personal and Professional Notes

It is with deepest regret that we report the untimely death on January 16 of Howard F. Taylor, Professor of Metallurgy, Director of the M.I.T. Foundry Laboratory, and one of the world's authorities on foundry engineering. Professor Taylor, who graduated from Michigan State College in 1938, joined the M.I.T. staff in 1945 and was made Professor of Metallurgy in 1952. More than any other person, he led the way in making a science out of a field which for centuries had been based on a tradition of trial-and-error.

We were saddened also by the passing of three of our distinguished Professors Emeriti. They are Ralph R. Lawrence, Professor Emeritus of Electrical Engineering (March 13, 1962); Lyman Miner Dawes, Assistant Professor Emeritus of Industrial Applications of Electrical Engineering (March 6, 1962); and Robert S. Williams, Professor Emeritus of Metallurgy (December 11, 1961). Professor Lawrence was graduated from M.I.T. in 1895 and had from that date been associated with M.I.T. He was appointed Professor of Electrical Machinery in 1922, and his career was filled with achievement in that field, including the authorship of several important texts. Professor Dawes, after 23 years of industrial experience with independent telegraph companies, came to M.I.T. as a student in 1920. Receiving his Bachelor of Science degree in 1923, he joined the staff and was made Assistant Professor in 1941. He made many contributions to the fields of electrical machinery and industrial applications of electricity. Professor Williams, head of the Department of Metallurgy from 1937 to 1946, was graduated from M.I.T. in 1902 and received his Ph.D. from the University of Gottingen in 1907. He enjoyed a long career of technical contribution, academic administration, and service to the U.S. Government in many advisory capacities.

Dr. William W. Seifert, Associate Professor of Electrical Engineering, was in May, 1962, appointed Assistant Dean of the School of Engineering. While his administrative duties in this capacity will demand much of his time, Dr. Seifert will continue to play an active teaching role in the Department of Electrical Engineering.

In September, 1961, Professor Charles L. Miller was appointed Head of the Department of Civil Engineering. Professor Miller succeeds Dr. John B. Wilbur, noted structural engineer, who served with distinction as Head of the Department for over fifteen years. Professor Miller, who joined the faculty in 1955, will continue his activities in applying information systems and computer methods to civil engineering problems.

Professor John Chipman retired from his post as Head of the Department of Metallurgy, after a distinguished tenure of sixteen years in that office. Dr. Chipman joined M.I.T.'s faculty in 1937. During the war he played a major role for the Manhattan Project in uranium metallurgy. He is internationally known for his research in metallurgy and physical chemistry and the application of thermodynamics to metallurgical processes. Professor Thomas B. King has been appointed Acting Head of the Department. In addition to his teaching activities and distinguished research in transport phenomena and kinetics in metallurgical processes, Professor King has served the Department as Executive Officer since 1956.

Professor Raymond L. Bisplinghoff, Deputy Head of the Department of Aeronautics and Astronautics, has been granted leave-of-absence to accept the post of Director of Advance Research and Technology, National Aeronautics and Space Administration. Professor Bisplinghoff will return to M.I.T. after two years at this post.

In addition to the five Ford Professorships discussed earlier in this report, two other members of our faculty have been honored by appointments to endowed chairs. Professor John Wulff of the Department of Metallurgy has been named the first occupant of the new Class of 1922 Professorship. Professor Wulff, who is internationally known as an educator and a research metallurgist, joined the M.I.T. faculty in 1937 and has distinguished himself through his research in the areas of powder metallurgy and superconducting alloys. Professor Rene H. Miller of the Department of Aeronautics and Astronautics has been appointed the first holder of a new endowed chair, the H. N. Slater Professorship in Flight Transportation. In this capacity, Professor Miller will take immediate steps to establish a graduate program of teaching and research in flight transportation.

The many other professional activities and honors of our faculty during the past year are listed at the back of this volume.

GORDON S. BROWN
WILLIAM W. SEIFERT

Department of Aeronautics and Astronautics

Space technology, the complex of scientific knowledge, engineering, vehicles, support equipment, test installations, industrial facilities, management organizations, and other factors that create vehicle systems for operation in regions outside of planetary atmospheres, has developed rapidly during the past year. Within the span of twelve months, orbital flights carrying men several times around the earth have been accomplished by the Soviet Union and by the United States, and both countries have announced plans for vehicles able to take crews of several people on trips to the moon and back well before the end of this decade. Scientific research by vehicles in earth orbits continues of great importance; the number of satellites has now become so large that another launching is given almost no attention in the press. Several ballistic missile systems developed by the United States have achieved satisfactory tests and reached the stage of operational readiness.

The problems of life support, reliability, and complexity that attend any realization of human travel into space are just now being brought under intensive study. Future developments cannot be exactly described with high confidence, but it is safe to predict that even a short period will see fantastic advances over the present state of technology.

Studies of flight problems at the interface of the earth's atmosphere and outer space have been continued with the X-15 research airplane. These flights and other investigations of conditions existing at supersonic speeds have shown the feasibility of aircraft such as the B-70 for operation at speeds in excess of 2,000 miles per hour. At the other end of the spectrum, helicopters are being steadily improved for practical operation, and VTOL craft will surely soon become important factors in short-range transportation. Subsonic airplanes with gas-turbine-driven propellers and jets are providing excellent performance for today's airline operations, but the over-all field of flight transportation is just beginning to be given serious attention as a profession and as an educational discipline.

All these areas of development are currently receiving significant financial support. Very great sums are available to the National Aeronautics and Space Administration and to the military services for the development and production of ballistic missiles, earth satellites, lunar craft, interplanetary vehicles, and their propulsion systems.

Challenging problems and support at high levels combine to provide great opportunities for engineers who wish to follow the broad field of flight vehicles and the systems in which they serve as essential components. These are engineers well rounded in the humanities and the elements of good citizenship, who have a sound and broad education in basic and applied science, understand the principles of professional engineering, are willing to accept responsibility, and have a working familiarity with the methods and efforts required to meet stated performance specifications on schedule and within the limits of available funds. The Department will consider that it has been successful only if its students prove themselves capable of dealing effectively with the problems associated with all types of flight vehicles and the systems in which they operate.

EDUCATIONAL POLICY

Education for aeronautics and astronautics must cover the full range of fundamental physics, chemistry, and mathematics. Materials, communications, data handling, and computing are also essential subjects. Economics and management are needed to round out the qualifications of good engineers. Indeed, the range of professional knowledge required for flight vehicle design is very broad; the breadth and depth required in such fields as mechanics, structures, gas dynamics, propulsion, control, and guidance make necessary a series of always-changing subjects in these areas. The restriction of a four-year undergraduate curriculum for sound preparation for either research or engineering in all fields from helicopters to interplanetary craft is difficult. But it is not beyond our capabilities. The professional growth of faculty members in aeronautics and astronautics is favored by working closely with advanced research and by consulting directly with government agencies, industry, and schools. Teachers who appreciate current situations and trends for the future are in the best possible position to prepare students who must deal not only with the problems of today but with those that will appear during the period of five to fifty years after graduation.

The background of basic science, applied science, and the engineering principles provided by the Department curriculum are broad enough to deal with the problems of flight from helicopters to space craft. To reduce this complex field to manageable proportions, we emphasize a single over-all point of view and method which is effective in all cases without distinction among the many possible vehicle types. Thus a student is expected to deal as effectively with airplanes as with craft designed for trips to the moon.

Two options are provided by the Department for its students: a science curriculum intended for those who are primarily interested in research, and an engineering course adapted for the education of individuals who expect to follow design, fabrication, and testing of flight vehicles and the systems in which they operate. Laboratory activities play a strong role in both options. All undergraduate students are required to take Project Laboratory subjects in which they accept responsibility for designing and carrying out on their own initiative experiments that cut across the conventional boundaries of several disciplines. In addition, the Department's extensive program of sponsored research offers opportunities with part-time pay for undergraduates and graduates who are interested in research and thesis work. Internship-type employment is also available for postgraduates in the form of full-time jobs for those wishing to further improve their professional qualifications.

CENTER FOR AERONAUTICS AND ASTRONAUTICS

In order to bring its strength to bear effectively upon the problems of aeronautics and astronautics, the Institute urgently needs a center in which the teaching and research interests of the entire staff in these fields can be integrated within a single unit.

A Center for Aeronautics and Astronautics will assure space and facilities for scientific and engineering education intimately associated with research in areas pertinent to these fields. It will provide needed new space. Student interest in aeronautics and astronautics has outgrown our already crowded physical plant. In 1958 the Department awarded thirty-five Master of Science degrees; now the annual average is of the order of 60. In 1958, one Doctor's degree was awarded; in 1961 there were twelve, in 1962, eleven.

The Center for Aeronautics and Astronautics will be both complementary and supplementary to the other major interdepartmental centers now being planned and built. The potential interaction of the Center for Materials Science and Engineering with that of Aeronautics and Astronautics may be cited as an example of mutual strengthening. The efficiency and performance of flight vehicles and their guidance and propulsion systems are usually dictated by limitations of materials. The technologies of high-lift and high-drag re-entry vehicles, rocket nozzles, space-power reactors, supersonic transport structures, and surface environmental effects on space-craft are a few examples of problems in which the materials sciences play important roles in aeronautics and astronautics. It is of interest to note that the Centers of Materials Science and Aeronautics and Astronautics will occupy adjoining buildings if the latter is located in the space connecting Buildings 7 and 33.

Because of the extreme importance of communications and means for life-support in future air and space craft systems, it is not difficult to visualize strong interactions between the Centers for the Communication Sciences and the Life Sciences with the Center for Aeronautics and Astronautics.

For several years the Department has been actively planning a research and teaching organization for the new Center for Aeronautics and Astronautics. These plans have virtually been put into effect within the Department at the present time. Several arrangements of building facilities have been worked out as preliminary architectural drawings. Needed physical research facilities have been carefully studied and documented in detail by Department committees. The symbiotic coupling between basic research and education has been recognized for many years by the Department as a massive source of strength. It is in this spirit that the Department plans to augment its capabilities by the formation of a Center of Aeronautics and Astronautics.

FLIGHT TRANSPORTATION

With the permanent appointment of Professor Rene H. Miller to the Slater Professorship of Flight Transportation, it has become possible to centralize much of the Department's activities in flight vehicle design and operation around the concept of transportation of the surface of the earth. All flight vehicles, from helicopters to space craft, are included in the Department's treatment of this subject, since we recognize that the rapid advance of technology will very quickly reduce to obsolescence any teaching concerned mainly with current situations. However, certain of the problems involved are fundamental and will remain important for the indefinitely extended future. Consequently, the teaching and research program for flight transportation has been broadened beyond the disciplines involved in the design and development of vehicles to include the factors that make up the environments in which the vehicles must operate. For example, the economics of short-haul transportation, requiring mainly an answer to the "commuter" problem in which costly equipment can be fully utilized during only a fraction of the day, has never been solved for surface transportation. This problem is currently introducing major obstacles to efficient interurban air travel and will be a serious difficulty for transoceanic travel when the supersonic transport becomes a reality. A satisfactory resolution requires an integrated approach by the transportation engineer in which vehicle design, operational problems, economics, sociological problems of airport siting, and geopolitical problems of route allocation must be carefully considered. A similar question involving the interplay of many disciplines is that of air traffic control, particularly in the terminal area. An answer to this problem may come from new vehicle concepts permitting steep or even vertical approaches, or an answer may come from new concepts of guidance and control in which each vehicle is always exactly positioned with its location continuously known and recorded in both the cockpit and ground control stations. More likely the solution will be a combination of these or may involve devices not yet imagined.

Because of the breadth of flight transportation problems, the background material required to educate engineers draws on several Departments at the Institute in addition to the Department of Aeronautics and Astronautics. During the coming fall term a new subject in Flight Transportation will include contributions from the Department of Civil Engineering on airport construction, from the Department of Electrical Engineering on communications, from the School of Industrial Management on airline financing, and from the Departments of Mechanical Engineering and Naval Architecture on the general problems of transportation as seen in the established forms of surface transportation, from which flight transportation may have much to learn. In addition to formal lectures by the Institute staff, there will be seminars by people prominent in the air transportation industry, the regulatory agencies, and the national and international air carrier associations in order to relate the academic approach to the real problems of present day air travel. Teaching in depth, always a problem in a subject of such broad coverage, will be achieved by allowing each student to select and carry out a project on his own initiative, reporting on the result at an end-of-the-term meeting of his class.

Related research projects are a necessary ingredient in any graduate activity, to provide sources of thesis support and close associations with outside activities in government and industry. We are making a continuous search for means to broaden research in flight transportation in directions where a real contribution may be made by the Institute; this is an area of great potential in which there remains to be done much systematic research of a high caliber promising major benefits to mankind. Flight safety is certainly one of these areas and remains a primary consideration in planning for both teaching and research. Currently, the Department is conducting research in advanced concepts of VTOL guidance and control and in the aerodynamics of these aircraft and the supersonic transport.

Teaching and research in flight transportation will remain closely associated with our continuing programs in vehicle design and system engineering and indeed may provide the common core about which this work is oriented. Many basic economic and operational questions—such as heavy investments in ground equipment, trade-offs between weight, performance, and reliability, and control and guidance in three dimensions—are common to all flight vehicles. This forces a fundamental approach which considers all forms of air transportation, interplanetary as well as in the atmosphere, and thereby avoids the danger of obsolescence and preoccupation with transitory problems.

ASTRONAUTICS

Astronautics, the art and science of flight "among the stars," involves knowledge of astronomical bodies and the conditions existing in space as well as scientific and engineering background for the design and construction of vehicles adapted to these conditions and needs. Some ten years ago the Department realized the coming importance of astronautics and began to systematically modify its existing subjects and to add new ones as necessary to provide sound education for students professionally interested in astronautics. A condition imposed on these modifications was that no relaxation of the already established high standards for education in aeronautics was permitted. Thus it was required that aeronautics, the art and science of flight within the earth's atmosphere, should be given adequate coverage by the same curriculum that provided education for astronautics. The method chosen to achieve this goal was to extend the range of variables under study from the levels existing at the earth's surface to the levels of interplanetary space and use generalized terms for treating the problems of fluid dynamics, structures, propulsion, control, and guidance. In addition, subjects on celestial mechanics and the physics of space were organized and integrated with the introductory work in aeronautical mechanics. Design options in engineering subjects were extended to include the full range of astronautical vehicles from missiles to interplanetary craft. Theories of plasmas and magnetohydrodynamics were added to the fluid dynamics teaching material. The problems of materials exposed to high vacuum and high-speed particle bombardment received special treatment, and communication, data handling, and computing became an important area.

These changes are still in progress, and a substantial part of the Department faculty is now engaged in astronautical work of some kind. In particular, Assistant Professor Winston R. Markey's Experimental Astronomy Laboratory has started to attract students in reasonable numbers. Another source of opportunities for undergraduates, graduates, and postgraduates is the Apollo Guidance Project under which the Instrumentation Laboratory has full responsibility for guidance of vehicles carrying three-man crews to the moon and back. This comprehensive project is providing part-time and full-time employment for many individuals who are interested in space travel developments.

During the past academic year the Department was fortunate in having Dr. Samuel Herrick as the Jerome Clarke Hunsaker Professor of Aeronautical Engineering. In this position he delivered a series of lectures on astronomy and astrodynamics and climaxed the year with his Minta Martin Lectures on "Space Navigation." Professor Herrick added much to the Department during his stay and contributed largely to the education pattern for astronautics.

AEROSPACE RESEARCH DIVISION

The newly established Aerospace Research Division, consisting of the Aerophysics, Aeroelastic and Structures, Fluid Dynamics, and Experimental Astronomy Laboratories, the Wright Brothers Wind Tunnel, and the Naval Supersonic Facility, has completed its first full year of operation. Its Steering Committee, of which Professor Raymond L. Bisplinghoff is Chairman and Lawrence E. Beckley, Executive Officer, is Secretary, met twice monthly during the past year to study the important policy problems concerning the facilities of the Division as well as other matters which required faculty decision. In this scheme of operation, which appears to be successful, the Chairman is responsible to the head of the Department for the over-all management of the facilities and the services, and the Executive Officer is responsible for the day-to-day operation, including such matters as salaries and wages, contract negotiations, fiscal control, liaison with the Division of Sponsored Research, purchasing, and employee relations.

PROPULSION

The operational capability of any flight vehicle is dependent very largely on the performance of its propulsion system. The modern jet transport is made possible by the great efficiency and light weight of turbojet engines; future developments in vertical-takeoff aircraft must wait for the development of very light turbojet or turboprop engines; our present space exploration program would be impossible without the highly-developed liquid-propellant rocket engines, but these may presently be supplanted by more efficient and reliable large solid-propellant rockets; propulsion systems to make interplanetary travel practical have been conceived and are the subject of current research efforts.

It is clear that the Department must maintain a vigorous program of teaching and research in propulsion. All graduates must have a sound understanding of the characteristics of major propulsion systems, and as their number increases, more efficient teaching methods and shifts in emphasis will be required to insure the proper coverage. It is not sufficient to educate graduate students through research in areas concerning currently operable systems; strong emphasis must be given to the systems which will be current five or ten years hence.

FORD FOUNDATION SUPPORT

Grants from the Ford Foundation to improve engineering education have brought about extensive revisions of the Department's undergraduate subjects. While it is normal to revise the material each time a subject is given, the Ford funds make possible large-scale modifications of many subjects. The extent and depth of these changes are indicated by the examples cited below:

Solid Mechanics. A milestone during the year was the first class in Solid Mechanics II, and teaching notes have now been completed for the two-term sequence. These two subjects, without question, put

M.I.T.'s undergraduate Solid Mechanics on an exceptionally advanced base, thanks to the painstaking organization by Professors Raymond L. Bisplinghoff, James W. Mar, and Theodore H. H. Pian. The three underlying ideas of equilibrium, compatibility, and state conditions are introduced at the outset. The whole subject is cast in the language of cartesian tensors, a useful tool to employ because it is so well adapted to describe the transformation properties of stress and strain. There is unusual emphasis on complex variable techniques for representing plane strain and generalized plane stress. The efforts during the coming year in Solid Mechanics curricula development will shift from statics to dynamics of solid continua with emphasis on wave propagation phenomena.

Dynamics. The efforts of Professor Robert L. Halfman under the Ford program in the area of Dynamics has been completed, temporarily at least, with the publication of his text, *Dynamics—Particles, Rigid Bodies, and Systems.* A second text, *Dynamics—Systems, Variational Methods, and Relativity,* is to be published during August, 1962. The Ford funds expedited these efforts very substantially. We believe that these texts will extend to many other institutions the new developments in teaching undergraduate dynamics for the space age which are represented by the Dynamics subjects given here.

Gas Dynamics. The preparation of notes for a two-term sequence in Aerodynamics of Wings and Bodies, completed by Professors Holt Ashley and Marten T. Landahl, was partially supported by the Ford Foundation. The subjects treat classical and recent problems of aerodynamics from a modern point of view. Among the principal innovations are the use of the inner and outer expansion method of Kaplun and Lagerstrom for dealing with aerodynamic problems such as lifting-line theory and slender-body theory and the formulation and treatment of lifting-surface problems and other complicated flow situations by means of digital computer solutions. Fundamental theoretical aspects are emphasized with checks from experimental data where possible.

Some Ford Foundation support was used to help with the writing of a new book, *Principles of Aeroelasticity,* by Professors Ashley and Bisplinghoff. This very useful text for courses in structural dynamics and aerodynamics will be published in July, 1962.

The subject in Flight Vehicle Aerodynamics and Dynamics has been revised by Professor Joseph Bicknell to include fundamentals of viscous fluid mechanics. The material on aerodynamics has been closely correlated in subject and matter and emphasis with Professor Ashley's preceding subject in Aerodynamics. This continuity is aimed at eliminating the difference between the theoretical and applied treatments of vehicle aerodynamics.

Projects Laboratory. As reported last year, the Department has introduced two new undergraduate laboratory subjects, Experimental Projects I and II, with support by the Ford Foundation grant. The first is required of all undergraduates, while the second is required only for students in the engineering science option. These subjects are intended to give students a better sense of reality and to teach them how to use experiments as tools to understanding. The first has now been given four times, the advanced twice. The Department believes that the reasons for starting the Experimental Projects subjects have proved to be sound, that the subjects are successful from the standpoint of teaching, and that they should be continued as a permanent feature of education in aeronautics and astronautics.

An important byproduct of the Projects Laboratory is the opportunity for students to conduct seed research that begins as a project and continues as a thesis. Two such project-theses are being published. The Projects Laboratory was in charge of Professor Erik L. Mollö-Christensen, assisted by fourteen other members of the Department faculty, this past year; he will be replaced next year by Professor Walter McKay, as supervision of this Laboratory is by agreement to be rotated among the available staff members.

Propulsion. Under the leadership of Professor Edward S. Taylor, a week-long series of meetings of faculty engaged in teaching and research in the propulsion area was held under Ford sponsorship at Endicott House last September. The result was a decision to develop a unified four-term sequence in propulsion and to write textbooks for these subjects. Professors Philip G. Hill (Mechanical Engineering Department) and Carl R. Peterson are engaged in writing a text on *Mechanics and Thermodynamics of Propulsion,* and Professors Myron A. Hoffman, Jack L. Kerrebrock, and Gordon C. Oates offered a two-term graduate subject in Astronautical Propulsion.

Engineering. Professor Rene H. Miller has been actively engaged in a revision of the subjects in Flight Vehicle Engineering. This is the only area within the Department where professional engineering practice is taught, and these subjects are badly needed to provide education for the technology of aeronautics and astronautics.

STUDENT HONORS

The Luis de Florez Award for outstanding ingenuity was given to Stanley Harrison. The James Means Memorial Prize for professional promise was awarded to David A. Kleinhen. David J. Coker won the Henry Webb Salisbury Memorial Award for outstanding work in Aeronautics and Astronautics. All students were of the Class of 1962.

UNDERGRADUATE ACTIVITIES

The undergraduate program has continued in a very strong position, with enrollment remaining at the level of the last few years. The Class of 1963 is the first group to follow the new curriculum which will probably remain stabilized except for the normal continuous changes in subject matter.

Undergraduate registration in the Department as of June, 1962, is forty-three juniors and sixty sophomores. A total of forty-one Bachelor's degrees were granted in 1962. Of these graduates, twenty-one went on to graduate work at M.I.T., and many went to other schools.

The Honors Course under Professors Ashley, Hoffman, and Markey met throughout the year with twenty-five regular members. Six members of the class of 1963 and seven members of the class of 1964 will be invited to join in the fall.

The Cooperative Course continues to be an important option in our undergraduate curriculum. Enrollment is eleven in the Class of 1964, twelve in the Class of 1963, and eight in the Class of 1962.

The preference of students for the engineering or engineering science programs is difficult to determine exactly because of overlapping electives. Using the students' registration in either Flight Vehicle Engineering (16.71) or Projects Laboratory II (16.63) as an index, seventeen students of the Class of 1962 elected the engineering program and thirty-one elected the engineering science program. Last year the division was nearly equal.

Professor C. Stark Draper and Dr. John Hovorka offered an Undergraduate Seminar on Guidance and Control of Space Vehicles in both terms, and Professor Markey led a seminar group of freshmen in the new laboratory project which was carried out in the Experimental Astronomy Laboratory. Professor Mollö-Christensen made a similar contribution to the Undergraduate Seminar program with special experiments in fluid mechanics. Professor Emeritus John R. Markham conducted an Undergraduate Seminar in High-Speed Aerodynamics.

GRADUATE PROGRAMS

The continued growth of the field of astronautics is felt in the demand for more and higher graduate education. The Department is anticipating and meeting these new demands in several areas.

Professor Landahl undertook the task of reorganizing the doctoral thesis program of the Department. A reasonable, uniform, minimum passing standard has been established, and doctoral theses are now subjected to the scrutinizing review that is standard in material submitted to the better scientific journals.

The graduate program for the Air Force and Navy officers has been expanded in the past year. In addition to the original curricula in guidance and control and in astronautics, courses have also been put together for dynamics, solid mechanics and materials, and propulsion. With the arrangements now existing, the programs for military students now have a flexibility similar to that available for civilian students.

The graduate enrollment as of June, 1962, consisted of ninety-two civilian students and forty-seven students sponsored by the government. Special students are not included in these numbers.

Advanced degrees granted in 1962 included 49 Master's degrees (18 military), 9 Engineer degrees (6 military), and 11 Doctor's degrees (7 military).

The revision of course content continued at a brisk pace. In the gas dynamics area, Professors Ashley and Landahl developed a new two-term sequence on the Aerodynamics of Wings and Bodies, replacing the Aerodynamics of Missiles subject. The object of the new subject is to put classical aerodynamic theory into a modern unified concept. Ford Foundation funds helped support this development. Professors Ashley, Judson R. Baron, Halfman, Landahl, and John Dugundji gave a new subject in Atmospheric Entry which was well attended, for which Professor Landahl was responsible for organization and coordination. Professor Baron developed new material for Topics in Gas Dynamics; this introduces statistical mechanics as a method of description and includes non-equilibrium flows of current interest. Professor Yao T. Li initiated a new interdepartmental laboratory subject, Special Studies in Information Systems, in which three other departments in the School of Engineering are participants. Professor Wallace E. Vander Velde helped Professor Li in organizing and teaching the new material. Professor Bisplinghoff upgraded the approach to Advanced Theory of Structures. The three-dimensional theory of elasticity and plasticity is framed in terms of Riemannian tensor calculus. Although the majority of the class were unfamiliar with this branch of mathematics, it was found that its relevant principles could be taught in sufficient detail along with the primary subject matter. This branch of mathematics has also been employed as a tool by Professors Mar and Pian in the treatment of advanced shell theory. Lectures on the propagation of strong shock waves in solids were introduced in the graduate subject on Dynamics of Structures by Professor Emmett A. Witmer during the past year.

Graduate student support is a growing problem. Graduate student enrollment is determined to a large extent by the quality and quantity of our fellowships and assistantships. In the size of its fellowship awards, M.I.T. is not competing favorably with other schools of comparable quality, and improvement must be made if M.I.T. is to continue its leadership in education at the graduate level.

STAFF CHANGES

Professor H. Guyford Stever was appointed Head of the Department of Mechanical Engineering and of the Department of Naval Architecture and Marine Engineering but, in accordance with his own request, retained his status as Professor of Aeronautics and Astronautics.

Dr. Saul S. Abarbanel was given an appointment as Assistant Professor. Professor James L. Stockard was granted a leave of absence for the second term to work with an industrial firm. Professor Paul E. Sandorff requested leave for one year to extend his professional experience with the Lockheed Aircraft Company. Professor E. Eugene Larrabee spent the year teaching at the University of Cairo as a Fulbright lecturer.

Guests of the Institute in the Department included Dr. Stanislaw M. Skowronski of the Polish Academy of Sciences, a specialist in nonlinear vibrations, who worked with Professor Li; and Marat B. Vakhitov of the Kazan Aviation Institute, Russia, whose specialty is structures and elasticity, and who worked with Professor Bisplinghoff. Dr. T. Brooke Benjamin of the University of Cambridge was a guest for six weeks, working with Professor Landahl on boundary layer stability and the porpoise problem.

The participation of the faculty in professional society work and on advisory committees continued as an important function. The most important of these assignments are listed elsewhere.

SEMINARS AND LECTURES

On March 8, Professor C. Fayette Taylor of the Mechanical Engineering Department presented the fifth Lester D. Gardner Lecture on "A Review of the Evolution of Aeronautical Power Plants."

The Department has in the past year continued its H. N. Slater Seminars in the field of air transportation. Prominent among the speakers were M. Poisson-Quinton of the Office National d'Etudes et de Recherche Aeronautiques (ONERA) and Mr. Raymond Utterstrom of the Boeing Aircraft Company. M. Poisson-Quinton discussed the aerodynamic development of the French Super-Caravelle. Mr. Utterstrom's seminar dealt with the problem of reducing the weather minima required for safe air transport operation.

The Fluid Dynamics Research Group sponsored a series of fluid mechanics seminars on current topics in this field.

RESEARCH ACTIVITIES

The Department's research activities are organized in two divisions: the Instrumentation Laboratory, directed by Professor Draper, and the Aerospace Research Division, an association of the remaining Department laboratories.

INSTRUMENTATION DIVISION

Instrumentation Laboratory activities have expanded somewhat during the past year. Success with Laboratory-developed inertial guidance systems for Titan and Polaris missiles has continued, and both of these weapons are now in the operational inventory of our country. Development has continued on components and systems under sponsorship of the Air Force, the Navy, and the N.A.S.A. Many items from the Laboratory are now accepted and are in production by industrial concerns to fulfill demands from government agencies.

The most notable event of the past year has been the action of the N.A.S.A. in assigning to the Laboratory the full responsibility for designing and supplying guidance equipment for the Apollo vehicle which will be designed to make round trips to the moon with a crew of three men. The work associated with carrying out the Apollo guidance project will require some expansion of Instrumentation Laboratory facilities and personnel. It is hoped that the increases involved will not exceed 20 per cent. The challenges for the Laboratory remain great, and its usefulness in research and education continues to increase.

AEROSPACE RESEARCH DIVISION

The organization and development of the Aerospace Research Division has been described earlier in this report. The past year's activities of the several laboratories which make up the Division are reviewed in the paragraphs which follow.

Aerophysics Laboratory. The current projects and outstanding proposals indicate clearly that this group now constitutes a true university research laboratory. Emphasis is placed on attaining a thorough understanding of several areas of research that are presently, and will continue to be, of interest in aerospace technology.

Work is progressing on the aerodynamic problems underlying supersonic transport aircraft, sonic booms, real gas phenomena at high velocities and temperatures, low density gas dynamics, and the flow of ionized media.

Serious attention is given to the development of the tools needed for future research work. As an example, a magnetic suspension system for holding models in the hypersonic tunnel free of any mechanical support has been completed. This opens the way to the study of various dynamic phenomena and to basic studies heretofore unreachable. A program for the development of a very high-speed tunnel in which an ionized stream is accelerated by magnetic fields has been initiated. Instrumentation developments are involved with most experimental programs.

The development of a cohesive research program has eased a formerly difficult problem of funding until, at the present time, full support is apparently available for the years ahead. Such a situation allows the Laboratory to accept an increasing number of thesis students while receiving support from only the most desirable projects. However, projects and thesis work are not a sufficient measure of this Laboratory's contributions toward the position of M.I..T. in research. The Laboratory has made its facilities and personnel available when requested by staff and students in the Physics and Electrical Engineering Departments, and this kind of collaboration will be continued and extended in the future.

The Director of the Laboratory is Professor Morton Finston. Professor Judson R. Baron, Dr. Leon H. Schindel of the Department academic staff; Dr. Beverly J. Beane, Dr. Eugene E. Covert, and Dr. Manfred P. Friedman; and Frank H. Durgin of the D.S.R. staff provide supervision for the Laboratory's activities.

Aeroelastic and Structures Research Laboratory. During the past year, diverse research activities intimately connected with both the undergraduate and the graduate educational program have been carried out in the Aeroelastic and Structures Research Laboratory under the direction of Professor Bisplinghoff. Broadly speaking, these research problems may be classified in seven categories: aerodynamic noise, aerodynamics of helicopter rotors, unsteady aerodynamics, vibration and flutter, dynamic response of structures in the linear and nonlinear regimes, dynamic behavior of solids, and properties of composite materials. This research, sponsored by industry and governmental agencies, has been supervised by Professors Ashley, Bisplinghoff, Mar, Miller, Mollö-Christensen, Pian, Witmer, and Dugundji.

Gas Turbine Laboratory. The Gas Turbine Laboratory, directed by Professor Edward S. Taylor, has continued the investigation of three-dimensional boundary layer characteristics of turbine and compressor blades. New methods of flow measurement in the present of separated boundary layers have been developed.

Fluid Dynamic Research Laboratory. The Fluid Dynamics Research Laboratory, including Professor Leon Trilling as Director and Professors Ashley, Landahl, and Mollö-Christensen at the faculty level, has been active in the fields of gas dynamics, rarefied gas flows, and unsteady viscous flows.

Experimental Astronomy Laboratory. The Experimental Astronomy Laboratory, headed by Professor Markey, continued experimental studies of sky brightness using balloon vehicles. In addition, support for research on the propagation of electromagnetic radiation through turbulent media was received. Student participation in the laboratory activities increased sharply this year. Five research assistants have been added to the staff, and one of the new Undergraduate Seminars was integrated into laboratory projects. Thesis support continues at the Bachelor's, Master's and Doctorate levels.

SPACE PROPULSION RESEARCH

Propulsion research directed by Assistant Professors Kerrebrock, Hoffman, and Oates within the Aerospace Research Division includes: an experimental study of the mechanisms of conduction in noble gas-alkali metal plasmas, with particular emphasis on non-equilibrium and surface effects; analytical studies of boundary layer behavior in plasma accelerators and magnetogasdynamic generators; an analytical study of the stability of the conduction process in a plasma; and an experimental study of the electrical properties of pure alkali metal vapors at very high temperatures.

A heat exchanger facility has been developed to produce an unusually pure and predictable noble gas-alkali metal plasma in steady flow.

WIND TUNNELS

With the transition of the Aerospace Research Division to a university research laboratory, the operation of Naval Supersonic Wind Tunnel has been considerably modified. The tunnel operation is now more intermittent, more model setup and checkout time is needed, and less straight operating time is involved. To reduce the standby costs, the full-time operating crew has been reduced to one man. When the tunnel is run, engineering and technical personnel are borrowed from the Aerophysics Laboratory. From a sizeable deficit on January 1, 1962, tunnel operations have now reached a state of solvency.

The Wright Brothers Wind Tunnel was used principally for student thesis and project work during the past year. Arrangements have been completed for the tunnel to undertake D.S.R. contracts. This will ease the problems of funding associated with sponsored research work.

Professor Bicknell has been responsible for the operation of both the Naval Supersonic and Wright Brothers Wind Tunnels.

CHARLES S. DRAPER

Department of Chemical Engineering

The curriculum revisions that have been under development for several years have resulted in major changes in all of the four undergraduate years. They give students greater depth and breadth in the experimental, analytical and theoretical aspects of chemical engineering.

UNDERGRADUATE LABORATORY AND RESEARCH

The Department has always placed a strong emphasis on the value of experimental studies as a method of developing students' ability to handle new problems and situations with competence. Students may now take a program of laboratory instruction of the research or project type in any or all of his four undergraduate years. This program gives the students an opportunity to work in laboratories where the advanced graduate research studies are underway and thereby lets them see, in their early years, the scope and exciting frontiers of chemical engineering. We find that this approach helps many students obtain a better understanding of their classroom subjects and that it develops their ability to integrate several fields and to apply engineering judgment.

Five of our staff participated in the Undergraduate Seminar programs and had small groups of freshmen students in the history of science, process design, and applied chemistry. These Seminars involved both discussion groups and laboratory research and gave the students involved an introduction to chemical engineering problems and the methods by which they are solved.

A new laboratory subject in supervised group research was introduced for sophomore, junior, and senior students by Professors Warren K. Lewis, Herman P. Meissner, and Harold C. Weber. This subject was given in both semesters and involved students from all three years. The group selected a research problem and worked as a team on its solution, with individual students taking responsibility for different parts of the problem commensurate with their level.

For several years the seniors in chemical engineering have taken a major laboratory subject in either the applied chemistry or engineering aspects of the field. The program involves supervised research by students in small groups, usually three, with each group doing three projects during the semester. Each student, in turn, serves as leader for one of the research problems. The topics are suggested by the whole Departmental staff, and the staff member who proposes the problem acts as an adviser or consultant to the student group. Major emphasis is placed on both oral and written reports. The students have shown a much greater interest in this type of work than in standardized laboratory work.

UNDERGRADUATE CLASSROOM SUBJECTS

In addition to the increased emphasis on laboratory work, a major revision is underway in the undergraduate subjects. A few years ago the thermodynamics subjects were moved from the junior to the sophomore year to make room for new syntheses of material in the engineering science, material science, and applied chemistry areas.

This year Professor Harold S. Mickley gave the first two semesters of a three-term sequence which he has been developing under a Ford Foundation grant. This involves a major revision of the instruction in unit operations, the objectives of which are: to provide the physical concepts and mathematical methods needed to analyze and predict the response of real matter to all types of forces and fields; to use this information to determine the rates of transport of momentum, energy, and matter within and between material phases; to develop methods of utilizing the transport rate information in the synthesis of staged and continuous processes; and to lay a firm foundation for advanced work and for student self-education. The new subjects covering the first two topics were given to a selected group of students during the past year, and although the treatment differed drastically, the students' reaction was favorable and they obtained a strong grasp of the essential ideas. The preliminary material is being revised and improved, and the subjects will be presented again during the next school year.

The rapid postwar development of the engineering science subjects has focused attention on analysis as a tool of great power for the practicing engineer. With four years still the norm for the Bachelor's degree, time for design subjects has necessarily been reduced in order to treat the basic engineering sciences properly. Neither analysis nor design should be slighted in the engineering programs; the problem is to maintain a proper balance, and, most important, to fuse the two so that they complement each other while each is kept in proper perspective in relation to the student's objective. With this problem in mind, a new senior subject was developed by Professor Thomas K. Sherwood during the academic year 1960-61, using staff time made available by the Ford Foundation grant to M.I.T. A number of open-ended design problems, representing real engineering situations, were developed; each involved theory, sophisticated analysis, optimization, and engineering judgment. The new program was first offered during the fall term 1961-62, and it was well received, appearing to stimulate both high-ranking students competent in analysis and students who are more interested in the applied aspects. It was repeated, with new cases, during the spring term. The experience with the new subject makes it clear that good students can be as interested in the design as in the analytical aspects of engineering.

Catalysis is the foundation of most modern chemical processes, but the field has heretofore been essentially an empirical art. It is now rapidly acquiring a scientific basis under the impact of several related disciplines such as solid-state physics, chemical kinetics, surface chemistry, and materials science and engineering. The chemical engineer of the future will be increasingly concerned with catalysis phenomena. During the fall of 1961, Professor Charles N. Satterfield gave a trial version of a new elective subject in catalysis. The subject was taken by about fifty seniors and graduate students, including students from biology, chemistry, and aeronautical engineering. The material presented focused on the modern theories of catalysis, including the relationships between catalytic activity and electronic structure, but also considered some of the practical problems involved in the preparation and evaluation of catalysts and their application. It is planned to continue the development of the subject on catalysis, and we expect to have a preliminary set of class notes available when the material is repeated in the fall of 1962.

During the spring term of 1962 Professors Satterfield and Raymond F. Baddour directed a seminar in catalysis. This program brought together graduate and undergraduate students engaged in research on problems involving catalysis. Their research interests included the relations of catalytic activity to electronic structure, catalysis in fuel cells, irradiation effects on catalysis, reactions in catalyst melts, simultaneous mass transfer and reaction in porous catalysts, and carbon formation on and regeneration of dehydrogenation catalysts. As a part of the seminar program a group of distinguished guests, each of whom has made a substantial contribution in some field of catalysis, were invited to the Department. These men gave lectures and participated in conferences with the students and members of the staff. The development of the programs in catalysis has been assisted by funds from the Ford Foundation grant.

An important part of the curriculum studies and revisions in the engineering school are the interdisciplinary efforts of the engineering departments. The same scientific areas have been developed independently by various departments with the emphasis on the phases that are most useful in each department's particular field. There is a great advantage in having the staffs of the different departments work together in presenting such subjects, and during the past school year the Chemical Engineering Department participated in two such programs.

Thermodynamics is a basic subject in many fields of engineering, and several engineering departments give undergraduate subjects. During the spring term of 1962 the Metallurgy and Chemical Engineering Departments exchanged staff in their undergraduate thermodynamics subjects. Professor Clyde M. Adams of the Metallurgy Department worked with Professor Sherwood and gave a section of the chemical engineering subject, and Professor Kenneth A. Smith of the Chemical Engineering Department worked with Professor John Elliott of the Metallurgy Department and participated in teaching one of their thermodynamics courses.

The Institute's rapidly expanding interest in the field of materials has prompted re-evaluation and modification of the Department's teaching program in the fields of high polymers and in surface chemistry and physics to emphasize the interdisciplinary character of these areas. In the fall term, a new undergraduate elective subject in Physics of Chemistry of Surfaces was initiated under the co-direction of Professor Alan S. Michaels of Chemical Engineering and Professor Philip L. deBruyn of Metallurgy. Our subject in Structure and Properties of Polymers, which was initiated in the spring term of 1961, was broadened in scope this year to include contributions from the Department of Civil Engineering and from industrial researchers on the frontiers of polymer physics; there are plans to make this subject an interdepartmental responsibility of chemical and civil engineering in the spring of 1963. More thorough coverage of the areas of physical chemistry of polymers and of polymer synthesis are contemplated for the fall term of 1962. In addition, a series of graduate seminars covering specific topics in polymers and in surface and colloid chemistry are being considered for the coming academic year. The Departments of Civil and Chemical Engineering are also exploring the possibility of establishing a teaching program in polymer processing, supported by a well-equipped laboratory.

RESEARCH

The research activities of the Department are a major portion of the graduate education program, particularly at the doctoral level. With the increasing number of students on the doctorate program and with the increasing financial support of this work by the government agencies, a large portion of the staff time is devoted to research at a more advanced level. A portion of the current work is described in the following sections.

Transport Processes. Professors Robert C. Reid and P. L. Thibaut Brian are conducting an investigation of simultaneous heat and mass transfer in the cryogenic temperature range. The experimental work is concerned with the effect of the fluid dynamic variables on the heat and mass transfer coefficients during frosting and with the effect of these variables and the nature of the surface itself on the properties of the frost deposit. The experiments indicate that the nature of the surface is an important factor.

Professors Mickley and Kenneth A. Smith have shown that the transpired turbulent boundary layer is an equilibrium layer in the sense of Clauser. The equilibrium is with respect to the maximum shear in the boundary layer. In a non-transpired boundary layer, the wall shear and the maximum shear are the same, but this is not true for a transpired turbulent boundary layer. This gives rise to the concept of a two-layered transpired turbulent boundary layer, with the outer layer behaving in the same fashion as the non-transpired turbulent layer exhibiting the same maximum shear and with the effects of transpiration confined to the inner layer and serving mainly to determine the maximum shear values. If these ideas may be extended to other boundary layers which are currently regarded as non-equilibrium layers, an important stride will have been made in the understanding and prediction of the behavior of a turbulent boundary layer.

Non-Newtonian fluid behavior continues to be an area of great interest to the chemical engineering profession. Professors Edward W. Merrill and Mickley have carried out an experimental and theoretical study of the shear stress–strain rate behavior of a number of polymer solutions up to shear strain rates of 100,000 sec^{-1}, including the second (high shear) Newtonian viscosity to an extent never before reported. The principal results were: the intrinsic viscosity calculated from the second Newtonian viscosity appears close to, or identical with, the conventional low shear intrinsic viscosity, contrary to several prominent theories; the curves of second Newtonian viscosity number versus polymer concentration are totally different in kind from the usual curves of low shear viscometry, showing "plateaus" indicative of a precise balance between interpenetration of molecular segments and compression of the solvated coils; contrary both to previous theory and to experiments, the Taylor criterion for onset of instability of flow between counter-rotating concentric cylinders is applicable directly to polymer solutions in general if the absolute viscosity calculated *at the critical* *shear rate* for instability instead of the viscosity at zero shear is used in the Taylor group.

Work has continued by Dr. Frank Feakes on the transport of neutrally buoyant materials of various shapes through conduits under conditions where the major dimension of the particle approaches the diameter of the conduit. This work has had as one of its aims a better understanding of the hydrodynamics of the flow of blood in capillaries. The initial work with nylon spheres in neutrally buoyant salt solutions has been extended, and it is now possible to predict flow rate–pressure drop relationships for many cases where the diameter of a transported sphere approached that of the conduit. Flow rates have been extended to the range where non-laminar flow occurs between consecutive spheres while laminar flow persists in the region between the moving sphere and the conduit wall. One aspect of this work which is more closely related to blood flow in capillaries has concerned an attempt to explain why motion pictures of blood flow through capillaries indicate that many of the red cells move down the capillary with their major planes at right angles to the axis of the capillary. Studies using dimensioned models of red cells constructed of neoprene make this condition appear to be largely a consequence of cell interaction caused by the large ratio of volume of red cells to the volume of plasma in blood.

Theoretical and experimental work on gas chromatography under Professor Baddour indicates that several factors are important in causing dispersion of the chromatographic bands. One of the main problems is the difficulty of separating the mass transfer effects from the other factors. Operating the column with and without sorption under otherwise identical conditions has proven most effective for doing this. In order to eliminate any measurable sorption on the support, new tailor-made supports are being developed which appear to have properties sufficiently interesting and different as to suggest many other applications of these materials.

In many applications of microporous solids, the conditions are such that considerable adsorption of one or more gases occurs on the surface of the solid. The migration of this surface layer has been shown to contribute significantly to the over-all rate of gas transport through these materials, in some cases being the controlling transport mechanism. Work under the supervision of Professors Gilliland and Baddour on single gases and mixtures of light hydrocarbons, hydrogen, and noble gases has successfully correlated the movement of adsorbed gases in a surface by a rate expression using the spreading pressure gradient as the driving force. The study is being extended to include systems in which strong interactions between the gas and solid exist, such as in the migration of large organic molecules or polar gases through polar microporous solids.

Many theoretical studies of mass transfer with simultaneous chemical reaction have been made, but in general, theory has not yet been adequately checked by experiment. The short wetted wall column technique is being used by Professors J. Edward Vivian and Brian to study a typical reacting gas-liquid system involving rapid reversible reaction. Experimental results to date, combined with numerical results calculated on the IBM 7090, indicate the value of a model such as the short wetted wall column not only in mass transfer studies but also as a new tool to obtain kinetic data which cannot be easily obtained by other means on this type of fast reaction. The design and operation of gas absorption systems depend to a large extent on the behavior of the liquid flowing over the packing, and a project studying this behavior has as its objective the determination of the effect of several factors on the liquid phase mass transfer process not yet understood. Of particular concern are those factors which control liquid distribution and surface life-time: such as spreading or wetting phenomena and body forces. Through the cooperation of the Instrumentation Laboratory the large centrifugal machine at Bedford is being used to observe the effect of the "gravitational" field and its interaction with other properties of the system on the mass transfer process.

Chromatographic transport of reverse wetting additives continues to look promising as a means for increasing the efficiency of recovery of trapped oil from the pores of petroleum reservoir rock. Recent studies of this process under the direction of Professor Michaels carried out in packed sand columns and in a two-dimensional micromodel have revealed interesting and unexpected insight into the mechanism of oil-detrapment. The influence of such variables as pore-texture, oil-to-water mobility ratio, and additive chemical composition and concentration are now being investigated.

Professors Merrill and Gilliland are directing a research program of the fundamental parameters that govern blood's viscous properties. The key research tool—a GDM viscometer, based on electromagnetic instrumentation, developed in the Instrumentation Laboratory by Philip Gilinson, Jr., and Charles R. Dauwalter—was made available to the Blood Rheology Laboratory by Professor Charles S. Draper of the Department of Aeronautics and Astronautics. The work began as a joint experiment of Professor Merrill and Dr. Roe E. Wells of the Harvard Medical School three years ago, and it is now supported by the National Institutes of Health and has among its collaborators the Blood Bank of the Massachusetts General Hospital and Dr. George Fulton's group in the Department of Biology at Boston University. It has been found that normal healthy human blood shows a distinctive type of non-Newtonian viscosity that follows the "Casson" equation. Obedience to the Casson equation implies that the red cells (flat circular discs) line up in stacks like poker chips, held together by weak forces which permit the stacks to disintegrate under fast flow, form again under slow flow; blood from women is significantly different from man's blood. A new relation between the clinically used "sedimentation rate" test and the GDM viscometer readings has been established; it clarifies in part the physical principles underlying the "sedimentation" rate. Under the direction of Professor Merrill and Dr. Peter Davison of the Biology Department, the GDM viscometer will also be applied to the study of the non-Newtonian rheology of DNA (deoxyribosenucleic acid) solutions at very high dilutions, in an attempt to learn more about structural differences in DNA molecules through observations of their hydrodynamic response in solution. In this project, the first Newtonian viscosity of a solution of DNA of six million molecular weight has been accurately determined at shear rates less than 0.2 sec^{-1}.

Professor Ronald E. Rosensweig has been investigating the "meandering" characteristics of tagged fluid elements injected into a turbulent flow field. This experimental work follows theoretical work by Professor Chia-Chiao Lin of the Mathematics Department and is leading to an improved understanding of the influence of mixing in chemical process operations. The experimental method utilizes a variaation of the optical probe technique pioneered in the Chemical Engineering Department, which makes it possible to study the motion of fine particles in a fluid stream.

The flow pattern of the reacting fluids in heterogeneous packed bed reactors is a major factor in their efficiency, and this fact has led to a research program on the mixing of gases in such packed beds directed by Professor Gilliland and Dr. Feakes. Transient studies were made with nitrogen oxides as tracers using light sources and photocell detectors placed in the packing particles. The residence time functions of the bed and the individual layers of the bed were evaluated from the measured input and output values. The effect of bed depth, packing arrangement and fluid velocity were studied. The maximum and minimum conversions in a packed bed chemical reactor were calculated from the results.

Catalysis and Applied Kinetics. Industrially, a large number of important chemical reactions are carried out by contacting the reacting streams with solid catalyst packed into a tubular reactor. The Department of Chemical Engineering has initiated a multipronged investigation of packed bed reactors of this type. Professor Mickley and Dr. Feakes have begun a study of the flow patterns and turbulence parameters in the interstices of a packed bed, using hot wire techniques. These studies are giving information concerning the details of packed bed flow and means for improving the performance of packed bed reactors.

Professor Mickley has directed an analytical investigation of the sources of yield losses when a packed bed is used as a heterogeneous chemical reactor. The results show that the losses are caused by interaction between the radial transport of heat and matter and the kinetics of competing chemical reactions; these studies have also suggested means for improving reactor performance and have provided information needed by designers of industrial reactors. Work is also in progress to test the use of an adiabatic packed bed reactor as an experimental device for determining the kinetics of heterogeneous reactions. The results show that in certain reaction systems, the adiabatic reactor technique is advantageous and provides a new procedure for obtaining vital kinetic data.

Professors Satterfield and Reid are investigating the homogeneous oxidation kinetics of propylene. The resulting data are used to delineate a mechanism of the reaction and to define quantitatively the kinetics of this type of oxidation.

Solid catalysts are the basis of many important chemical reactions. The structure of the solid lattices of catalysts has a significant effect on their catalytic activity, and radiation offers a promising means of producing lattice rearrangements. Professors Reid and Edward A. Mason of the Department of Nuclear Engineering have studied the oxidation of carbon monoxide with oxygen over a cuprous oxide catalyst in a batch reactor at temperatures in the vicinity of 150°C and at pressures near 1 atmosphere. A first irradiation of the catalyst resulted in a 30 per cent decrease in its activity; after a second irradiation, the activity decreased by another 25 to 30 per cent. Measurements of the electrical properties of cuprous oxide showed that the conductivity and p-typeness decreased with irradiation. The irradiation increased the surface area of cuprous oxide while the activity decreased. The percentage decrease in the kinetic rate constant in the carbon monoxide oxidation was very nearly the same as the drop in the bulk positive-hole concentration of the catalyst. The concentration of positive holes appears to be intimately related to the catalytic activity. The work is being continued with zinc oxide crystals instead of cuprous oxide to determine the irradiation effects on an n-type semiconductor.

A theoretical investigation of adiabatic reactions in short fixed beds is being conducted by Dr. Feakes. The work is evaluating the importance of axial mixing in short fixed beds for homogeneous reactions of various orders with typical enthalpy changes and activation energies; both Gilliland-Mason and Zwietering models are being considered. The results indicate that the departure from the calculated "piston flow" conversions in isothermal reactors are amplified for the case of the adiabatic conditions. Another program involves an experimental investigation of the importance of mixing in a liquid system in a packed bed. Using two conductivity cells placed in a packed bed, the degree of alkaline hydrolysis of methyl acetate (a second order homogeneous reaction of known kinetics) was measured: reaction conditions were carefully controlled and mixing conditions chosen so that Vermeulen's experimental values of axial diffusivity were applicable. The conversions measured were less than those which would be calculated using the Gilliland-Mason model, but closely approximated those expected from an application of the Zwietering model.

Professor Baddour is conducting an intensive investigation of the activity of semiconductor catalysts. A technique has been designed to measure the electrical properties of a catalytically active semiconductor surface during a chemical reaction which it catalyzes. The studies using this new technique should provide a definitive test of the charge transfer theory and provide basic information broadly applicable to semiconductor catalysis. In another study, Professor Baddour is investigating the importance of the electronic interaction between a catalyst and its support; his findings should be important in the development of more effective catalysts through a better understanding of promoting agents.

One of the most important gaps in our understanding of catalysis is a lack of knowledge of the intermediate steps by which an over-all catalytic reaction proceeds. Professor Baddour is now investigating a method for the direct determination of the mechanism of a catalyzed reaction and the specific rate constants of the elementary steps which make up the over-all reaction. The method consists of irradiating a reacting system with visible and ultraviolet light and simultaneously measuring the infrared spectrum of the surface to determine the effect of the light on the chemisorbed species.

Professor Baddour has also studied the reactions of carbon monoxide and hydrogen on activated-alumina supported ruthenium-silver catalysts; the principal reaction products were methane, ethylene, ethane, water, carbon dioxide and deposited carbon. The over-all results indicate that the large amount of past work on the fundamentals of the catalytic hydrogenation of ethylene can be extrapolated to predict qualitatively the behavior of metal catalysts in the hydrogenation of carbon monoxide.

Autothermic reactors are efficient devices for conducting reversible exothermic reactions. However, the inlet temperature which maximizes the productivity of the reactor is very close to the blowout temperature. In order to design a suitable control system to permit operation near conditions of maximum productivity, the dynamic behavior of this type of reactor is being studied by Professors Baddour and Brian. A numerical analysis of the T.V.A. ammonia synthesis reactor is being made using the I.B.M. 7090 computer, since kinetic data and design information have been published for this system.

Professors Michaels and Brian are conducting research to clarify the mechanisms of crystal growth from solution and the effects of trace-additives and impurities on growth-kinetics and crystal habit, using cinemicrographic techniques to study the actual growth process and automicradiographic procedures to determine the extent of adsorption and the location of additives present on growing crystal faces.

Fuels Research Laboratory. Studies of mixing in turbulent jets, modelling of combustion processes, measuring of high gas temperatures, formation of soot in hydrocarbon-air flames, and of radiative transport have continued under the direction of Professors Hoyt C. Hottel and Glenn C. Williams. Professor Henry A. Becker's measurements of average and fluctuating velocities and compositions in turbulent ducted jets with recirculation have confirmed the validity of a single similarity parameter for determining flow patterns in geometrically similar systems; and generalized descriptions of both mean and fluctuating velocity and concentration fields have been formulated over the full range of recirculation. The smoke-scattered light technique for studying mixing has been extended to studies on a scaled-up model of the well-stirred reactor. Preliminary results from imposition of a step-function in the feed concentration indicate that mixing corresponds to a model in which the gas flows in parallel through two completely stirred volumes.

In the combustion of rich n-pentane-air mixtures in a well-stirred reactor, some seventeen components including furans and aldehydes from formaldehyde through crotonaldehyde and including acrolein have been identified from the non-aqueous liquid phase products.

Measurements of the polar diagram of light scattered from soot newly formed in a laminar benzene-air diffusion flame and comparison with theory and electron micrographs of soot particles collected from the flame indicate that the soot in the flame may consist of a large number fraction of small spherical particles mixed with a very small number fraction (10^{-5}) of their agglomerates with apparent equivalent spherical diameter about four times that of the small spheres. An experimental study of the growth and decay of thermal radiation from soot in flames of hydrocarbons in air has been started.

Studies of the development of a model for the spread of a conflagration through a fuel field indicate the necessity for supplying artificially to small-scale experiments some energy radiative flux which cannot be scaled conveniently. In model studies of the steady rate of spread of a fire front over beds of fuel uniformly spread with combustible (using a distance scale several times the flame height in assessing uniformity), the marked dependence of fire front velocity on thermal radiation externally supplied has been amply verified; and progress has been made on the development of a useful model for predicting fire spread on a full scale.

The problem of measuring gas temperatures in the range 4,000 to 12,000°K by optical means has been under continued attack. A photoelectric pyrometer to accomplish this by comparison of the intensity of direct radiation from the gas with the direct radiation plus that reflected from a mirror has been nearly completed.

Development of methods of allowing for the interactions of radiative transport with conduction, convection, and combustion in gaseous systems has continued under Professor Adel F. Sarofim. Two cases have been studied in detail: the steady flow of diathermanous gas between hot and cold parallel plates; and an axially fed cylindrical furnace in which the gas temperature field and the wall energy flux field were calculated with allowance for combustion progress, recirculation, convection, and radiation.

Applied Chemistry. The reactions of atomic hydrogen with low molecular weight olefins are being investigated by Professor Reid. The reaction is carried out in an isothermal tubular flow reactor in which the atomic species are allowed to pass over thin films of olefins deposited on the reactor walls and maintained at liquid nitrogen temperatures. The concentrations of atomic hydrogen and of any detectable hydrocarbon free-radical intermediates are monitored with an electron spin resonance spectrophotometer.

Professor Sherwood has directed a study of gas reactions at high temperatures, employing a simple heated-filament reactor for the reaction of ammonia with carbon to form HCN and for the pyrolysis of both liquid and gaseous hydrocarbons. Eleven volume percent acetylene was obtained by pyrolyzing methane. Ammonia reacted with both graphite and pyrolytic carbon to form HCN, the reaction being first order in ammonia. At low temperatures (about 1600°K) the rate is controlled by the surface reaction; at higher temperatures (to 2300°K), mass transfer to the surface controls the rate. Pyrolysis of liquid heptane gave high yields of ethylene with a maximum of 2.4 moles ethylene per mole of heptane at a temperature of 1650°K.

Vanadium pentoxide catalysts have been used industrially for partially oxidizing hydrocarbons to produce oxygenated chemicals. In current research Professor Satterfield is exploring the possibility of partially oxidizing hydrocarbons by bubbling their vapors through a melt consisting of a mixture of vanadium pentoxide plus salts such as potassium sulfate that provide lower melting points. Such a contacting method offers promising advantages over the conventional type of chemical reactors, and it is being used to study the partial oxidation of orthoxylene.

High intensity arcs between two carbon electrodes provide a convenient method for studying chemical reactions involving elemental carbon at temperatures in the range of 4,000 to 7,000°K. High concentrations of acetylene have been produced in studies under the direction of Professor Baddour. An improved reactor design, the substitution of methane for hydrogen, and the feasibility of producing carbon-halogen compounds in a high-intensity arc are being investigated. By analogy with the carbon-hydrogen reactions, it is expected that high concentrations of unsaturated carbon-halogen compounds should be produced by the high-temperature reaction of carbon and the halogens followed by rapid quenching.

Polymer Chemistry. In studies of the precipitation polymerization of vinyl chloride, Professors Mickley and Michaels have shown that when the monomer is diluted with an inert solvent such as cyclohexane, the molecular weight of the resulting polymer varies linearly with the monomer concentration. The use of an inert diluent thus provides a means for varying the molecular weight of the vinyl chloride polymer. The mechanism of heterogeneous precipitation polymerization was investigated, and the results suggest that the acceleration of the reaction by precipitated polymer is due to activated radical transfer between monomer and polymer.

Research activities in the field of polymer properties and surface chemistry have continued at a high level under the direction of Professors Michaels, Baddour, Harris J. Bixler, James A. Barrie, and Wolf Vieth. Results of research on gas-transmission through microcrystalline polymer films indicate that, with linear polyethylene, gas diffusional impedances are not uniquely determined by level of crystallinity but are profoundly influenced by the thermal treatment by which such crystallinity is developed. Controlled thermal processing of microcrystalline thermoplasts now appears to provide a powerful tool for adjusting the permeability and permselectivity of polymer films to gases. Detailed studies of the transport of organic liquids through polyethylene and other polymer films by pervaporation and of the effects of solvent- and thermal-treatment of the polymer on transmission-rates and permselectivity have revealed important new information about the relationships between polymer swelling-behavior, crystalline microstructure, and liquid permeation kinetics. The remarkable ability of polymeric materials to transmit molecules selectively according to subtle differences in molecular size and shape has been confirmed and extended to include a relatively wide variety of different polymers. Work is now underway to determine the permeability and permselectivity of solvent-expanded glassy polymers towards gases and liquids of varying molecular sizes and shapes. A recently completed study has provided direct experimental confirmation of Young's Equation for the wetting of clean solid surfaces and has provided evidence of what appears to be a new and important cause of contact angle hysteresis. This hysteresis is evidently caused by adsorbed interfacial-film compression during the advancement or recession of a liquid over the gel surface and may possibly provide an explanation of hysteresis observed on conventional solid surfaces.

Professor Merrill is conducting a program of experiments on the glass transition in polymers. Reproducible plateaus in temperature versus time curves (heating and cooling experiments) at the glass transition temperature suggest that the glass transition is a limited first-order transition process rather than a second-order transition. Other experiments by linear expansion versus temperature measurements on free-radical polymerized polystyrenes and on narrow-distribution anionic polystyrenes show, contrary to previous reports in the literature, that the glass transition lies near $82 \pm 1°C$ and is unaffected by the kind of molecular weight distribution.

Professor Merrill, in collaboration with the M.I.T. Instrumentation Laboratory, has constructed a new type of band viscometer, suitable for very viscous substances such as molten polymers, asphalt, and glass. By means of this instrument both the first and second Newtonian viscosities of butyl polymers have been established as well as the intervening range of non-Newtonian flow. Linear displacements as low as 10 millionths of an inch per hour are electromagnetically detected and recorded.

Electrochemistry. The electrode reactions are a limiting factor in the development of successful fuel cells, and the research activities of the Department on these devices are being directed to an understanding of the factors that are involved. Professor Satterfield is directing an investigation of the catalytic electrochemical oxidation of formic acid at ambient temperatures on platinum, with the aim of providing guidance in catalyst selection and optimization of operating parameters for a methanol-consuming fuel cell.

In fuel cell operation, dissolved fuels and oxidants must enter into the electrochemical reactions occurring at the electrode. Depending upon concentration of reactant, velocity of flow, type and shape of electrode surfaces, pH, etc., performance of the electrode is limited either by mass transport of the reagent to the electrode or by electrochemical reaction rate and adsorption rates at the electrodes. Professor Meissner is investigating these factors for an oxygen electrode in an aqueous reaction to determine the optimum design and operation of such an electrode.

Electrochemical cells in which the electrodes are held at different temperatures are interesting energy converters. Professors Meissner and David C. White of the Department of Electrical Engineering are focusing attention on molten salt systems operating at temperatures above 600°C, at which most solid thermoelectric devices fail.

STAFF AND STUDENTS

On Alumni Day, June 11, the Department honored Dr. Warren K. Lewis on his forthcoming eightieth birthday with an informal get-together of alumni and staff. The occasion was used to announce the establishment of the Warren K. Lewis Award in Chemical Engineering Education, to be supported by the Esso Research and Engineering Company and Humble Oil and Refining Company and administered by the American Institute of Chemical Engineers.

The Department has been fortunate in having two visiting professors on its staff during the past school year. Dr. James A. Barrie of Imperial College, London, as been a Visiting Assistant Professor working with the group in polymer chemistry; he has made significant contributions to the research program in this area. Dr. Nathaniel Schneider, who comes as Visiting Associate Professor from the U.S. Quartermaster Laboratory in Framingham, is also associated with the polymer and surface chemistry work; he will continue with the Department during the coming year.

Professor Mickley was honored by appointment as Ford Professor of Engineering.

Three of the senior class were honored for their outstanding accomplishments; Stephen C. Root received the American Institute of Chemists Award; William I. Koch was awarded the Hunneman Prize; and Philip A. Ruziska received the Robert T. Haslam Cup.

Jean P. Leinroth, Jr., was given the Eastman Kodak Scientific Award in Chemical Engineering for outstanding contribution and progress as a graduate student in research and teaching.

EDWIN R. GILLILAND

Department of Civil Engineering

A new program to provide identity and direction for civil engineering at M.I.T. was initiated by the Department during the past year. Over the years, civil engineering has evolved into a collection of fields identified by such labels as structural engineering, soil engineering, hydraulic engineering, sanitary engineering, building engineering, transportation engineering, construction engineering, water resources engineering, surveying, and similar designations. Each of these fields represent important problem areas to society, government, industry, and the profession. The basic premise of the Department's new program is that we can make the greatest contribution to the many branches of civil engineering by concentrating on a few fundamental disciplines instead of attempting to operate a collection of programs in the separate branches, each in competition with the other for resources, students, and recognition. Hence, our focus will be on basic strengths in depth in one kind of engineering—civil engineering. Breadth will be achieved by full exploitation of the total resources of M.I.T. through inter-disciplinary activity with other departments, laboratories, and centers having capabilities and activities related to the many branches and problem areas of civil engineering.

The fundamental disciplines to be emphasized by developing strength in depth include structures, materials, soils, hydraulics, and civil engineering systems—the first four built on the applied physical sciences, the last built on the applied mathematical sciences and information technology. Structures and materials will be closely coupled to achieve strong interaction. Soils and hydraulics will play key roles in achieving integrated strengths in the applied earth sciences. The civil engineering systems effort will be concerned with methods of performing the engineering of transportation systems, water resources systems, and similar systems of constructed facilities.

Significant progress has been made in implementing the new program during the few months since its formulation. Leadership assignments have been made, regrouping has been initiated, major space change and laboratory development plans have been developed, and important new staff appointments have been made. The progress which has been made is attributed to the strong backing and constructive support we have received and an enthusiastic and hard working group of key faculty members.

Although the changes which are being made will have considerable impact on the direction of future developments, we do not imply that radical or revolutionary changes have been or are being made. Rather we are clarifying answers to the basic question of "Where are we going and what are we trying to achieve as a Department?" Such clarification is fundamental to the continuing development of a strong, healthy, and enthusiastic community of people identified as the Department of Civil Engineering at M.I.T.

Although the new program is based on capitalizing on our existing strengths and is aimed at achieving a stronger and expanded Department, we must paradoxically, go through a period which will seem to many people both internally and externally, to be one of decline. This is due to short-term difficulty in overcoming misunderstandings from the disappearance of such time-honored labels as sanitary engineering, building engineering, transportation, surveying, construction, and similar fields which will not be continued as separately identifiable divisions of the Department. We trust that the focus on the total program of the Department instead of on its parts will help overcome these misunderstandings. Beyond that, we would hope that our actions will speak louder than our explanations.

CIVIL ENGINEERING EDUCATION

The development of the educational program of the Department continued with the support of the Ford Foundation grant to the School of Engineering. Minor changes were made in the new curriculum to take full advantage of our experiences with the new subjects and to increase our capability to implement it. The new subject in the geotechnical sciences was shifted from the second year to the fourth year and will now follow the basic study of thermodynamics, fluid dynamics, and particulate mechanics. The first term of structures has been shifted from an elective to a required subject, and the human ecology subject has been shifted from a requirement to an elective. One term of computer methods has been added as an elective in a specified area. The computer methods subject will normally be taken in the first term of the second year.

Professor James W. Daily has been placed in charge of the undergraduate academic program and Professor Myle J. Holley in charge of the graduate academic program of the Department. Particular attention will be given during the coming year to the development of the interface between undergraduate and graduate education in terms of subjects, instructional laboratories, and student participation in research. The sections of this report which follow provide additional details to illustrate the close relationships between education and research in the new program of the Department.

STRUCTURES

Under the leadership of Professor Holley, the Structures Division has selected the following four areas for major attention: the development and exploitation of techniques of experimental analysis and design utilizing small-scale physical models of structures and components; coupling of the rapidly increasing machine computation resources and the techniques of systems analysis with the ultimate goal of "direct design;" application of statistics and probability theory to the design process toward a more rational provision of acceptable performance over a finite service life; and closer coupling of research in structures and research in materials, toward the goal of more efficient structural utilization of new materials, combinations of materials, and fabrication processes.

During the past year, the Division has made substantial progress in the area of structural models under the leadership of Professor Robert J. Hansen. Our efforts in this area have been concerned particularly with rapid, relatively inexpensive techniques for fabrication and testing of models for use in teaching structural behavior; techniques for fabrication of miniaturized structural elements of reinforced concrete and steel; the investigation of new model materials; and methods of modelling dynamically-loaded structures. A successful application of the last-mentioned technique was achieved in a test of 1/25 scale models of prototype structures previously tested at the Nevada Test Site. The utilization of the models approach has been particularly successful in our educational program. This effort will be accelerated during the coming year with the formation of the Laboratory for Structural Models as a joint venture with the Department of Architecture. Professor Hansen will be the first Director of the new interdepartmental laboratory, to be funded in part by a grant from the Perini Foundation.

MATERIALS AND CONSTRUCTION

A significant realignment of efforts and resources marked the activities in this area during the past year; this can be separated into two principal effects. First, a more explicit effort is planned to achieve a working integration betwen the fields of civil engineering, architecture, and industrial management. With construction representing one of the largest industries in our present society, the benefits to be derived from better planning and more effective controls over design, construction, and operation of such projects appear substantial. Professor Albert G. H. Dietz will head this effort.

The second element in the realignment involves the departmental efforts in construction materials which have been regrouped into a new Materials Division. Working closely with the activities in structures, this group will direct their work toward a tighter materials-structures coupling based upon fundamental principles; in addition, it will represent the Department in the new Center for Materials Science and Engineering. Professor Frederick J. McGarry will head the Materials group.

SOIL ENGINEERING

A major portion of the year's research effort in the Soil Engineering Division, under the leadership of Professor T. William Lambe, was aimed at a better understanding of the fundamentals of soil behavior. This work was supported by the Office of Naval Research, the Corps of Engineers of the U. S. Army, the National Science Foundation, and various industrial sponsors. Emphasis was placed on the nature of interparticle forces in clays, the geometrical arrangement of clay particles (fabric), and the effect of environmental conditions on strength. The utilization of X-ray diffraction and light microscopic and radiographic methods for quantitative measurement of clay fabric proved most promising and helpful in delineating the influence of the physicochemical forces on the engineering behavior of clays. The improvment of soil properties by additives concentrated on an investigation of the mechanism of stabilization through chemical analyses and high pressure shear tests with measurement of pore fluid pressures. A companion project was aimed at studying the relationship among applied and internal pore stresses in three-phase systems and their engineering properties.

The objectives of the research in soil dynamics were the determination and explanation by laboratory tests and theoretical analyses of the behavior of soils when subjected to transient loadings and the effects of basic soil properties on this behavior. In addition to triaxial and one-dimensional compression tests, this research used seismic wave propagation measurements for the determination of soil moduli. The seismic studies were also aimed at the development of methods for exploration and evaluation of foundation conditions and to develop a tool for investigation of the nature of stress transmission through clay-water systems.

In soil-structure interaction, the Division continued to investigate the stress-deformation behavior of various structural shapes buried in a surface-loaded soil mass and to develop new theories to predict failure mechanism under such conditions. Both the soil structure interaction and soil dynamic studies played an important role in the design and construction of hardened missile installations. This work was sponsored by the Corps of Engineers and the Air Force Special Weapons Center.

The educational program in soils has been completely overhauled with the addition of new subjects in soil engineering, theoretical soil mechanics, soil dynamics, and the physics of clay-water systems. A new X-ray defractometer which permits direct plotting of intensities and a pole figure device which enables determination of particle orientation have been added to the laboratory. Plans are well advanced for major expansion and improvement of laboratory facilities including space with temperature control, apparatus for fundamental study of erosion of clays by flowing water, and space for an expanded effort in applied earth physics.

HYDRODYNAMICS LABORATORY

The Hydrodynamics Laboratory, under the leadership of Professor Arthur T. Ippen, conducted research on a number of topics of significance in the areas of water resources, fluid mechanics, hydraulics and sanitary engineering, and the applied earth sciences. Professor Daily supervised research on non-Newtonian fluid mechanics with particular reference to suspensions, a topic of basic importance in the movement and deposit of sediments along shores, in streams and estuaries, in industrial processes, and in the transportation of coal and ore by pipeline; three-dimensional boundary layers and effects on surface resistance; and turbulent wake mechanics and hydroelastic effects, a topic of general importance wherever fluid moves past elastic structures forming wakes.

Important research conducted under the supervision of Professor Donald R. F. Harleman included the study of several problems in dispersion or mass transfer in porous media: mixing of salt and fresh water in a coastal acquifer due to lateral motion of an intruded saline wedge under the action of ocean tides, dispersion of waste water being recharged into a ground water acquifer, recharge of ground water in arid regions, and the fundamental correlation of momentum and mass transfer in porous media. Professor Harleman also supervised research on the mechanics of oxygen transfer in turbulent streams, a basic problem in determining the ability of a river to assimilate wastes discharged into it.

Professor Peter S. Eagleson continued fundamental research investigations related to beach erosion problems; supervised a comprehensive digital computer study of transients in hydro-power plants; and is responsible for the development of a special-purpose analog computer for the study of random processes in fluids, a very important addition to the laboratory facilities of the Department. To illustrate the breadth of the research activities of the faculty, we report that Professor Phillip A. Drinker was appointed Research Associate in Obstetrics and Gynecology at the Harvard Medical School and participated in an investigation of the mammalian pulmonary circulation which occurs at birth. This study, which was performed on lambs delivered by Caesarian section, was designed to clarify the mechanisms whereby the respiratory function is transferred from the placenta to the lungs.

CIVIL ENGINEERING SYSTEMS LABORATORY

In the transportation systems area, a new program of research on methods and techniques for predicting highway transportation demand in metropolitan areas has been initiated under the supervision of Professor Alexander J. Bone. Advanced operational versions of the Digital Terrain Model System for design and the vehicle simulation-operating cost system were completed under the supervision of Professor Paul O. Roberts. Released for field use by highway engineering organizations, these systems are finding important application in the location, design, and economic analysis of major highway projects throughout the world.

Important new work was initiated in the area of engineering analysis. Theoretical studies are being conducted which may lead to the development of techniques for predicting the optimum order for an engineer to consider a set of requirements and the conflicts between these requirements. The objective is to optimize the design procedure for complicated problems having conflicting requirements. Extensive computer and mathematical analysis is involved in developing the system. Dr. Christopher Alexander of Harvard University is participating with the staff of the Department in this work.

A computer programming system for civil engineering problems of a geometric nature was developed by Professor Charles L. Miller. First placed in operational use in the Puerto Rico Bureau of Highways, the system has attracted widespread attention. The system includes a language, COGO, which allows the civil engineer to communicate with the digital computer in civil engineering terminology and a processor which eliminates the need for a library of fixed programs. A major expansion of our work in the computer programming languages and systems area is anticipated.

The digital computer facility of the Department completed an extremely busy year. Academic use by students and faculty accounts for about 75 per cent of the total use, involving typically twelve hours and twenty to sixty users per day. Approximately 150 students and faculty members made active use of the I.B.M. 1620 during the year. The staff developed a load-and-go version of the Fortran System which permitted rapid-turn-around service on the machine. The most important addition to the facility was the development of an on-line plotter capability by E. Phillip Gladding which provides graphical output from the computer. The capacity of the facility will be doubled in the near future and an extensive amount of new equipment for student construction of information systems will be acquired.

CIVIL ENGINEERING, ARCHITECTURE, AND MANAGEMENT

Considerable interest has been shown in developing closer working relationships between civil engineering and architecture at M.I.T. Numerous meetings were held during the year by representatives of the two departments, particularly with respect to the handling of the building technology area. The materials, structures, and systems efforts of the Department provide strong input to this area. The joint Laboratory for Structural Models will provide additional significance. Professor Dietz is to have a joint appointment as Professor of Building Engineering in the Departments of Civil Engineering and of Architecture in order that he may give first-order attention and leadership to these important developments.

In the area of construction, the Department is also developing new relationships and new activities. The emphasis in construction has turned to modern management control systems including the application of computer techniques, systems, and operational analysis methods. Considerable potential is offered for joint activity involving the Schools of Engineering, Architecture and Planning, and Industrial Management.

THE INTER-AMERICAN PROGRAM IN CIVIL ENGINEERING

After more than two years' study by our faculty, a unique education-research program involving developments in Latin America has been formulated and subsequently endowed by a grant of $250,000 from the Carnegie Corporation of New York. The key to the special potential of this program is the involvement of students and professors in authentic unsolved civil engineering problems of technical, social, and economic importance to both Latin America and the United States; a cooperative effort will be mounted by research teams composed of faculty and students from M.I.T. and certain selected Latin American universities. From the inception of this Program the Center for International Studies has participated fully in the planning, and representatives of this group will continue to be members of the Program as it now moves from the planning to the execution stage.

ACTIVITIES OF THE STAFF

Many of the principal professional assignments of the staff are tabulated at the end of this report.

Professor Dietz served as a U. S. delegate at the International Conference on New Sources of Energy, organized by the United Nations and held in Rome in August, 1961.

Professor Arthur T. Ippen visited Russia with a State-Department-sponsored group of leading hydraulic engineers and conducted a six weeks' engineering conference and lecture tour through Pakistan, India, Thailand, the Philippine Islands, and Japan under the sponsorship of the S.E.A.T.O. Graduate School of Engineering. He also presided at the Ninth Congress of the International Association for Hydraulic Engineers in Dubrovnik, Yugoslavia. Professor Daily presented a paper and presided at the symposium at the same Congress.

Professor Harleman presented a paper at the Tenth Pacific Science Congress in Honolulu as a delegate of the United States Coast and Geodetic Survey; during the coming year he will be a visiting professor at the California Institute of Technology.

School of Engineering

Professor Lambe was a visiting lecturer at Rennselaer Polytechnic Institute, University of Florida, Illinois Institute of Technology, and Colegio de Ingenieros in Caracas, Venezuela.

Professor Robert V. Whitman continued as an active consultant for the government's protective construction program and received official recognition from the Air Force for his outstanding contribution to the ICBM program.

We regret to report that Professor Charles H. Norris, who has contributed so much to the development of the Department, will be leaving us to become Head of the Department of Civil Engineering at the University of Washington.

CHARLES L. MILLER

Department of Electrical Engineering

THE UNDERGRADUATE PROGRAM

Development of both subject-matter and technique in undergraduate education continues.

Professor Herbert H. Woodson has been engaged in a major revision of the subject in Electromechanical Energy Conversion (6.06), which now deals with the quasistatics of both lumped and distributed electromechanical systems; enough continuum mechanics has been introduced to do one-dimensional compressible magnetohydrodynamics problems. This material has been presented to a small group of students this year and will be taught on a large scale next fall.

Last year Professors Dean N. Arden and David R. Whitehouse ran two experimental sections of the Introductory Circuit Theory subjects (6.01 and 6.02) on a tutorial basis. The results were so gratifying that this year Professors Amar G. Bose, Kenneth N. Stevens, and Alfred K. Susskind adopted the same kind of program for all the 250 or so sophomores taking these subjects. Three additional techniques of communication with the students were used: first, students in groups of four spent an hour a week with the faculty member in charge of their section in a tutorial session; second, each student had his homework graded in his presence by a teaching assistant who had available a detailed outline of the problem, why it was assigned, the educational points it was trying to make, etc.; and third, the lecturers met with a group of students representing the sections for an hour a week in a feedback session in order to find out how lecture material had been getting across. Next year the tutorial part of the program will be adjusted to seek an optimum balance between staff time and educational effect.

The program as a whole was clearly successful. The feedback section initiated by Professor Bose has been adopted by several lecturers in other large undergraduate subjects in the Department and by some lecturers in other departments, and the individual problem grading is in use in the introductory fields subject, Electromagnetic Fields and Energy (6.03).

Professor Arden has been working with Ford support on the construction of a series of questions for use in programmed instruction of d.c. circuits. A small segment of the series was tested during the spring of 1962, and there will be further development during the summer. As seems to be the case in all educational development at the undergraduate level, the main requirement for success is discovery and strengthening of the points in the subject-matter which no one has recognized as not being fully understood.

A considerable amount of educational experimentation is going on in the area of electrical properties of materials. Professor John Blair, with some Ford Foundation support has been working with Professors John Wulff and Robert M. Rose of the Department of Metallurgy in developing some lecture notes and laboratory experiments for a section of the metallurgy subject in Engineering Materials (3.14) which is taken by electrical engineering students. The subject matter has by now diverged considerably from that presented to the other sections of this subject, although it retains a thermodynamic and metallurgical flavor, and a new name and number may be needed. Professor Arthur C. Smith has presented a new subject in Electric and Magnetic Properties of Matter (6.13) which discusses the origin of conductivity, dielectric constant, and magnetic moment in terms of solid-state physics to the juniors in the electrical science and engineering program. This subject will be available to all juniors next year as an elective.

Professor Paul Gray has presented a new elective subject in semiconductor electronics (6.34), which is a one-semester prerun of a two-semester elective sequence to be presented next year. The objectives of this program are more ambitious. The Semiconductor Electronics Education Committee, with Professor Campbell L. Searle as Chairman and with the active participation of people from ten academic institutions and eight industrial organizations, has as its objective the development of text, laboratory experiments, take-home laboratory equipment, and films of a few experiments which will take students from the solid-state physics of semiconducting materials through the terminal characteristics of the transistor and semiconductor diode as devices and on into circuit applications, including detailed practical questions of biassing arrangements, etc. This kind of complete device experience has not been available to students in recent years. The work of this group was financed initially by the Ford Foundation grant. After the 1961 summer workshop produced a draft of about one-third of the text, the National Science Foundation, through Educational Services, Inc., undertook support of the continuation of the program. Others from M.I.T. associated with this committee are Professors Richard B. Adler, Richard D. Thornton, and Paul Grey.

We have also been making progress in undergraduate laboratory work. In the electronics laboratories (6.70 and 6.71), Professors Thornton and William F. Schreiber last year made available to the students two new aids both made possible by the Ford grant. First, we obtained for the first time an adequate supply of identical oscilloscopes, power supplies, and signal generators so that students could keep their laboratory work set up for a 12-hour day although they might spend only three or four hours doing experimental work during that period; and second, all the 250 or so students involved checked out kits of electronic components, a wiring board, and a multimeter which they could use in the laboratory but could also take home for additional experimental work. We made available some old oscilloscopes to groups of students, and in some cases quite elaborate work was done in the dormitories; other students preferred the laboratory and did little work outside it. Next year Professor Thornton plans to permit interested students to substitute a series of experiments leading to the construction of a portable oscilloscope for the introductory laboratory experiments. These students will be able to keep the oscilloscopes they assemble for the cost of the parts or to turn them back in at the end of one or several terms. In addition to their use in the laboratory or for doing laboratory work at home, these kits may make it more possible to assign experimental home problems in classroom subjects. One instance of this which has already occurred was the assignment of field-plotting homework to 6.03 students, who used their power supplies and meters to draw isopotentials on conducting paper and thus to solve two-dimensional field problems.

The Electromagnetic Laboratory (6.72) was taught for the first time this year to the third-year students. Professors Louis Smullin and Ward Getty did an ingenious job of developing techniques by which electrical and magnetic fields as well as wave phenomena could be observed and measured simply. It is not as easy to develop new experiments in fields as it is in circuits work, where the same economical components can be connected differently without advance recourse to the machine shop. The result is that 6.72 is inevitably more restricted in the options given to the students; there is more demonstration and measurement of phenomena, and it is harder for a student to do a project which is an independent experimental investigation. Professor Robert L. Kyhl will be running 6.73, the fourth of the undergraduate laboratories, for the first time next fall and will attempt to give the students as much freedom as possible by having available for the first half of the term a variety of challenging laboratory situations in areas such as VHF and UHF techniques, microwave techniques, and noise figure measurements to be solved without complete specific instructions. The second half term will follow with a project which might well continue as senior thesis work.

GRADUATE PROGRAM

The heart of the graduate program is, of course, the research activities of the faculty and students in the various laboratories and groups associated with the Department. New graduate subjects develop from these activities, and a number have been added, including Magneto Fluid Dynamics (6.525), Professor William D. Jackson; Algorithms for Optimization and Approximation (6.533), Dr. Allen A. Goldstein; Language, Symbolic Processes and Computers (6.541J and 23.791J), Dr. Victor H. Yngve; Mechanical Translation and Language Processing (6.542J and 23.792J), Dr. Victor H. Yngve; Heuristic Programming (6.544J and 18.16J), Professor Marvin L. Minsky; Biological and Neurological Control Systems (6.595J and 7.595J), Dr. Lawrence Stark; Special Studies in Information Systems (6.604J, 1.16J, 2.745J, and 16.362J), Professors William W. Seifert, Charles L. Miller, Henry M. Paynter, and Yao T. Li. The interdisciplinary character of much of our graduate education is indicated by the number of these subjects that are offered jointly with other departments at M.I.T.

We have relied in the past on the research groups themselves to give students the equivalent of graduate laboratory instruction, and a few years ago had very few graduate laboratory subjects. We have recently added two such subjects: one organized by Professor Whitehouse on plasma dynamics (6.634) and one organized by Professor Arthur C. Smith on Molecular Engineering (6.641). These subjects have been very successful in introducing the increasing number of full-time fellowship students to the techniques and problems of these two currently exciting experimental fields and permitting students to enter into Master's thesis research with some experimental competence during their second term. The Molecular Engineering Laboratory has been equipped with funds from the Westinghouse Electric Corporation, and the Ford Foundation is supporting a summer program to be run by Professor Smith in the summer of 1962 using this equipment for faculty members from about twenty electrical engineering departments who would like to gain direct experimental experience with techniques used in modern solid-state research.

The size of the graduate program continues to grow. The Department began the year with a total of 511 graduate students, 374 of them in graduate degree programs; the remainder were special students studying only one subject.

Most of the students in degree programs had financial assistance. A total of 95 were on the teaching staff, 106 were research assistants, and 98 had fellowship assistance.

The number of students in the doctoral program was 137. This represents an increase of 11 per cent over the previous year. The number in the Engineer degree program was 22 and in the Master's degree program, 215. Many of the latter will continue for the doctorate.

The responsibility for counseling these graduate students, formerly assigned to three registration officers, was distributed this year among twenty-two departmental graduate counselors. With this new plan, each student is counseled by a faculty member whose interests closely match his own.

Colonel Frederic H. Fairchild, U.S.A.F. (retired), joined the staff of the departmental graduate office to assist in coordinating the increased activities.

RESEARCH ACTIVITIES

The federation of scientists and engineers interested in materials research into the Center of Materials Science and Engineering is proceeding as effectively as will be possible until the new building is constructed. Taken altogether, the Department's program in materials now encompasses the activities of seventeen faculty members supported by a professional and student staff of about seventy-five. The existing materials research groups preserve their individual identities but have issued the first joint annual report of the Center and have been actively engaged in planning future common facilities and sharing facilities currently available. Elwood W. Schafer, appointed as a Research Associate this year, has been coordinating faculty participation in building and facilities planning for the Center.

LABORATORY FOR INSULATION RESEARCH

A growing faculty, improved funding, and a climate of appreciation for modern materials research support our expanding research and teaching program in the Laboratory for Insulation Research, under the direction of Professor Arthur K. von Hippel. The alliance of molecular science and molecular engineering has come in its own and extends its inquiry from atoms and molecules to systems of ever-increasing complexity. In this search for a deeper understanding of structures, properties, and devices, many sophisticated tools are required for chemical analysis and synthesis, for crystal growing and the preparation of polycrystalline samples, for nondestructive testing and fine-structure studies. Consequently, much effort has to be expended in the improvement of techniques and facilities. A few examples from the past year may illustrate this aspect of our work.

Accurate analysis is required of the surface and volume compositions of materials, of the molecules and chemical reactions in vapor phases, and of the ionization probabilities of atoms and molecules in electron impacts; a new quadrupole mass spectrograph has been developed for these purposes by Charles K. Crawford and Charles E. Woodward and is now undergoing its first trial runs. The formation of films and surface layers under strictly controlled conditions demands ultrahigh vacua and continuous supervision by means of optical absorption and electron diffraction; an evaporator operating at 10^{-10} torr is being readied for this purpose (Dr. Fred Chernow). The elucidation of electric and magnetic phenomena (e.g., ferroelectricity and maser effects) requires broad-band spectroscopy ranging from the ultraviolet to d-c; spectroscopic facilities and semiconductor bolometers operating at 1°K are being developed by Professor Perry Miles, S. James Allen, and Dr. Steven N. Goldstein to link between the electric and optical spectrum. The mobilization of charge carriers at high temperatures is a fundamental problem for astronautic devices; our dielectric measuring facilities therefore have been extended into the high-temperature range (1600°C) by William Westphal. Dislocations and phonon and magnon spectra are frequently of decisive influence on the electric and magnetic properties of materials; a first study in ultrasonic spectroscopy has just been completed under Emmanuel Papadakis.

The individual research fields of our faculty cover many areas:

Crystal Physics. Under the direction of Professor Alexander Smakula, three main problems are presently under investigation: crystal growth, defects in crystals, and the interaction of charge carriers with crystal lattices.

In crystal growth, nucleation processes in solution are studied and crystal defects revealed by thermal and chemical etching, high-precision density measurements, and ionic conductivity. The interaction of charge carriers (electrons and holes) with the lattices of mixed ionic crystals gives new insight about trapping processes. The exchange of cations or anions, crystal composition and temperature alter the trapping action. An understanding of these effects promises better insight into the behavior of semiconductors, photoconductors, phosphors, and metals.

The Magnetics Group. This research supervised by Professor David J. Epstein presently centers around studies of the electric and magnetic properties of oxides of the first series of transition elements. During the past year our major activity concerned the study of a new magnetic phenomenon discovered by this group and named "dynamic squareness." Materials which show this effect are characterized by a "square" hysteresis loop at frequencies exceeding a threshold value; below this critical frequency the hysteresis loop appears quite normal.

A model has been developed that explains the major features of this "dynamic squareness." Basically, the effect results from the existence of 180° domain walls subjected to a viscous-like drag that decreases with increasing wall velocity. Transient effects occurring during the interval of instability are under investigation.

A study of the electric and magnetic properties of V_2O_3 clearly established that high p-type conductivity at room temperature is an intrinsic property of this material.

Magnetic Spectroscopy. Notable progress has been made under Professor Miles in the development of interferometer techniques for spectral analysis at wavelengths between 1 and 0.1 mm, and in studies of the interaction of high-intensity coherent light beams with crystalline solids.

In the first project, our primary interest centers on an investigation of the absorption spectra in ordered magnetic crystals and paramagnets where exchange interaction and crystal field effects bring the characteristic resonance frequencies (usually found in the microwave range) into the submillimeter region. A whole new field of research appears in the interaction of excited magnetic systems with optical modes of lattice vibrations.

The nonlinear response of crystals to high-energy light beams, particularly in resonant systems, allows the generation of optical beats and may lead to new techniques in coherent spectroscopy. Our work concentrates at present on accurate measurements of the nonlinear response terms.

Optical Modulation. This group continues its work under the direction of Professor Charles C. Robinson. The near-infrared photoelectric ellipsometer has been put into operation by Stephen Russell. Measurements on an opaque iron film between 0.5 and 1.96μ determined the rotation and ellipticity of the polarization in the reflected light; the contribution to these values of the longitudinal Kerr effect and of ordinary reflection were separated. From this information the magneto-optic element of the complex conductivity tensor was calculated for iron and a sharp resonance found at 0.74μ, which is still unexplained. Nickel and permalloy and possibly yttrium iron garnet will be included in further studies.

The previous results for the optics of ferromagnetic films can be generalized for other materials (ferrites, glasses, and so forth). Second-order magnetic effects included in the calculations take into account the Voigt effect as well as the Kerr and Faraday effects.

Investigations of multi-layer dielectric coatings on a ferro-magnetic film magnetized in the transverse direction have been completed by Roberto C. Callarotti, and hysteresis loops for a permalloy film studied by employing the longitudinal Kerr effect by William R. Schonbein. In reflected light, domain-wall motion and domain rotation can be separated by suitable polarizer alignment and the slower domain-wall motion readily observed.

Crystal Algebra. Professor Arthur L. Loeb supervised the group on crystal algebra. The classification of crystal structures containing closely packed ions has been rounded off by the discovery that a hexagonal net can be subdivided into ($k^2 + hl + l^2$) equivalent nets, where k and l are integers. The structures can now be correlated with chemical formulas; since no integer values of k and l exist such that $k^2 + hl + l^2 = 2$ or 8, the structures of certain zinc compounds and of spinel are explained satisfactorily.

The translation of the crystal algebra code into a physical array is facilitated by the crystograph, a decoder containing a switch box (the coded pattern) and a hexagonal array of lights (the physical pattern). This device is almost completed.

Applications of crystal algebra to the field of programmed instruction are now being explored in collaboration with the staff of the Committee on Programmed Instruction at Harvard University.

Structure Analysis. The structure analysis group under Professor Robert E. Newnham is investigating the physical properties of various rare earth and transition metal compounds. Crystallographic studies of single crystals and oxide ceramics are carried out by means of X-ray and neutron-diffraction techniques augmented by optical, dielectric, and magnetic measurements. Materials currently under investigation include chrysoberyl, rare earth transition metal double nitrates, rare earth borates, molybdenum telluride, and cobalt titanate.

Dielectric Research. Two large projects are in progress under Professor von Hippel which draw on many facilities of the Laboratory; in addition, a variety of individual studies continues to probe the behavior of electric dipoles and charge carriers in liquids and solids. The program on high-dielectric-constant materials, supported by the Air Research and Development Command, centers on ferroelectrics of the perovskite type, the effects of cation substitution, frequency and temperature dependence, and the fading-out of the ferroelectric response in the infrared. The aim is to reach a broader understanding for the formation and reaction of electric dipole systems, and to arrive at a clear appraisal of their applicability for energy storage and their competitive position in relation to magnetic dipole systems. A program on high-temperature dielectrics, sponsored by the Aeronautical Systems Division, intends to clarify basic phenomena such as: charge carrier mobilization and transfer at high temperature, questions of chemical stability, and self-destruction of dielectrics—for the guidance of astronautical materials research. The development of new tools and techniques mentioned at the outset, the growing of crystals by flame fusion, and the formation of ceramics by hot-pressing and extrusion, belong to this part of our activities.

Individual studies in the Laboratory have included continuation of our breakdown research on single crystals into the liquid-helium region by Francis W. Kaseta; development by Dean A. Powers of a prototype equipment for measuring the true breakdown strength of materials by pulse techniques; hydrogen bonds and their transfer studied by Matthew W. Sagal in alcohols and now also extended to water and ice; field emission in rutile and CdS; electron injection and trapping in alkali halides; and research on dislocations in polar materials.

ENERGY CONVERSION AND SEMICONDUCTOR LABORATORY

The Energy Conversion and Semiconductor Laboratory has continued its investigations of the properties and device applications of solid-state materials, primarily semiconductors.

Semiconductor materials which have been prepared and evaluated for their electronic properties and potential device utilization include the bismuth-antimony-selenium-tellurium system, the mercury-cadmium-tellurium system, and the lead-tin-tellurium system. The Seebeck coefficient, electrical resistivity, thermal conductivity, galvanomagnetic coefficients, and optical properties have been measured to characterize the materials and correlate performance with microscopic electronic structure.

Work on other types of materials includes a study of electrical and magnetic properties of hard superconductors, and an investigation of the suppression of spin instabilities associated with high-power ferromagnetic resonance.

Theoretical studies on materials have included an investigation of lattice thermal conductivity at high temperatures, using classical theory for the mechanical power flow in three-dimensional, anisotropic, discrete lattices; a study of ferro- and antiferromagnetism, with emphasis placed on the many-body treatment of ferromagnetism using the thermodynamic Green's function method of Martin and Schwinger; and the energy band calculation for lead telluride using the computer program and techniques of Professor John C. Slater's laboratory.

Energy conversion devices studied have included: a thermoelectric generator using lead-tin-telluride couples; the germanium p-n thermophotovoltaic converter; and a graded-gap converter based on the PEM effect.

Other devices and related effects that have been studied include space-charge limited solid-state devices, the germanium junction diode as a thermometer, high-current tunnel diodes, noise in field effect transistors, gain-bandwidth limitations in varactor amplifiers, semiconductors as microwave switches or limiters, and ultrasonic amplification in semiconducting piezo-electric crystals.

During the last year the Laboratory has continued to expand its activities in the solid state field with additional funds from the A.R.P.A. support for the Center for Materials Science and Engineering at M.I.T. and from the A.R.P.A. program for research on materials, processes, and devices related to energy conversion. The interdepartmental activities that have resulted from both of these contracts have materially helped the interchange of information between our Laboratory and others at M.I.T. In addition, the increased funding has enabled us to expand our program to include a broader range of energy conversion and semiconductor materials and devices.

The Laboratory has continued to maintain contact with Professor Pierre Agrain of the University of Paris, who again visited us for a set of stimulating lectures in February and has continued to make suggestions and contributions to the over-all program.

The Laboratory was directed by Professors David C. White and Adler, aided by Professors Blair, Jose Borrego, Gray, Alan L. McWhorter, Frederic R. Morgenthaler, George W. Pratt, Smith, and Thornton. The area has supported eleven Doctoral students and twelve Master's students, of whom four Doctoral students and seven Master's students completed their research programs and received their degrees during the year.

ELECTRONIC SYSTEMS LABORATORY

The research efforts of the Electronics Systems Laboratory under the direction of Professor J. Francis Reintjes, stressed graduate student participation. It embraced a variety of projects and problems in automatic control, computer technology, computer applications, instrumentation, and electronic components. A total of 43 graduate students and 34 undergraduates were associated with the Laboratory as research assistants, thesis students or part-time employees. Degrees earned through thesis research at the Laboratory included two Doctor's, four Electrical Engineer, nineteen Master's, and nineteen Bachelor's.

The research in process control under Professor Leonard A. Gould has continued in two major areas—experimental determination of dynamic behavior of chemical reactions, and methods of mathematical analysis of certain classes of commonly occurring transport processes, as well as analysis of the effects of interaction when plant units are coupled together to form plant complexes. The purpose of these investigations is to build up a body of knowledge related to classes of process operation in order that predominating effects can be quickly isolated when attempts are ultimately made to design computer-control systems for complicated plants.

The research in basic control theory being sponsored by the Army continues under the supervision of Professors George C. Newton, Gould, and George Zames. Emphasis has been on the design of optimum control systems and methods for describing complex physical and biological systems. One application, which is near completion, is an outgrowth of a joint effort with the Neurology Group of the Laboratory. This work concerns an attempt to develop a mathematical model for the behavior of the pupil of the human eye in response to variations in light intensity, using the mathematical theory of optimum control.

The Neurology Group of the Electronic Systems Laboratory, under the direction of Dr. Lawrence Stark, is applying communications-engineering concepts and servoanalysis techniques to biological and neurological systems. Nonlinear aspects of the pupil and lens servomechanism were studied experimentally and by simulation techniques; adaptive control of pupil gain by the retina has been demonstrated. Techniques such as electronic control of feedback, developed initially on the pupillometer, and on-line digital computer excitation and analysis of a system (developed initially for hand-coordination studies) were combined to test experimentally an analytic sampled-data model for the eye-tracking system. Diagnostic measurements are being evaluated using patients from Massachusetts General Hospital and the Massachusetts Eye and Ear Infirmary. A new digital computer acquired during the year should extend the range of these experiments. Special pulse-analysis equipment was developed, and a transfer function was obtained for a single neuron photoreceptor signal. Automatic pattern recognition is being applied to electrocardiology in cooperation with the Boston University Medical Center. An educational film on the pupil servomechanism was produced and a graduate seminar on Biological and Neurological Control Systems was conducted during the fall term. Grants from the Office of Naval Research, the National Institutes of Health, the Army, and the Air Force support these programs.

Under the leadership of Mark E. Connelly, the Computer Technology Group completed a study to determine the design of an analog-digital computer suitable for the simulation of aircraft dynamics in real-time. As a result of this study, work will start soon on the assembly of the computer system with the objective of providing a full-scale demonstration of its capabilities. Other applications of combined analog-digital computation are being studied in the simulation of process controls, the simulation of adaptive systems, signal analysis and synthesis, ray-tracing in the ionosphere, and the solution of partial differential equations. These studies, in time, will utilize modified versions of a basic analog-digital computer facility for experimental problem solving.

The work of the Computer Applications Group under the direction of Douglas T. Ross centered on the utilization of computers as aids in mechanical design. This work was carried out under Air Force sponsorship in conjunction with members of the Department of Mechanical Engineering. Specific activities of the Laboratory group included the design of a compiler for use in future computer-language developments more directly related to the problems of design and the development of graphical languages. New techniques for handling compiler languages developed by the group have been proposed to committees of the American Standards Association as a basis for international standardization of such languages as ALGOL and COBOL for scientific and business applications, respectively. As part of this program, John Ward has led a group which is investigating techniques for achieving more effective communication between man and computers. Studies have continued on programming and equipment techniques for efficient and versatile input-output consoles. Particular attention has been paid to display generation and light-gun techniques for graphical communication, display memory techniques to relieve the load on the main computer memory and program, and time-sharing techniques for multiple consoles.

A group in the Electronic Systems Laboratory under the leadership of Professor Newton has conducted extensive research in angular-motion sensors. Their objective is to achieve new forms of vibratory-output angular motion sensors for inertial navigation systems and space applications. An investigation of several microscopic phenomena—from the viewpoint of their utility for angular-motion sensing—has been completed. The phenomena include the Faraday effect in optical and microwave regions, nuclear magnetic resonance, induced polarization in dielectrics using large molecules and colloidal particles, and certain bulk fluid effects. In each case a theoretical estimate was made of the expected sensitivity of the phenomenon to angular motion in the presence of noise and other disturbances. Currently, rotary- and vibratory-drive devices are being analyzed and one vibratory-drive configuration has been constructed. This instrument is an angular rate sensor which will be used in a series of experiments to evaluate the effectiveness of a scheme of double modulation designed to reduce cross-coupling betwen the large driving signal and the small output rate signal. This cross-coupling has been a limiting factor in previous devices of this type and its reduction may lead to significant increases in sensitivity. This research is being sponsored by the National Aeronautics and Space Administration.

In a Navy-sponsored program under Professor Newton, efforts are being made to improve instruments and control-system components for underwater vehicles. One problem under current investigation is the measurement of hydrostatic pressure with an error of less than 0.01 per cent over a pressure range of zero to 2500 psi. Here the basic property of the velocity of sound in liquids is being exploited as a means for pressure measurement. Research conducted on this property in various liquids has indicated distilled water to be the most suitable of those tested so far. Further research on ultrasonic transducers and high-speed digital circuitry is in progress in order to make possible the design of a prototype instrument based on this approach. Another problem being investigated is the use of a pulsed servo valve for control-surface actuators to achieve high dynamic performance and reliability. This research is sponsored by the Department of the Navy, Bureau of Naval Weapons.

In the realm of new electronic components, Professor James G. Gottling and Dr. Martin S. Osman are conducting research directed toward development of a thin-film tunnel-emission amplifier. The electronic-conduction properties of metal oxide insulators are being examined in order to establish the nature of the fundamental conduction mechanism and to gain insight into the structure of the oxide film. Electron-beam-bombardment techniques have been developed for the evaporation of oxide films.

An intensive research program conducted by the Radar Systems and Devices Group in the Electronic Systems Laboratory yielded results in several areas. Under N.A.S.A. sponsorship, Professor Reintjes and his graduate students completed an analysis of space-craft radar systems for exploring the surface of the planet Venus. Air Force-sponsored research in high-power semiconductor-magnetic pulse generators, under the direction of Laurence Swain, attracted extensive attention from industry. Theoretical work resulted in a doctoral thesis on a new radar theory applicable to multiple-scatterers of electromagnetic energy. Investigations in the utilization of tunnel diodes for improvement of radar-circuit performance continued under the direction of Godfrey T. Coate.

HIGH VOLTAGE RESEARCH LABORATORY

The activities of the High Voltage Research Laboratory have included the application of megavolt electrons and X-rays to the therapy of superficial and deep-seated malignant disease, the preservation of tissue for surgical use, and the study of radiation effects on dielectrics, semiconductors, and other materials. With the support of the Damon Runyon Memorial Fund, and with the medical support of the Lahey Clinic in Boston, further progress has been made in the direct clinical use of high-energy electrons using the 4 Mev Van de Graaff accelerator in Building 28. About 160 treatment series were given to patients with extensive superficial disease during the calendar year. Studies, supported by the National Institutes of Health, of the effect of such radiation on blood components and tissue have advanced the technique of preserving human tissue for surgical use. The Columbia-Presbyterian Hospital in New York, which has been cooperating in this work, reports that 3,700 bone sections, cultured prior to electron irradiation, were transplanted into 2,600 patients during the past nine years with no evidence of infection ascribable to the bone.

Another group has studied the production and focusing of intense beams of ions, neutral atoms, and electrons. Their work has resulted in improved apparatus which has yielded higher beam intensities. Other experiments with a vacuum-insulated high voltage gap have shown that a thin dielectric film on the cathode electrode permits higher breakdown voltages in vacuum with dramatic reduction in the prebreakdown current.

In its educational activities, the Laboratory has, during the past year, maintained on its staff four research assistant candidates for the

Master's degree and one candidate for the Doctor's degree. The graduate elective subject, Production and Control of Intense Particle Beams, a formal study of one phase of the Laboratory's activity, was offered during the spring term.

STROBOSCOPIC LABORATORY

During this year there has been a continued interest in instrumentation with electronic flash (strobe) lighting and with photography, in which Professor Harold E. Edgerton has done so much pioneering work. In addition to students taking Electronic Light Measurement (6.202) who do an experiment (or an experience!) each week, there seems to be a parade of people from all over the Institute and elsewhere who need help in making measurements. Many of these problems are challenging ones, such as the high speed motion pictures of the blood circulation in the white of the eyes which is being tried for Dr. Roe Wells of the Peter Bent Brigham Hospital. At the moment photographs at a thousand per second with magnification seem feasible since strobe light offers many possibilities due to its efficiency and control possibilities. This effort follows the successful still photography system of the eye as developed for Dr. Searle Rees of the Diabetic Clinic for research work.

Effort continues on the various sonic sources developed in connection with underwater research during the last ten years. Of special interest is the "boomer," which enables the geophysicists to obtain seismic profiles one-half mile below the bottom in 2,000 fathoms of water. Professor Edgerton made a three week trip on the R/V "Chain" out of Woods Hole in November-December of 1961. Sample sediment depth information was obtained at numerous locations with the "boomer," with Dr. Earl Hays and Dr. J. Brackett Hersey.

Two experimental "mud penetrators" were sent to Edwin Link and Captain Jacques Y. Cousteau in Europe for precise subbottom sonar explorations sponsored by the Research Committee of the National Geographic Society. The main object will be to detect archaeological objects with a 12-kilocycle pulse of 1/2-millisecond duration. Preliminary tests indicate that some objects as deep as 6 feet in soft mud can be detected.

A "boomer" system of 13,000 watt second capacity is to be used on the *Calypso* in the summer of 1962 by Captain Cousteau for a study of the deep sediments off the southern coast of France. This project is also sponsored by the Research Committee of the National Geographic Society.

COMPUTER GROUP

In September, 1961, the Department received the very generous donation of a PDP-1 digital computer from the Digital Equipment Corporation, to be used primarily for educational purposes. The PDP-1 is the commercial successor to the TX-0 Computer used in scientific investigations by the Research Laboratory of Electronics. During the past year this machine has permitted a small group of freshman students of computation to have a more extensive and informal contact with a machine than has been previously practical. The PDP-1 also served as an instrument of model making and analysis for a sizeable number of term projects and dissertations.

Recently, the general need for easier access to the computing machines by students and researchers has been noted by a number of the faculty and others in the field of computation. The time-shared use of a digital computer by many users communicating through a number of typewriter consoles promises a large improvement in quality of computation facility by providing convenient access without sacrificing utilization of machine capacity. To put the concept of a time-shared computer facility to test and to provide for even greater informal access to the digital computer by students, a multiconsole time-sharing arrangement is being developed using the PDP-1 as the basic machine. A magnetic drum auxiliary storage will be installed to temporarily hold users' programs while one program is being run in the PDP-1 memory. The system should not only provide a more accessible computational facility for students in the Department, but will be an instrument for studying and evaluating the use of machine teaching techniques in our educational program.

RESEARCH LABORATORY OF ELECTRONICS

A separate report on this interdepartmental laboratory appears elsewhere in this volume. However, the research support provided for faculty and students deserves brief mention in the academic activities of the Department.

During the year 74 members of the electrical engineering faculty participated in the research activities of the Laboratory. A total of 150 electrical engineering graduate and undergraduate students were engaged in the research which covers three broad areas, communication sciences, plasma dynamics, and electronic devices and systems. The Laboratory supported 51 Bachelor's, 38 Master's, 4 Engineer, and 13 doctorate theses in electrical engineering.

LINCOLN LABORATORY

Interchange of people and cooperation with the Lincoln Laboratory continues. Professor Robert M. Fano spent this academic year at the Laboratory and returns to Cambridge in September, 1962. Professor McWhorter will leave the campus for Lincoln Laboratory in July, 1962, and Professor Harry C. Gatos, jointly appointed in electrical engineering and metallurgy, will come to Cambridge from Lincoln Laboratory in September, 1962. A number of Lincoln staff members participated in a graduate seminar on fundamental properties of materials which was organized by Professor George W. Pratt, formerly of Lincoln. Wesley Clark, a member of the Lincoln staff and a Lecturer in the Department, participated in a very successful course in computer design. In radio astronomy Professors Alan H. Barrett and James W. Graham have been discussing joint projects with Lincoln staff members. A committee of faculty and Lincoln staff members under the chairmanship of Professor Fano has been set up to assist in planning joint work in the area of communications, and similar working arrangements in other areas are likely to evolve in the near future.

PERSONNEL

An unusual number of visiting professors were in residence during the year. Professor Maurice Boisvert from Laval taught a section of Introductory Circuit Theory (6.01) in French. Professor Ahmed El-Abiad from Purdue University studied system theory. Professor Eiichi Goto from Tokyo taught a course on computer logic, found a minimum-delay solution to the firing-squad problem, and prepared to hunt for free magnetic poles during the summer. Professor Edward F. Moore from Bell Telephone Laboratories taught machine theory at M.I.T. and at Harvard and enjoyed his exploration of the academic subculture about which he has prepared a brief report. Professor Mary A. B. Brazier of the Brain Research Institute of the University of California at Los Angeles came several times during the year to give lectures. Professor Thomas J. Lewis from the University of London helped to teach a subject in solid-state, and Professor John Cocke from

International Business Machines Corporation joined in a subject in computer design.

Alan Barrett joined the staff as an Associate Professor. The appointment of Professors Fano and White to Ford Professorships of Engineering was announced, as was the appointment of Professor von Hippel as an Institute Professor.

Professor Tucker, who has been running the Department as Executive Officer with great success for the past twenty years, will continue to do so on a half-time basis next year. He retired from full-time service this June.

The Department faculty and many former students and associates heard with regret this year of the deaths of two of our Emeritus Professors. Professor Lyman M. Dawes died March 13, 1962, at age 89, sixty-six years after joining the M.I.T. staff. Professor Ralph R. Lawrence died on March 6, forty-two years after he joined the M.I.T. staff.

PETER ELIAS

Department of Mechanical Engineering

Three years ago the undergraduate curriculum in mechanical engineering was revised to include a new program for engineering science and an improved program pointed toward the applications of mechanical engineering. The three years' operation of this revision has pleased the faculty of the Department. There has been a marked interest in both branches of the bifurcated curriculum. This year has been characterized by intensive activities to improve the individual subjects taught in the revised curriculum as dictated by the growing experience with it.

Substantial changes in the teaching of undergraduate mechanics have started this year. A new subject, Dynamic Systems (2.021), which treats dynamic analysis and the response of physical systems from an interdisciplinary point of view, was taught for the first time in the spring semester. It was introduced as a part of the core curriculum in mechanical engineering and was also given to students from civil engineering, naval architecture, chemical engineering, and industrial management. The reaction of the students and faculty is quite favorable, although it must be polished for further presentation. This subject is an outgrowth of a workshop conducted in the summer of 1961 with support from the Ford Foundation grant for engineering education, led by Professor J. Lowen Shearer with Professors Henry M. Paynter, Dean C. Karnopp, Shih-Ying Lee, Herbert H. Richardson, and Arthur T. Murphy of the Department also participating, together with fourteen faculty members and six visitors from other departments at M.I.T. and other engineering schools.

Another new subject in mechanics is being developed by Professors Stephen H. Crandall, Karnopp, Edward F. Kurtz, Jr., and David C. Pridmore-Brown of the Department and Professor Paul L. Penfield, Jr., of the Department of Electrical Engineering. The object of this development (which again resulted from a summer workshop supported by the Ford Foundation) is a new dynamics subject for juniors and seniors to follow the new sophomore subject in linear systems response described above. The new junior and senior subjects in dynamics (2.03 and 2.031) emphasize the formulation of mathematical models over a wider spectrum of fields of application than has been traditional, using Hamilton's principle as the unifying link in studying rigid body mechanics, fluid mechanics, electromechanical circuit theory, and the interaction of electric fields with mechanical systems. The faculty members who developed the subject were aided in the summer workshop by Professors Ernest Rabinowicz, Steven I. Freedman, and Murphy from the Department, as well as Professor Raymond L. Bisplinghoff from the Department of Aeronautics and Astronautics. This subject will become part of the core curriculum in mechanical engineering next year. It was given in trial form in the spring semester this year as an option for seniors in engineering science and, in its trial form, seemed extremely successful. The interested parties will further refine the subject material this summer before it is taught next year.

During the past year undergraduate instruction in heat transfer has been completely revised with the publication of a new textbook, *Heat, Mass and Momentum Transfer*, by Professor Warren M. Rohsenow and his colleague, Professor Harry Y-H. Choi from Tufts University. The multiple-subject offering has been eliminated in favor of multiple sections of a single subject, Heat Engineering (2.43), which presents a unified treatment of transfer processes emphasizing heat, mass, and momentum transfer and showing the analogous electricity transfer process where applicable. Included are quantitive kinetic theory explanations of transport processes for both continuum and rarified gases and a statistical mechanics explanation of black body radiation.

For the junior subject in Mechanical Behavior of Materials, nine staff members of the Department have collaborated in preparing notes, published with the support of the Ford Foundation grant, giving extensive supplementary material as well as a core of information for the average student.

The revised and extended version of Thermodynamics (2.403) for second-term sophomores has developed to the point where the individual instructors are able to carry the subject without so much dependence upon general lectures. The number of general lectures will be reduced next year and the number of discussion sessions correspondingly increased. A revision of the text by Professors Joseph H. Keenan and George N. Hatsopoulos is now closer to publication. In this area of work, Professor Charles L. Brown of Purdue University spent a year as a Guest of the Institute teaching in the spring semester a section of sophomores in Thermodynamics (2.403), and contributing substantially to the development of the subject. Professor Hatsopoulos has been granted a leave of absence next year to pursue industrial development of direct-energy-conversion devices; however, he does plan to continue work with Professor Keenan on the development of the new textbook for teaching thermodynamics of irreversible processes to graduate students.

The integration of design in the undergraduate as well as the graduate curriculum continues. At the freshman level it is integrated through the media of graphics and descriptive geometry subjects and freshman seminars; at the sophomore level through Engineering Design and Manufacture (2.861); Engineering Design (2.731), and projects in Experimental Engineering (2.671), in the junior year; and through elective senior and graduate subjects, projects, and theses. The subject, Engineering Design and Manufacture (2.861), is undergoing a revision in which Professors Nathan H. Cook and Deane Lent are undertaking to more closely coordinate the two rather separate portions of the subject. This reexamination of the subject will continue next year.

Under National Science Foundation sponsorship the members of the Division of Design and Graphics this summer will present to eighty engineering educators the over-all philosophy and selected detail material from the design and graphics subjects of the Department. The initial invitation for this program was substantially oversubscribed, necessitating a selection of the representative outstanding people from throughout the country for attendance. The computer-aided design project under Professor Steven A. Coons, which has had a considerable impact on professional engineering and on graphics and design education, will be an important part of the presentation at the National Science Foundation conference this summer.

The purpose of this computer-aided design work is to devise a system which combines a human designer with a computer so the designer can perform the creative acts of the design process while the computer performs the non-creative tasks. Considerable progress has been made—enough to cause enthusiasm concerning its future. One of the first problems approached is the stress analysis of such structural assemblies as trusses, in which the geometry and loading is described graphically and the analysis proceeds automatically. Aiding Professor Coons in this effort are Professors Robert W. Mann, Frank A. McClintock, Dwight M. B. Baumann, Ernesto Blanco, and Kurtz. The project is quite productive of theses.

Under Professor Mann the project in the junior engineering design subject this year was, "the concept, specification, and design of a research apparatus for exploring inner space—the abysmal depths of the sea." To provide background for this design project there were a field trip of the entire class to the Woods Hole Oceanographic Institution, movies and lectures by Professor Harold E. Edgerton of the Department of Electrical Engineering, and a seminar by a physical oceanographer from Woods Hole. The student designs were evaluated by outside juries of engineers and scientists from industry and from the field of oceanography.

Again in the design area, there has been encouragement and student interest in projects and theses concerned with the underdeveloped countries. This last year, for example, theses were undertaken on an adjustable gauge locomotive frame to integrate the African railroads, a desalination plant, an economic study of a solar pump for irrigation, and machinery for automating the production of Indian bread.

The Department has played its part in familiarizing students at the freshman level with engineering. Many freshmen come to M.I.T. quite unacquainted with the real nature of engineering, having had only basic science in their preparatory years. Even at M.I.T. basic science and humanities are so stressed in the freshman year that the concept of engineering is still not developed in the students' minds. The lack of contact with engineering in the formative years, combined with the misuse of the word "science" applied to many engineering activities today, results naturally in a considerable number of students pursuing courses in basic science while their natural, though unrecognized, interest is in engineering. The Department of Mechanical Engineering is participating in several attempts to acquaint our freshmen with the engineering field at an earlier date. One of these special efforts is a freshman elective subject, Introduction to Engineering, taught by Professor Paynter. An entirely new syllabus has been developed for this and is being published on a grant by the Ford Foundation. This year's subject for Introduction to Engineering dealt with the progress over the decades of trans-Atlantic communication. This included, among other things, the laying of the Atlantic submarine cable, the development of wireless telegraphy and telephony, and the establishment of the Telstar satellite communication system.

In addition, several members of the Department have presented Undergraduate Seminars this year. They are Professor McClintock on ductile fracture, Professor Mann on Braille, Professor William M. Murray on industrial engineering, Professor Rabinowicz on the liquid thermocouple, Professors Warren M. Rohsenow and Raphael Moissis on radiation absorption, Professor Tau-Yi Toong on combustion and propulsion, and Professor Kenneth R. Wadleigh on power.

The laboratory portions of Fundamentals of Electrical Engineering (6.18) are being reworked in conjunction with Professor Richardson and a research assistant. New laboratory apparatus is being planned and constructed. This electrical engineering subject is to be taught by Professor Richard H. Frazier and is to become gradually integrated into our proposed sequence of electromechanical design subjects.

The Department is determined to present in the undergraduate program first-class engineering science subjects with a broad interdisciplinary base and at the same time to instill in students an interest and capability in using the basic sciences and the engineering sciences in their approach to real engineering projects. The faculty is dedicated to a close contact with undergraduate students in pursuing these objectives. As the undergraduate enrollment in the Department has dropped, the capability of the staff to undertake this close personal contact has increased.

The Admiral Luis de Florez Awards for creative and imaginative accomplishments by undergraduates have again provided a strong motivation for using common sense together with the best analytic ability, to do something original in design or experiment. Admiral de Florez again was here in person to present the awards this year. The culmination of this contest and the award presentation is a high point in the activities of the Department.

Superior Students. There are two special programs for superior students in mechanical engineering—the Honors Course and the Advanced Undergraduate Program, for both of which Professor McClintock has served as adviser. The Honors Course is made up of students of unusual promise selected at the end of their junior year to proceed with a two-year program which leads to the simultaneous award of the Bachelor's and Master's degrees. The Advanced Undergraduate Program is for a small number of students selected at the close of the sophomore year, who are encouraged to substitute graduate fifth-year subjects for third- and fourth-year subjects and to select their programs from a broad range of science and engineering. Both of these programs serve to challenge students who are capable of progress at greater speeds than normal and who have the breadth of comprehension to roam broadly through all of the sciences and engineering sciences as they lay the foundations for their engineering careers.

ENGINEERING PROJECTS LABORATORY

Unquestionably the high point in Department activities this year was the opening of the Engineering Projects Laboratory—an interdisciplinary engineering laboratory which has been formed by consolidating many of the laboratories of the Department of Mechanical Engineering. Professor Mann has served as the chairman of the steering committee of the Laboratory for its first and most critical year of operation, and Karl N. Reid, Jr., has been the coordinator. Other members of the steering committee have been Professors George A. Brown and James Holt.

The Engineering Projects Laboratory contributes in several ways to education in the School of Engineering on both undergraduate and graduate levels—through research in all the engineering sciences and in synthesis and design based upon them, and through projects in engineering research and development which include the production of prototype devices. It is based on the premises that an engineering faculty must itself be directly and continuously immersed in engineering to maintain its competence in a rapidly evolving technology, that research involvement is mandatory for exemplary graduate education in engineering, and that undergraduate experimental experience is best undertaken in an authentic environment where undergraduate students work as interns with faculty and graduate students on research investigations in advanced engineering projects. The staff and projects of four previously unrelated Mechanical Engineering Department laboratories—the Dynamic Analysis and Control Laboratory, the Heat Power Laboratory, the Heat Measurement Laboratory, and the Mechanics and Dynamics Laboratory—have been merged together with other mechanical engineering faculty into this interdisciplinary unit. As the year has progressed the effort toward introducing some active faculty and graduate students in research projects from the Department of Electrical Engineering has progressed. The physical move of the Electronic Systems Laboratory, an important electrical engineering group, to space contiguous with the Engineering Projects Laboratory will be a step toward a deeper interdepartmental involvement by this laboratory. Soon undergraduate and graduate students from both mechanical and electrical engineering will use the Laboratory facilities for subjects and project work in the fields of control systems and human factors.

A considerable portion of the Engineering Projects Laboratory space is the rearranged and remodeled area of the Heat Power Laboratory in Building 3. The familiar well in Building 3 has been floored. Extensive support from the Ford Foundation grant made possible renovation of all of the space in that area, resulting in approximately 5,000 square feet of new floor area, a rearrangement of 17,000 square feet of presently satisfactory area, and a rehabilitation of 16,000 square feet of margin space. A new central instrument room has been provided and partially equipped. Facilities (steam, gas, compressed air, vacuum, electric power, etc.) have been manifold throughout the experimental area. Special test facilities have been provided for noisy, potentially hazardous experiments in combustion, high pressure fluids, noxious materials, etc. Supporting activities—shops, document rooms, offices—have been provided. Instrumentation funds for the Engineering Projects Laboratory were provided initially by the Ford Foundation grant, and they were substantially augmented by approximately $25,000 from a National Science Foundation grant under the undergraduate scientific equipment program.

In summary, the Engineering Projects Laboratory provides the environment and facilities for challenging, sophisticated participation in research by undergraduates through the merging of faculty-supervised sponsored research with the undergraduate instructional program. By this direct involvement in engineering research and development, students can begin to appreciate fully the role experiment plays in establishing and understanding engineering science and experience the challenge and satisfaction of carrying engineering works to completion. Thus we exploit the role of experiment in developing the creative abilities of our young students.

RESEARCH

Mechanics. Professor Crandall's research programs on random vibration and machine computation work have made substantial progress in providing challenging problems and research support for a number of graduate students and visiting fellows. In September, 1961, Professor Crandall reported some of the results of this work at an international symposium on nonlinear vibrations held in Kiev, Russia.

Professor Karnopp has been doing research centered on two fields: random search techniques for optimization problems and multiplexing techniques for improving reliability and accuracy of continuous signal systems. In the first of these fields some results are shortly to be reported, and work is continuing to adapt the random search techniques for process identification and adaptive control.

Materials and Materials Processing. A committee under the chairmanship of Professor Cook and with representatives from the several laboratories involved with materials and processing–the Materials Division, the Materials Processing Division, the Surface Laboratory, and the Textile Division—investigated the desirability of a closer linkage between these materials-oriented programs. It appears that there are many advantages inherent in such a regrouping, and it is strongly urged that these laboratories and divisions be grouped closely physically, administratively, and intellectually. Improved service and greater utilization of equipment and space would result from physically coalescing the Materials Processing Laboratory, the student shop, and the professional shop. The mutual advantage of the intellectual cross-fertilization among the faculty and students of these groups would be of great value.

In order to bring about this physical regrouping, the Department and administration are studying substantial space moves and space renovation in Buildings 5 and 3. Because of the involved interlinking of such moves, however, with other major relocations contemplated in the School of Engineering, the negotiations are proceeding slowly.

Professor Egon Orowan, with Westinghouse Professorship funds, has concentrated on a study of the mechanism of fracture in high temperature refractory materials such as Al_2O_3 and MgO. One phase of this work involved the development of a high temperature (4000°F) machine for tension and torsion by George Keith, the other phase consisted of an investigation by Professor Argon of the fracture mechanism of alkali halides and magnesium oxides.

Professor McClintock has continued research on fracture. In this work, Charles A. Berg has analyzed the effect of viscous flow around cracks on the strength of brittle materials, and Professor Gonzalo Leon has developed theoretical models for the fracture of solid rocket fuels. A seminar research program for freshmen has been conducted in which the students have managed to control the usually unstable fracture in ductile materials and have shown how fine cracks are involved. This is an interesting example of how the professional research of faculty, graduate student thesis work, and undergraduate learning can be involved together even at the undergraduate level.

In the Materials Processing Laboratory this year fifteen students conducted thesis work ranging from investigations of electrical phenomena for metal removal to development of laboratory equipment for Processing Laboratory teaching. The latter work is sponsored by the National Science Foundation and has resulted in a simple machine enabling correlation of manufacturing processes with material behavior characteristics capable of a wide range of materials tests together with a variety of instrumented processes. Again to show the links between research and teaching, this development parallels the recent revision of the subject content in Design and Manufacturing (2.861), in which the manufacturing emphasis is placed on the interrelation between material behavior and manufacturing processes.

In the Surface Laboratory, Professor Brandon G. Rightmire has been studying the gradual deterioration of the minute amounts of lubricant used in the spin axis bearings of inertial guidance systems. The failure seems to be an oxidation of the oil catalyzed by the metal surfaces. In a closely allied area, the behavior of monolayers of organic compounds on sliding surfaces has been investigated. The friction force seems to have all the characteristics of a rate process. Under

Professor Rabinowicz' direction, research has been conducted on the effect of surface energy on friction and wear phenomena in an attempt to develop a comprehensive theory of surface interaction behavior. Recent calculations suggest that the laws of wear break down at sufficiently low loads and that, consequently, the formation of wear particles ceases. Experiments have confirmed this behavior. Furthermore, a close correlation has been found between the size of wear particles produced during sliding and the roughness attained by the sliding surfaces. This may have practical applications, since it suggests that surface roughness measurement constitutes a simple reliable test for lubricant effectiveness under sliding conditions.

Professor George S. Reichenbach is continuing his study of rolling contact fatigue. The role of the lubricant and the mechanism by which it alters fatigue life is being studied, using a replica technique to follow gradual changes in the rolling contact surface. In another program, Professor Reichenbach is studying the role of environmental atmosphere on the behavior of typical lubricants. It has been shown that excluding water vapor or oxygen can substantially change friction and wear.

In the A. V. de Forest Laboratory of Experimental Stress Analysis under Professor Murray, the efforts of the staff have been directed very successfully to Special Summer Programs for industry and the development of special equipment for this purpose. Professor Murray and the others involved in that laboratory are often invited to present the program in Experimental Stress Analysis at other universities and at research organizations.

In the Textile Technology Division a considerable reorientation of the research and teaching program has been brought about due to the tragic death of Professor Edward R. Schwartz in July, 1961. The Textile Division research program this year under Professor Stanley Backer, assisted by Dr. Henry M. Morgan and William Klein, has emphasized study on the mechanism of fiber entanglement during processing, on the mechanical behavior of fiber at high strain rates, and on new techniques for fabricating textile structures.

Dynamic Analysis and Control, and Design. A substantial number of the faculty involved in the Dynamic Analysis and Control Laboratory under Professor J. Lowen Shearer, including Professors Thomas B. Sheridan, Paynter, Richardson, Mann, and Lee, presented an Industrial Liaison Symposium on dynamics and control in Los Angeles in July,

1961. This group not only presented their M.I.T. research but also visited and conferred with a number of the participating firms in that area.

In the Laboratory there were several research problems. In fluid power control research for air and space systems, work has been done on pneumatic hot gas gyro mechanisms, pneumatic signal transmission and generation, and pneumatic sensing and control for propulsion systems; fluid jet amplifiers with no moving mechanical parts; hot-gas rate-gyros for flight stabilization and control; and reaction-jet servomotors. All of this work in the fluid power control research for air and space systems has been under the supervision of Professors Shearer, Lee, and Richardson and Mr. Reid.

Professor Sheridan has done significant work in the area of man-machine systems and Professor Paynter has continued to develop his interests in a wide variety of systems analysis topics. These include prime mover control and power system governing studies. Professor Paynter initiated a continuing research program in process dynamics and systems engineering and developed a new technique for hybrid (analog-digital) computing including an automatic scaling and setup procedure for the Engineering Projects Laboratory analog facility.

Professor Mann has continued his investigation of controlled burning of solid propellants with the concentration on the physical phenomenon influencing the process. Although the over-all phenomena is quite complicated, the predominant effect is heat transfer from the chemically reacting gases through the material of the ram impinged upon the propellant surface and on into the solid fuel. Criteria for optimum design of rams to enhance the burning rate under rammed burning conditions have been promulgated and computer studies carried out demonstrating the feasibility of techniques for constant mass flow gas generators under widely varying environmental conditions or gas generators whose mass flow will respond to demand.

Professor Coons' investigation of a computer-aided design to combine a human designer with a computer has been described in the educational portion of this report.

Professor Douglas P. Adams has continued his work on nomographic electronic multi-specific-purpose computers for the Air Force. The promise of the computer continues to grow particularly in the solution of partial differential equations, and it continues to offer new challenges in organization concept and evaluation. Professor Adams has also extended his work for the Naval Ordnance Laboratory on purely mechanical linear acceleration integrators to include acceleration integrating devices for missiles travelling in curved paths of space. In other words, he has enhanced the value of the computer in the field of modern kinematics by extending the use of peripheral and on-line output plotting equipment for several well known computing machines to permit visual and quantitative discrimination within output solution spectra.

Gas Turbine Laboratory. Research in the Gas Turbine Laboratory has been supported during the past year by grants-in-aid from the General Electric Company and the Allison Division of General Motors Corporation, together with contracts from the Office of Naval Research and the National Science Foundation. Twenty-four representatives attended the Annual Sponsors' Conference for the purpose of discussing the research program on December 12, 1961. Under the direction of Professor Edward S. Taylor of the Department of Aeronautics and Astronautics assisted by Professor Philip G. Hill, a number of important research results have been obtained. These include the following: the complex flow pattern in which exists a blade-shroud or wing-fuselage junction has been recorded in motion pictures using smoke to visualize flow, thus making it possible to explain hitherto unpredictable burnouts in rocket nozzles; a theory which agrees remarkably well with measurements has been developed to predict the effect of centrifugal force on the behavior of boundary layers on turbine and compressor blades; the importance of Coriolis forces on the behavior of the boundary layer in radial flow impellers has been established; a newly conceived, simple apparatus for measurements of flows having separated boundary layers was built in which no side effects such as secondary flow, unsteadiness, etc. are present, and measurements can be made rapidly and easily. A number of publications have been promulgated from these research results.

There is continuing research in the Gas Turbine Laboratory on measurement and prediction of periodic forces resulting from a blade passing through the wakes of a previous blade row; prediction of separation of turbulent boundary layers; the effect of Coriolis acceleration on turbulent boundary layers; the behavior of a boundary layer in a highly favorable pressure gradient; and vortex motion in an unfavorable pressure gradient.

Fluids, Plasmas, and Energy Processing. During the past year, Professor Ascher H. Shapiro has devoted a large amount of time to the work of the National Committee for Fluid Mechanics Films which he founded and of which he is Chairman. This Committee, with support from the National Science Foundation, has taken on a national responsibility for producing some 25 half-hour films on experimental phenomena in fluid mechanics. In addition, the committee is producing some 100 or 200 short four-minute films to be used with the new cartridge-loop projector of the Technicolor Corporation. About six of the half-hour films are now in production, and about six more are to be produced during the forthcoming year. A cooperating group of some twenty schools throughout the country is helping in the work of the National Committee for Fluid Mechanics Films. The demand for the two films already available and the enthusiastic comments concerning the value of demonstration-experiment films in teaching the engineering sciences indicate strongly that films of this type are highly acceptable to the academic community.

In Fluid Mechanics Division research, a large annular magnetically driven shock tube has been brought to completion and is now being calibrated, and its first use will be to explore experimentally questions concerning the existence and stability of various types of magnetogasdynamic shock waves; in the area of magnetohydrodynamics, experimental results are being produced for the reading of pitot tubes in the flow of liquid mercury in the presence of a transverse magnetic field; research is continuing on the mechanism of propulsion by oscillating fins as in the swimming of fish; research has been completed on the aero-elastic behavior of a thin, highly flexible membrane rotating at high speed close to a very flat surface—a problem of importance in magnetic memory systems; and research has been concluded on the fundamentals of the molecular flow through cascades of moving blades with special reference to the use of axial-flow bladed machines for ultra-vacuum pumping.

In the area of heat transfer, Professor Rohsenow continues investigation of forced-convection boiling heat transfer, thermal contact resistance, and the effect of electrostatic fields on boiling. He has also initiated new work on condensation of liquid metals in an attempt to understand the significant discrepancy between experiment and theory currently existing. Professor Peter Griffith continues his work in boiling heat transfer and the mechanism of two-phase flow in various regimes. Professor Raphael Moissis has continued his work in two-phase flow and has begun experimental studies of the mechanism of drop-wise condensation. Professor George A. Brown also has continued his work in two-phase flow and will be joined in this area by Professor S. William Gouse who returns from active duty with the army this summer. Professor John M. Reynolds, III, is initiating work on the effects of electric fields on heat transfer and fluid flow of non-conducting fluids. Professor Freedman will continue work on the effects of chemical reactions on boundary-layer heat transfer. Last April the heat transfer group presented an all-day symposium for the Industrial Liaison Office and this summer is offering a two-week Program in Modern Developments in Heat Transfer for representatives of industry, government, and academic institutions.

Under the direction of Professor W. Craig Moffatt, substituting for Professor James A. Fay who is on leave of absence, the research has continued in the general areas of plasma heat transfer, electromagnetic acceleration of shock-ionized gases and plasma containment by magnetic fields. This work has been to a large extent experimental and has centered around shock tube facilities in the Magnetogasdynamic Laboratory. Several papers describing this work have been presented to technical symposia about the country.

Professor Hatsopoulos, Professor Eustratios N. Carabateas, and Professor Robert E. Stickney have continued their active research in energy conversion. Considerable progress has been made in equipping the Energy Conversion Laboratory with modern vacuum stations, a high frequency induction unit, and a mass spectrometer leak detector. A thermionic converter has been operated giving an output power of 2.5 watts per square centimeter at an emitter temperature of 1700° K. Work is in progress on thermionic properties of monocrystals and other areas. A thermodynamic analysis of the surface effects of cesium on refractory metals allows extrapolation of experimental data into regions where such data is very difficult to obtain. This research work in the area of direct energy conversion has led to the establishment of a new graduate subject in Direct Energy Conversion, in which is included both theory and experimental results in this important new technology.

Professor John C. Chato continued his investigations on some aspects of natural circulation flow in multiple channel systems.

In the Cryogenic Engineering Laboratory under Professor Samuel C. Collins a number of investigations have continued, including novel cycles for low-level refrigeration, quest for greater reliability in helium and nitrogen liquefiers, miniaturization of helium refrigerators for maser cooling, pump-oxygenators for blood, and cryogenically cooled magnets. The Laboratory has also delivered to other laboratories of the Institute during the last year about 300,000 liters of liquid nitrogen and 20,000 liters of liquid helium for research work. Professor Joseph L. Smith, Jr., is participating more in the work of the Cryogenic Laboratory and expects in the next years to make this a principal area of his research.

Professor Tau-Yi Toong has begun the investigation of electromagnetic effects in the dynamics of chemically reacting gases, with current emphasis on studies of propagation of flames and detonation waves in electric and magnetic fields. Recent experiments have demonstrated the significant effect in flames, and related theoretical studies have also indicated possible interactions between chemical and electromagnetic effects. Considerable progress has been made in the study of the basic mechanism of self-sustained flame oscillations. As these oscillations were found experimentally to bear an important effect on the initiation of high frequency acoustic oscillations in a combustion chamber, a better understanding of their mechanism might lead to a practical engineering solution to the problem of combustion instability.

Professor Augustus R. Rogowski, in the Sloan Laboratory, has continued research work in the effects of air motion, chamber size, and geometry on the combustion of fuel sprays both inside and outside of engines and on the combustion of pre-mixed charges, using unique equipment designed by the staff of the Sloan Laboratory. Work is also continuing on the problem of general turbulence measurement in a gas which is otherwise stationary.

Professor August L. Hesselschwerdt operates the Refrigeration and Air Conditioning Laboratory primarily as a teaching laboratory to serve mechanical engineering, nutrition, food science and technology, and architecture. There are two projects in operation at the present time: one on the processing and storing of shellfish involving the chemical, physicochemical, and physical studies of the protein and fat components of selected shellfish stored at various temperatures; and another on the heat transfer from humid air which is an analytical and experimental investigation of the effects of condensation on heat transfer from humid air to develop methods of predicting the "wet" performance of air-cooled heat exchangers.

Information Systems. Research has been continuing in the development of techniques and devices for the automated storage and retrieval of scientific information. During the past year data input techniques for storage of coded information on 4 x 5-inch photographic plates have been developed and tested. Retrieval of the coded information has been previously demonstrated at rates exceeding 10^6 words per second.

The phase of the scientific-information storage program related to the "reading" or encoding of printed information into binary coded information has also made significant progress. A prototype character-recognition machine was built and tested on printed numeric characters. A full-scale reading machine for all printed texts is now being designed. The next year should see the completion of the character detection portion of the machine.

Bio-Engineering. The Department has a continually growing interest in engineering problems relating to human physiology, psychology, and therapy. The work on sensory and prosthetic aids under the sponsorship of the Office of Vocational Rehabilitation, Department of Health, Education and Welfare, is conducted by Professors Mann, Sheridan, and Baumann. Professor Mann has been concerned with a scheme to augment greatly the availability of Braille to the blind by taking advantage of the encoding process associated with ink-print publishing by acquiring the type-compositor tapes. Under such a system, with suitable error correction and translation, all type print now available to the sighted could be made available to the blind without the intercession of the human who reads and understands the printed page and translates it into the appropriate Braille symbolism. Braille-encoded material available from such type-compositor tape systems could be published as standard embossed paper Braille. However, Professor Mann proposes the dissemination of this material directly to the blind in a manner which reduces the expense and the delay in embossing Braille and avoids the serious storage and handling problems associated with embossed Braille material. Several mechanical Braille transducers have been devised whose input is punched tape and which presents to the fingers of the blind pinheads or small ball-bearings in much the same fashion and with the same tactile sensation as in embossed-paper Braille. Such continuous tactile displays will be useful not only as an output for this over-all information handling system, but also in studies being undertaken to simplify and enhance the computer-interpretability of contracted Braille forms.

The Braille-transducer will be used in psychophysical tests to determine the acceptability to the blind of these encoding changes.

An electric Braille typewriter is being designed for use as a computer output—a punched-paper-tape-to-Braille translater, a proofreading aid for blind typists, a standard-typewriter-keyboard-to-Braille converter, and a producer of zinc Braille masters for multiple production—or as a standard Brailler. The first prototype has been entirely designed and about half of the more than 300 parts have been made or procured. The Brailler will operate at electric typewriter speeds without the requirement of a time delay for a carriage return. This is accomplished by arranging multiple heads on a chain similar to the chain printer technique used on computer print-out devices. Upon completion of the prototype the necessary design changes will be made and the drawings will be made available to an organization or agency that is able to carry out the production and distribution plans of the electric Brailler project.

The audio-vis probe project is continuing with the development of small tactile stimulators. A prototype of a low-energy solenoid-type stimulator has been designed and built. The completed probe will enable a blinded individual to track visual patterns by the tactile presentation of the intensity gradient of reflected light.

Another sensory aid project now underway is a study of the possible means of simplifying the rules for contracted Braille so that it can be learned more easily and have a more direct mechanical translation from typewritten inputs.

The faculty engaged in the prosthetics and orthotics field have made a systematic study of the energy and power requirements for upper-extremity amputees of various degrees and have considered the various energy storage and conversion techniques applicable to the external powering of prostheses.

Other bio-engineering projects include the work by Professor Chato and his students on the development of a refrigerated brain probe in connection with his consulting work at the Massachusetts General Hospital. This work includes the pump-oxygenator for blood in the Cryogenic Engineering Laboratory.

STAFF

The Department has been fortunate this year in having three visiting Associate Professors. Dr. George W. Sutton from the General Electric Company's Missile and Space Vehicle Department has participated in the teaching and research in the general field of plasmas and magnetohydrodynamics; Dr. Arthur T. Murphy, head of the Mechanical Engineering Department at the University of Wichita, has participated in teaching and research in the field of mechanics; and Dr. Joseph K. Royle from the University of Manchester has participated in the teaching of fluid mechanics.

The Department had three Sloan Foreign Postdoctoral Fellows of the School for Advanced Study—Dr. G. Anthony Jameson from Cambridge University and Dr. Wojciech A. Szczepinski from Warsaw Technical University, both of whom worked with Professor Jacob P. Den Hartog; and Dr. Yves G. Jullien from the Centre National de la Recherche Scientifique, who worked with Professor Crandall.

There were five Guests of the Institute in the Department last year: Dr. Charles L. Brown from Purdue University worked with Professor Keenan; Dr. Herbert Heitland of the University of Aachen spent three months working in the Internal Combustion Engines Laboratory; Dr. Samuel R. Maloof from Avco Corporation was with Professor Orowan; Dr. Jerzy Rutkowski from the Warsaw Technical University arrived in March to spend one year working in the Internal Combustion Engines Laboratory; and Dr. Fedor V. Sedykin from the Mechanical Institute of Tula, U.S.S.R., worked with Professor Cook.

Professor Robert E. Stickney, who obtained his Ph.D. at the University of California, Berkeley, joined the Department last year.

Professor James Fay has been on leave of absence during this year working at the Everett Research Laboratory of Avco Corporation in his field of magnetohydrodynamics. Professor Maurice E. Shank has continued his leave to serve as Director of Advanced Materials Research and Development for the Pratt and Whitney Division of United Aircraft Corporation. Just as this report is written we regretfully learn of his resignation from M.I.T.

Professor John C. Chato has returned from a leave of absence spent at the Institut fur Warmetechnik und Verbrennungsmotoren at the Technische Hochschule, Aachen, Germany.

Professor S. William Gouse has returned from leave of absence serving on active duty with the army. Professor Prescott A. Smith returned from a nine-months' leave of absence during which he made an industrial study for the National Council of Applied Economic Research in New Delhi under the auspices of the Center for International Studies. Professor Peter Griffith returned from a year's leave of absence spent at Cambridge University.

Professor Norman C. Dahl has left for a several-year period to lead the American effort to aid the development of the Indian Institute of Technology at Kanpur, India. His absence from the Department places an extra burden on the other faculty members in the field of Applied Mechanics. The importance of this work, however, is recognized by everyone.

Professor Edward R. Schwartz' death, shortly after the beginning of the 1961 Summer Session, saddened his colleagues and friends. Professor Schwartz was an internationally recognized authority in textile engineering and had organized and directed the first graduate program in this field. His students occupy many of the key positions in textile research throughout this country, and his ideas on the basic engineering problems confronting the textile industry have received wide acceptance.

This year Professor James Holt, our Executive Officer, and Professor Carl L. Svenson have reached retirement age. Most of Professor Holt's career has been spent in the Department at M.I.T. following his graduation from M.I.T. and Harvard in 1919. Professor Svenson began the same year and has served in the Department throughout the same period, and was also active as Chaiman of the Committee on Academic Performance. Both of these men will be sorely missed by the Department, though we will continue to have their services as part-time lecturers.

Finally, one more staff matter: My first year as Head of the Department, following in the footsteps of such mechanical engineering giants (who are also my close personal friends) as Professors Joseph Keenan, Jacob Den Hartog, Richard Soderberg and Jerome Hunsaker—has been a busy and stimulating one. The Department inherits strength from a distinguished past and is moving rapidly into the new era of engineering teaching and research.

H. GUYFORD STEVER

Department of Metallurgy

This year the first group of students, comprising about half the seniors in the Department, graduated in the new Materials Science Course III-B. Development of the new subjects of instruction which were instituted for the benefit of this group but which were also shared by the students in Metallurgy has proceeded with vigor. The two subjects, Materials Science I and II (3.31 and 3.51), have proved to be popular not only with students in the Materials Science option but also with those in Metallurgy and with a considerable number from other departments.

The teaching of materials science was discussed among a group of educators meeting under the sponsorship of the American Society for Metals and the Metallurgical Society of A.I.M.E. at M.I.T. in April. On that occasion Professors David A. Thomas and John T. Norton discussed the course content and laboratory activities of Materials Science I and II. Comparison with reports from other institutions indicates that our presentation is farther advanced than most; the general reaction of the assembled metallurgical educators was quite favorable.

The success of Materials Science I (3.31) has led to revision in Physical Metallurgy (3.32). Professors Morris Cohen and Thomas have been busily engaged in devising new and more elaborate laboratory experiments which take the form of small research projects with considerable emphasis on proper report writing. Similar success in Materials Science II (3.51) is demonstrated in Professor John Norton's report of great interest in experimental work, which includes long unscheduled hours spent by students in the laboratory.

The first semester's work in Materials Science has proved to be appropriate preparation for further study in the field of ceramics. Thus the Department, which has for many years had an active program of graduate study in ceramics, now finds itself able to offer instruction also to the undergraduate. An excellent undergraduate program in this field can be found in Professor Alfred R. Cooper's subject, Ceramics and Ceramic Processes, and Professor William D. Kingery's subject, Physical Ceramics, which emphasizes the relationship of structures to thermal, electrical, and mechanical properties of nonmetallic materials.

Substantial revisions are still being made in instruction in Engineering Materials (3.14). Under the direction of Professor John Wulff, this subject has been developed to fill the needs of students from engineering departments other than metallurgy and to offer them the same general kind of instruction that students in Metallurgy or Materials Science find in 3.31. A new text for use in this subject is well on its way toward completion. New experiments have been added in the laboratory to improve the demonstrations of relationships between structures and properties in materials as diverse as high-carbon steel, polyethylene, and building brick. Collaborating with Professor Wulff in this enterprise are Professors George W. Pearsall and Robert M. Rose of this Department, Professors Frederick J. McGarry and Rodney D. Andrews of civil engineering, Professor James W. Mar of aeronautics, and Professor John Blair of electrical engineering.

All of the developments in materials science and engineering curricula, particularly in laboratory instruction, have been generously supported by grants from the Ford Foundation. Refurbishing and re-equipment of laboratories, in particular, would not have been possible without such support.

Other activities supported by Ford funds have been the work of three Ford Postdoctoral Fellows: Professor Thomas R. Clevenger, Dr. William G. Moffatt, and Professor Rose. These staff members have been able to pursue research and teaching activities with considerable freedom and financial security, prior to embarking on planned teaching careers. Professor Clevenger spent the summer and a semester's leave of absence in Japan where he worked on electronic bodies and gained much broad experience in the general ceramics field. As a consequence he has been able to revise many of our laboratory experiments to make this part of our instruction more effective.

Professor John F. Elliott has devoted considerable time this year to developing means to broaden and improve our teaching of thermodynamics. One step has been to include the new subject Metallurgical Thermodynamics I (3.00) in the curriculum for the sophomore year. A second step has been an exchange program with the Department of Chemical Engineering in which Professor Clyde M. Adams from metallurgy assisted in presenting Chemical Engineering Thermodynamics (10.13), and Professor Joseph L. Smith from chemical engineering assisted in Metallurgical Thermodynamics II (3.20). The purpose of the exchange is to find common areas of interest in the subject and to exchange ideas on teaching methods.

Professor Wulff's freshman subject, Structure of Materials (3.09), has continued to attract freshmen who look for an insight into the basis of engineering. This has also been supported by the Ford grant.

The Laboratory for Materials Processing has expanded under the guidance of Professor Merton C. Flemings, and this year saw its first formal use as part of the Materials Science curriculum.

Many graduate students in metallurgy have displayed a strong interest in teaching. Over the years an impressive number have realized their ambition to teach. Now Ford predoctoral fellowships are making it possible for five graduate students with family responsibilities to earn their doctorates and prepare for teaching careers.

Space changes have been completed—at least temporarily—by the reorganization of part of the fourth floor of Building 35 which houses the welding, joining, and heat-treatment laboratories. These facilities are now among the most up-to-date in the country, due largely to Ford Foundation support and generous gifts of equipment from the Linde Corporation.

This year for the first time a prize made possible by a gift from the Dow Chemical Company was offered for the best senior theses in the Department. Award winners were George F. Hurley, first prize, and John C. McCloskey.

RESEARCH ACTIVITIES

All members of the departmental faculty continue their active interest and participation in research. Graduate student enrollment in the Department this year totalled 156, all of whom took part in research activities, and in addition some 22 postdoctoral workers participated in the research effort of the Department. Research activity also includes all the seniors in the Department who spend a significant fraction of their final year in solving an individually assigned research problem. This year's research activity extended also to freshmen who were invited into the laboratories through the Institute's Undergraduate Seminar program. The Department of Metallurgy attracted 30 freshmen to its seminars, and all members of the faculty who came in contact with these students have reported most favorably upon the results. This innovation is one which fits very well into the research and teaching effort of the Department, and many members of the faculty are eager to continue it.

Professors Nicolas J. Grant and Arthur W. Mullendore have been working for some years on the properties of metals at very high temperatures. With the aid of an active group of graduate students, they have succeeded in raising the recrystallization temperature of metals and alloys (the recrystallization temperature is a measure of the stability of a crystalline material) to 0.90 to 0.97 of the absolute melting temperatures. This is done by means of a finely dispersed insoluble oxide. (Pure metals recrystallize at about 0.2 to 0.3 of the absolute melting temperature.) In line with this performance, these same metal-metal oxide alloys are stronger than the usual alloyed systems by large margins at temperatures of 0.5 to 0.7 of the absolute melting temperature.

Research on heat effects in molten metals has been carried on in two separate laboratories of the Department. Professor Elliott's recently completed calorimeter has been used to measure successfully the heats of mixing of nickel and of tin with molten copper at 1200° C. Projected temperatures as high as 1600° C will include studies of molten nickel and molten iron. Professor Michael B. Bever's work at somewhat lower temperatures, using liquid tin, has been aimed at determinations of the heats of formation of alloys and intermetallic compounds and at measurements of the stored energy of cold work in metals. This latter program has included the effects of cold deformation at temperatures as low as 4° absolute where a considerable fraction of the energy of deformation remains stored in the deformed piece.

Research on the superconductivity of metals and alloys at low temperatures has been vigorously pursued by Professors Wulff, Pearsall, and Rose. With support from A.R.P.A., the National Science Foundation, and the Office of Ordnance Research, they have built up a laboratory and are actively engaged with seven graduate students in studying the relationships between superconductivity and the structure of metals, alloys, and compounds. Equipment for vacuum melting and annealing of small ingots and processing them to wire by swaging and drawing has been developed, as well as low-temperature equipment for measurements in strong magnetic fields. This group has succeeded in developing a solid-solution type alloy possessing excellent superconducting properties and having a value of the critical magnetic field strength some 20 kilogauss in excess of that of earlier alloys. An additional advantage is that the new alloy is much more ductile than the intermetallic compound alloys investigated elsewhere. Direct verification has been obtained of the strong influence of structural defects on superconductivity, and the importance of relating features of metallurgical structure to electrical behavior has become evident.

Studies of self-diffusion in alpha iron during compression creep by Professors Cohen and Benjamin L. Averbach, and Dr. Ken-Ichi Hirano have shown that the self-diffusion coefficient during plastic flow can be increased by large factors; the increase in diffusivity is proportional to the strain rate and is accentuated at lower temperatures. Diffusion coefficients which are 3000 times the normal diffusivity have been observed at high strain rates and low temperatures. This effect has been interpreted as arising from the generation of excess vacancies during the deformation, and the resultant lifetimes of the vacancies are of the order of one second at 800° C.

Professors Cohen and Averbach, with Dr. Roy Kaplow who will be with us next year as Assistant Professor and Ford Foundation Fellow, have studied the structure of liquids by means of x-ray and neutron diffraction. They have shown that the characteristic association between gold and tin atoms in the compound AuSn is retained in the liquid. Considerable local structure is observed in the liquid, and atomic correlations appear to extend for several atomic shells.

Professor Backofen and his graduate students are developing a concept of texture hardening, a new and basically different approach to materials strengthening. There are excellent indications, from preliminary work carried out in a doctoral thesis, that this technique may allow remarkable strength increases in anisotropic materials under the practically important conditions of combined-stress loading. The essential consideration is development of proper crystallographic texture. A number of the newer metals and alloys—including titanium, zirconium, and beryllium—as well as some much more widely used steels are good candidates for such hardening. Useful implications for thin-section highly-stressed devices such as pressure vessels and space vehicles are very clear.

A new process for sorting copper ore has been evolved by Professor Antoine M. Gaudin and Dr. Harald Ramdohr. This process depends on preliminary irradiation in a neutron field and represents a totally new development for ore sorting.

Work on the chemistry and physics of surfaces has been in progress for some years. In a cooperative program Professor Philip L. de Bruyn, and Professor Alan S. Michaels of the Department of Chemical Engineering have been teaching a new subject entitled Physics and Chemistry of Surfaces. Its evident success will warrant its continuance. Professor Gaudin and Dr. August Witt (a Research Associate who will be an Assistant Professor next year) have been studying the behavior of contact angles at the junctions of solid, liquid, and gas phases. They have made marked advances in understanding the factors affecting the hitherto mysterious hysteresis of the angle which results when the line of contact is moved over the solid surface. This is an important aspect of the wetting of minerals and other solids; its elucidation will be of considerable interest not only with respect to the flotation of minerals but to other phenomena as well. In line with the wide interest in surface phenomena, the colloquium series of the year was organized by Professor de Bruyn around this major topic, including the Robert S. Williams Lectures by Professor Nicolas Cabrera of the University of Virginia.

Professor Adams has been engaged in a program of electron beam processing. One interesting application consists of the vacuum deposition of metallic and nonmetallic structures. Evaporation and condensation in vacuum can be performed at rates high enough to be of interest in generating void-free structural shapes. Techniques have been successfully addressed to beryllium, tungsten, high-melting oxides, and other pure materials which are difficult to shape by conventional means. Deposition rates of the order of 0.001 inch per minute are not unusual. By using microprobe sources, alloys, unstable compounds, and mechanical mixtures have also been deposited. The process is now being adapted to dispersion-hardened combinations such as nickel with aluminum oxide. Deposition also offers some potential as a technique for joining.

A second application is found in the melting of highly refractory metals and casting into a cold mold. Cold-mold melting procedures have been evolved for preparation of refractory alloy ingots, including superconductors, which represent a substantial advance over the conventional arc or electron beam drip melting and accommodate larger sizes than are feasible in floating zone refining. The process combines very rapid freezing with zone levelling to produce a high degree of homogeneity and can be adapted to direct casting of simple shapes.

Professor Adams' program on solidification and hydrate crystallization from aqueous solutions is being expanded with the joint support of the Koppers Company and the Office of Saline Water of the Department of the Interior. Details of crystallization kinetics, particularly factors which govern the size and growth rate of individual crystals, have been clarified to the extent that substantial improvement in processing schemes for desalination of sea water are contemplated.

Planning for the new Center of Materials Science and Engineering has continued. Professor Grant serves on the steering committee while Professors Thomas B. King and Kingery are concerned, respectively, with analytical facilities and the laboratory for materials preparation. New equipment has included a Hitachi electron microscope which supplements the overworked Siemens instrument.

An international conference on the Physical Chemistry and Technology of Steelmaking was held at Endicott House during June, with representatives from ten countries present. Professors John Chipman, Elliott, Grant, King, and Venkatachari Ramakrishna as well as many alumni of the Department participated.

Professor Cyril S. Smith, distinguished metallurgist and historian formerly with the University of Chicago, joined the M.I.T. faculty as Institute Professor. Continuing his interest in the history of metallurgy, he will be associated with both the Department of Humanities and of Metallurgy. His recent book, *The History of Metallography,* was awarded the Pfizer Prize of the History of Science Society as the best book of the year in the Society's field.

We record with deep sorrow the passing of Professor Howard F. Taylor on January 16, 1962, and of Professor Emeritus Robert S. Williams, former head of the Department, on December 11, 1961.

JOHN CHIPMAN

Department of Naval Architecture and Marine Engineering

The primary theme of the Department has been the design and construction of marine craft and their components for naval, commercial, pleasure, and scientific research usage. This theme over the years has proved to be a powerful motivating force for faculty and students alike in their education, research, and professional activities in the world at large.

There is no intention to change this motivating central theme of the Department. That does not mean that the Department will not present challenging and new creative professional activities for all participants—faculty and students alike. There are many opportunities in naval architecture and marine engineering today. The ocean medium is a frontier for scientific research. We are learning more about the conditions of the surface of the sea including ice coverage and wave properties, as well as the conditions underneath the sea. Ship designers today are using new knowledge to enlarge the region of ship operation—in the arctic regions, for example, beneath the surface, and above the sea in the form of hydrofoil boats and ground-effect machines. The demands for increased performance of naval ships, for increased economy in commercial ships, and for new research craft for oceanographers and other scientists interested in the sea are all stimulating changes in our field. Several technologies—underwater physics, systems analysis, design, control, and energy conversion—are providing new opportunities for the naval architect and marine engineer. There is plenty of opportunity for our faculty and students for research and development in systems and complementary problems of naval architecture and marine engineering which embrace the most challenging of recent science and engineering fields.

CURRICULA AND ENROLLMENT

The major changes instituted in the undergraduate curriculum have now been in operation for a full year, and, in general, have proved very effective. The undergraduate curriculum program is based on the core of four substantial subjects with content unique to but not limited to naval architecture and marine engineering. These subjects are Principles of Naval Architecture (13.00), Ship Structural Analysis and Design (13.10), Energy Conversion Systems and Components (13.20), and Introductory Ship Design (13.40). The consolidation of undergraduate subjects has been made possible by heavy deletion of descriptive, drawing room, and computational material. These core subject requirements, when added to the General Institute Requirements of science, engineering, and humanities, leave to each student the election of six to eight subjects which can be used under effective faculty guidance to increase competence in general naval architecture and marine engineering or in some special discipline in the related component fields.

While not part of the Department's regular undergraduate curriculum, Professors Martin A. Abkowitz, Justin E. Kerwin, and S. Curtis Powell have had a group of freshmen occupied in the Ship Model Towing Tank and the Propellor Tunnel as part of the Undergraduate Seminar program. Ten students were enrolled in the first term this year and six in the second; most of them initially had no orientation toward naval architecture and marine engineering as a career. It appears that this program is successful academically, and we believe that, as a by-product, the concept of stimulating work in naval architecture and marine engineering has been enhanced. The enrollment in the freshman seminar together with the fourteen other undergraduates in the Department has made it a lively undergraduate year.

Graduate enrollment in Naval Architecture and Marine Engineering (Course XIII) was roughly constant at twenty-five though the enrollment in Naval Construction and Engineering (Course XIII-A) decreased somewhat. A renewed effort by the U. S. Navy, U. S. Coast Guard, and foreign navies, aided greatly by Captain Edward S. Arentzen, U.S.N., Professor of Naval Construction, has resulted in a substantial increase of highly qualified and motivated students in Course XIII-A for next year. Twenty-six students have reported for their summer program, compared to the current year's enrollment of sixteen.

The U. S. Coast Guard has agreed with the Department faculty upon a two-year master's program which will permit the Coast Guard, under limited budget and personnel ceilings, to educate more officers than has been possible in the past when all who were assigned as students to M.I.T. have taken the three-year engineer degree program. It is expected that some of the outstanding students from the two-year master's program can be transferred to Course XIII-A during the first year so that they may have the benefit of the three-year engineer degree.

The curriculum for Course XIII-A has undergone many modifications in the past four years. Some of these resulted from changes in subjects conducted at the Institute, and others were occasioned by a review by the Navy Bureau of Ships of the technical needs of its future officers. There are now four specialties: hull design and construction, marine electrical engineering (power and control), electronic engineering, and ship propulsion.

Dr. Donald Ross of Bolt, Beranek, and Newman, Inc., has served this year as a Visiting Lecturer, conducting Hydroacoustics (13.95) during the first term. The subject was extremely well received, and arrangements have been made for continuing the subject on a similar basis during the first term of the next year.

SEMINARS

This year the very successful seminar program which was started a year ago has been continued under the direction of Professor Evans.

The program included nineteen seminars which ranged over a wide variety of subjects presented by authorities in their respective fields. They covered subjects very closely connected with the fields of naval architecture and marine engineering, such as ship motion, propulsion, and structures, as well as a number of areas which are becoming increasingly important in the field. The latter included various aspects of undersea exploration and navigation and a consideration of the properties of sea ice. The success of the series over the past two years insures its continuance, possibly on a more formal basis.

RESEARCH AND RESEARCH FACILITIES

This has been a very active year in research. The space occupied by the Propeller Tunnel underwent substantial rearrangement in connection with the establishment of the Engineering Projects Laboratory; the net result has been a more effective logical grouping of activities in this laboratory. There has been considerable progress on Professor Frank M. Lewis' investigation of the force reactions between propellers and adjacent strut and rudder configurations. In addition, industrial assistance has made possible a major contribution to the art of propeller application in correcting service deficiencies and the design for a supertanker.

In the Ship Model Towing Tank, the new carriage rail system has been completed and has been in use during the last term, even before final adjustments on the main rail and speed control were made. This facility has already improved, expanded, and provided more flexibility in the research and thesis work that can be conducted in this facility. The Department is extremely pleased with the carriage design, which was carried out under the direction of Professors Abkowitz and Kerwin and supported by gifts from companies represented by members of the Visiting Committee, from the Ford Foundation, and from the National Science Foundation, as well as by M.I.T. general funds.

Another high point has been the initiation of a large contract with the Maritime Administration of the U. S. Department of Commerce for continuing research on the seakeeping qualities of ships, one of four such contracts awarded to academic institutions. A large number of the Department's academic staff and some graduate students will be involved. These include Professors Abkowitz, Evans, Philip Mandel, Powell, and Kerwin. Already this work has involved the addition to the Towing Tank of equipment to produce irregular seas and vibratory spectra through automatic program controls on the wave generator. Instrumentation has been added to record simultaneously the many variables occurring during seakeeping tests, in order to study correlations.

Other research activities include the work under Professor Mandel on separated flows in water and the investigation of control and stabilization of semi-submerged ships. Another of Professor Mandel's activities, although not conducted within the Department, deserves notice in recording our research. He served on a subcommittee of the National Academy of Sciences which has conducted an appraisal of novel ship types. The work resulted in several papers and seminars by Professor Mandel and has attracted considerable attention within the profession.

MUSEUM AND TELEVISION PROGRAM

The Francis Russell Hart Nautical Museum continues to attract a substantial number of visitors and requests for loans of models and material from the Kerreshoff and Paine collections. An interesting addition to the memorabilia is a collection of nautical books from Ernest E. Calkins.

The museum also figured in a very important activity of the Department—the making of a half-hour television movie entitled "Something New Under the Sea," a companion film to one made at the Portsmouth Naval Shipyard. This was made at the request of WGBH, the educational television station in Boston, and has been shown during May through July, 1962, in Boston, Washington, Pittsburgh, Chicago, Buffalo, San Francisco, and Dallas. Captain Arentzen acted as the Department's representative in putting this film together. The film centers around the theme of new designs and demonstrates education at M.I.T. by showing the work of the graduate students and naval officers in Course XIII-A, the Ship Model Towing Tank research facilities, and the museum. Professor Gordon S. Brown, Dean of Engineering, Captain Arentzen, Professors Evans and Abkowitz, and several graduate students were featured in the movie. We believe that copies of this movie can be of great use to the Department and to the profession as a whole in bringing the challenge of naval architecture and marine engineering to uninitiated young men.

STAFF

Professor Evans continues to serve as Executive Officer. His heavy duties in this capacity together with his professional work in structures will in part be alleviated next year by the expected arrival of Professor John B. Caldwell of the Royal Naval College, Greenwich, England. Dr. Caldwell has a one-year appointment as a Visiting Assistant Professor of Naval Architecture.

Professor Jacob P. Den Hartog of the Department of Mechanical Engineering, who has assumed one of Professor Lewis' subjects in vibration, was appointed at the end of the academic year to the Professorship of Mechanical Engineering jointly in the Departments of Naval Architecture and Marine Engineering and of Mechanical Engineering. Professor Philip Mandel has returned from leave of absence where he served as a professional consultant to the Panel on Naval Vehicles of the Committee on Undersea Warfare, National Academy of Sciences–National Research Council. Professor Abkowitz has been invited to be a Visiting Professor at the Technical University of Denmark during the year 1962-63 and has received a Fulbright Award for lecturing abroad. The Department will miss him next year, but this broadening experience will add great interest to his work.

It is noteworthy that, in addition to the awards to members of our faculty listed elsewhere in this report, two alumni, Lieutenant William E. Lehr, Jr., U.S.C.G., and Lieutenant Edwin L. Parker, U.S.C.G., received the Vice Admiral Edward L. Cochrane Award–completing a sweep by M.I.T. faculty and alumni of principal awards of the Society of Naval Architects and Marine Engineers.

I have now completed my first year as Head of the Department, together with my similar assignment in the Department of Mechanical Engineering. I have found the faculty, the students, and the program of research and teaching in the Department very stimulating.

H. GUYFORD STEVER

Department of Nuclear Engineering

The Department of Nuclear Engineering has continued to concentrate its attention on the two principal nuclear reactions of present practical interest, fission and fusion. Fission reactor technology has advanced to the point that we can foresee the cost of power from nuclear reactors to be as low as that from conventional fuels in new, large, central power stations. Knowledge of fusion is less advanced; the central problem of providing stable confinement of a deuterium-tritium plasma at a temperature and density high enough to support a self-sustaining fusion reaction has yet to be solved. Nevertheless, research on the production and confinement of plasmas is disclosing much interesting and valuable information on the properties of plasmas. Investigation of the problems of fission and fusion reactors is giving the Department many fine opportunities to provide graduate-level education in engineering physics and allied subjects.

During the past year, enrollment of graduate students reached a new high of 124. Registration is expected to level off around this figure; even though additional properly qualified students apply for admission, the number that can be accepted is limited by the funds available for research assistantships and fellowships. Thirty-five of the Department's students were supported by Atomic Energy Commission Fellowships in Nuclear Science and Engineering; this is out of a total of 157 fellowships awarded throughout the nation by the A.E.C.

The number of doctoral candidates recommended by the Department reached eleven, also a new high; thirty-three students received the Master's degree in nuclear engineering. Our graduates in nuclear engineering are playing an increasingly responsible role in the development of nuclear technology in the United States and abroad, in industry, government, and universities.

INSTRUCTION

Under the leadership of Professor David J. Rose, the thermonuclear process option of the master's program was broadened by the addition of two new subjects, Engineering Physics of Plasma and Particle Devices, offered by this Department, and Plasma Dynamics Laboratory, offered by the Department of Electrical Engineering. In addition, Professor Thomas H. Dupree introduced another new subject, Plasma Kinetic Theory, to round out the Department's curriculum in the fusion field.

The fission technology curriculum was augmented by Professor Edward A. Mason's introduction of a new subject, Nuclear Reactor Design. This subject combines development of the principles of reactor design with application to a specific reactor design project. A gas-cooled reactor for rocket propulsion was the first design project undertaken.

M.I.T. REACTOR

Under Professor Theos J. Thompson's able direction, the M.I.T. Reactor has been in operation at a power level of two megawatts twenty-four hours per day on a five-days-per-week schedule for the entire past year. During this time more megawatt-hours of operation were logged than in the previous three years. About 85 irradiations per month are being conducted for hospitals and medical research groups in New England and about the same number again for general research users.

With funds for reactor improvements received from the National Science Foundation, installation of piping and equipment to permit operation of the Reactor at its full design capacity of five megawatts is being completed. The actual increase in power to this level must await approval of the Atomic Energy Commission.

During the past year four additional major experiments were activated, including the organic loop under Professor Mason, a gamma ray spectrometer under Professor Norman C. Rasmussen, a triple coincidence gamma ray spectrometer under Professors Rasmussen and Thompson, and a neutron spectrometer under Professor Clifford Shull of the Department of Physics. In addition, a number of other experimental facilities have been installed and their use augmented. The reactor continues to have a sufficient volume of contract research to defray its direct operating costs and its share of M.I.T. overhead, but the volume is still not sufficient to permit building up a reserve for major repairs or unanticipated down time.

The M.I.T. Reactor continues to serve as a uniquely valuable facility for research and education. As one example, graduates of M.I.T. who have gained experience with our reactor are taking responsible positions on the operating staffs of a number of reactors elsewhere in the world.

RESEARCH

During the past year, tangible results have begun to flow from the M.I.T. Reactor Lattice Project, one of the major research projects made possible by the M.I.T. Reactor. This project is directed by Professors Irving Kaplan and Thompson and supported by the U.S. Atomic Energy Commission. Initial experiments, on heavy-water moderated natural uranium lattices, have been completed. Results of previous experiments elsewhere have been confirmed, and a number of previously unobserved phenomena which add to knowledge of reactor physics have been observed. Five major A.E.C. reports, based on doctoral thesis research, have been issued, and a paper was presented to the Brookhaven International Conference on Neutron Thermalization. Research continues on various experimental and theoretical problems in the physics of lattices of slightly enriched uranium rods in heavy water. A pulsed-neutron source has been put into operation, initially independent of the Lattice Project. Later it will be operated in conjunction with lattice assembly.

Under the direction of surgeons from the Massachusetts General Hospital and with the collaboration of Professor Gordon L. Brownell, the medical therapy facility of the M.I.T. Reactor has been used to treat nineteen patients with glioblastoma brain tumors. The results of these irradiations have not been as successful as desired, and during the past six months, attention has been shifted to basic radiobiological studies using tumor-bearing mice. The object is to determine much more precisely the radiation dose required to destroy tumor tissue and the optimum time of irradiation. Instrumentation to measure the radiation dose during irradiation is being improved.

Under sponsorship of the McDermott Foundation, Professors Brownell and Mason are studying the effect of ionizing radiation on methane. A new irradiation facility for use in the M.I.T. Reactor has been designed and constructed. Initial irradiations of methane have shown the production of a large number of saturated and unsaturated hydrocarbons. The object of the research is to investigate the role naturally-occurring radiation may have played in the formation of petroleum.

Under a grant from the National Science Foundation, Professor Rasmussen has been continuing operation of two bent quartz crystal spectrographs at the Reactor to determine precise energy values for the gamma rays produced by neutron capture. A bent crystal spectrograph has also been used to measure with high accuracy the energies of the gamma rays emitted from a spent reactor fuel element. This technique will have useful applications in determining the composition of spent cores of power reactors. A triple-coincidence pair-spectrometer has been put into operation; this allows studies of the higher energy (2 to 10 Mev.) capture gamma rays.

Valuable results are being secured from the loop in the M.I.T. Reactor for irradiating organic fluids which are being considered as coolants for power reactors. This project is directed by Professor Mason under contract with the U.S. Atomic Energy Commission. The loop was commissioned in August, 1961, and has since been operating satisfactorily 24 hours per day. The stability of the three terphenyl isomers has been found to be equal and constant over extended amounts of absorbed radiation.

Professor Mason and Professor Robert C. Reid of the Chemical Engineering Department are studying the effects of pre-irradiation on solid semiconductor catalysts. Studies of the oxidation of carbon monoxide on a p-type catalyst, cuprous oxide, indicated a relationship between the electron-radiation-induced changes in chemical activity and solid-state properties of the catalyst. Research of a similar nature was initiated on the oxidation of CO by zinc oxide in order to extend the work to an n-type catalyst.

Professors Mason and Reid are also investigating the effect of gamma radiation on the rate and nature of crystal growth from solutions, under sponsorship of the U.S. Atomic Energy Commission. Theories of crystal growth involve the formation and migration of defects on the crystal surface, and this research will study the effect of radiation-induced defects.

Professor Mason and his students have completed a study of the solvent-extraction chemistry of ruthenium, under contract with the Atomic Energy Commission. Further work on the extraction characteristics of niobium by amine extractants from nitrate solutions has been initiated. These are two of the fission-product elements most difficult to separate from uranium after irradiation in nuclear reactors.

With support from the Atomic Energy Commission, Professor Benedict and his students are continuing an experimental study of the rate of base-catalyzed deuterium exchange between water and dissolved hydrogen, a reaction important in a possible process for heavy water production. Under the same auspices a new computer code FUELMOVE for the rapid survey of nuclear reactor fuel cycles has been developed and applied to fuel cycle analysis of a heavy water moderated power reactor. This code is receiving favorable attention by a number of reactor design organizations.

The Department of Nuclear Engineering is beginning to make use of M.I.T.'s 3.5-Mev. Rockefeller Van de Graaff Generator. Professor Rasmussen, Dr. Leon Beghian and Edward Profio are using pulsed fast neutrons from this machine to study the behavior of fast neutrons in subcritical assemblies. The Rockefeller Generator will also be used to study the behavior of 14-Mev. neutrons in proposed fusion reactor blankets, in research directed by Professors Rasmussen and Rose.

Professor Rose has expanded his research on plasmas and the components of potential fusion reactors. A hollow-cathode arc plasma generator is being used to produce plasmas with density exceeding 10^{13} per cubic centimeter, temperature of 1 to 10 electron volts, and fractional ionization over 98 per cent. The diffusion of such a plasma and its interaction with a traveling magnetic mirror field has been investigated both experimentally and theoretically. A new form of instability of such a plasma column has been predicted.

Professor Rose and his students have constructed a superconducting solenoid with a field of 20,000 gauss in 1.5 cubic feet of working volume at room temperature. Methods have been developed for switching in superconducting circuits and for dissipating safely the magnetic energy on quenching of the superconductivity.

Professors Rose and Dupree have developed a general theory for the initial trapping and subsequent scattering loss of ions in a large class of magnetic confining structures; these configurations incorporate field perturbations that are spatially resonant with the orbits of entering ions and can provide a long-time trapping in the structure. The relatively small injected ion current for a controlled fusion experiment working on these principles has been calculated; a low-divergence ion gun and an electron-orbit analogue are being constructed.

The unique combination of talents in the Department in both the plasma and fission reactor fields has made possible a comprehensive study of the problem of nuclear energy recovery from proposed controlled fusion reactors. This study, conducted by Professors Rose and Kaplan and their students, shows that if the plasma can be stably confined, a deuterium-tritium steady-state fusion reactor is feasible; tritium can be successfully regenerated via interaction of the fusion neutrons with lithium.

Professor Dupree has initiated theoretical study of the behavior of high-temperature plasmas, particularly those phenomena associated with the discrete nature of individual particles. It has been possible to obtain solutions to the kinetic equations which furnish relatively simple conceptual understanding of plasma behavior and at the same time are realistic enough to be compared with the results of actual experiments.

Professor Kent F. Hansen has been engaged in a number of theoretical and computer-aided reactor physics research projects. These include power shaping of reactors for nuclear rocket engines, numerical prediction of control-rod worth, Monte Carlo calculation of the fast fission factor, and accelerated multi-group calculation methods.

Professor Henri Fenech is carrying out analytical work on the use of burnable poisons to extend fuel life in power reactors, on determination of optimum procedures for reloading fuel in a nuclear reactor, on procedures for optimization of over-all nuclear plant design, and on a new reactor concept for ship propulsion. Under sponsorship of the East Central Nuclear Group, Professors Fenech and Benedict are directing a broad economic survey of the effects on nuclear power costs resulting from changes in the nuclear fuel prices, reprocessing costs, and interest charges.

Professor Elias P. Gyftopoulos and a number of his students continued their investigations of nuclear reactor dynamics with particular emphasis on nonlinear effects. One of these students completed a detailed theoretical and experimental study of reactor oscillation tests at the National Reactor Testing Station in Idaho.

Professor Gyftopoulos and another group of students are investigating surface and transport phenomena in thermionic converters. This work has led to an interesting theoretical understanding of the basic processes involved in the absorption of metallic molecular films on refractory metal surfaces.

STAFF

A generous grant from the General Electric Foundation has made it possible for M.I.T. to give recognition for noteworthy contributions made to its educational program in nuclear engineering by student assistants. Carlos S. Ribbeck and George C. Theodoridis have received General Electric Awards in Nuclear Engineering for teaching assistants, and Lucien J. Donadieu, John M. Neill, and Dr. Richard E. Skavdahl have received similar awards for research assistants. Each of these awards consists of a citation and a check for $300.

It is with regret that we record the resignation of Professor Melville Clark, Jr., who is leaving M.I.T. in order to devote more of his time to musical acoustics. Since 1955 Professor Clark has been making outstanding contributions to the Department's program of advanced instruction in thermonuclear processes and fission reactor physics. He has inspired and directed some of the most original theoretical research done by our students.

Dr. Massoud T. Simnad, Assistant Chairman of the Metallurgy Department of the General Atomic Division of General Dynamics Corporation, will spend the forthcoming year at M.I.T. as Visiting Professor of Nuclear Materials in the Departments of Metallurgy and Nuclear Engineering. This will be very helpful in furthering M.I.T.'s research in the effect of radiation on nuclear materials.

Two men about to receive doctoral degrees in nuclear engineering will join the faculty as Ford Foundation Postdoctoral Fellows and Assistant Professors. James A. Larrimore, who has been Director of the M.I.T. Engineering Practice School at Oak Ridge, will specialize in fission reactor physics and engineering. Lawrence Lidsky will strengthen the Department's competence in plasma physics and fusion reactor developments. Another man about to receive his doctoral degree, David D. Lanning, has been appointed Assistant Professor and Assistant Director of the M.I.T. Reactor. L. Robert Enstice, who joined the M.I.T. Reactor staff in 1959 after participating in the ship reactor program of the Navy, has replaced Mr. Lanning as Operations Superintendent of the Reactor.

MANSON BENEDICT

Research Laboratory of Electronics

During the past year, faculty and students from eleven academic departments have conducted research on a wide variety of topics in the Research Laboratory of Electronics. The growth of departmental participation from two to eleven during the fifteen years since the Laboratory was established provides evidence that this basic research facility has encouraged the interaction of various technical disciplines. The pattern of operation has, in fact, been used as a model in the establishment of other laboratories and centers.

The activities of the Laboratory fall into three broad categories: general physics and engineering, plasma dynamics, and communication sciences. A few of the technical achievements of the past year are mentioned below.

GENERAL PHYSICS AND ENGINEERING

The research in general physics and engineering includes microwave spectroscopy, optical and infrared masers, radio astronomy, molecular beam studies, nuclear magnetic resonance, microwave electronics, acoustics, and several other topics. New this year, the work in radio astronomy is being conducted by Professors Alan H. Barrett and James W. Graham. A millimeter-wave antenna and receiver are being installed on the roof of the Laboratory and will be used for some experiments, while others will be conducted in collaboration with Lincoln Laboratory. Also new this year is the work on optical and infrared masers being conducted by Professors Charles H. Townes and Ali Javan. The program will emphasize basic physics and new techniques, but it will also make use of the precise measurement capabilities of optical masers in a number of interesting applications.

Professor Louis D. Smullin and Dr. George Fiocco succeeded in detecting the return of an optical maser signal reflected from the moon. This optical moon-bounce was first achieved on May 9, 1962. The cooperation of Lincoln Laboratory contributed to the success of the experiment.

Professor Malcolm W. P. Strandberg has been on leave at Grenoble, France, and in his absence Professor Robert L. Kyhl has continued the study of paramagnetic ions. Of particular interest has been the ground-state configuration of various atoms.

Professor Campbell L. Searle and his students have continued the investigation of stable microwave oscillators using a superconducting lead cavity as the stable element.

Professor William M. Whitney and a graduate student, William A. Jeffers, Jr., have measured the frequency dependence of the absorption of sound in liquid helium at temperatures below 1° K. Their results exhibit a variation with both frequency and temperature which appears to be different from that predicted by any of the existing theories of sound propagation in liquid helium at these low temperatures.

Professor Francis Bitter and Dr. Henry Stroke have contributed to the understanding of nuclear structure through the development of experimental and analytical techniques applicable to the spectroscopy of radioactive atoms. Professor Bitter has also started research on energy and particle flows in low density plasmas.

PLASMA DYNAMICS

The research in plasma dynamics ranges from basic physics to engineering applications such as microwave oscillators and amplifiers, ion propulsion, controlled thermonuclear reactions, and plasma magnetohydrodynamics. Professor David J. Rose and his group have discovered a new class of instabilities in long plasma columns and have evolved a general theory for a new kind of magnetic mirror to contain high-density plasmas.

Professors Sanborn C. Brown and George Bekefi have developed a far-infrared interferometer suitable for operation at electron densities between 10^{14} and 10^{16} per cubic centimeter. This electron concentration, which is of interest in modern high-density plasma research, was not suitably covered by either microwave or optical techniques.

Professors William D. Jackson and John M. Reynolds and their students have continued their studies of incompressible magneto-fluid dynamics and its applications to power generation, pumping, and flow measurement.

During the past year, James R. Melcher and his students have studied the phenomena that occur in electrohydrodynamic systems and have successfully operated EHD wave-type amplifiers and power generators on a laboratory scale. Professor Herbert H. Woodson and his students have continued to study the problems of a-c power generation by novel MHD interactions between flowing plasmas and electrical circuits.

Professor Louis D. Smullin and others have studied the effects of injecting high velocity electron beams into plasmas.

Professor William P. Allis has been asked to serve as Assistant Secretary General for Scientific Affairs of N.A.T.O. during the next two years. During his absence, Professor Sanborn C. Brown will serve as chairman of the Plasma Dynamics Committee.

COMMUNICATION SCIENCES

Investigations of various aspects of communication in both living and man-made systems comprise the activities of the Center for Communication Sciences. The major areas of interest include statistical communication theory, processing and transmission of information, artificial intelligence, speech communication, linguistics, communications biophysics, and neurophysiology.

Professor Yuk-Wing Lee and his graduate students have continued their work on the statistical theory of nonlinear systems. Professor John M. Wozencraft conducted experiments on high data-rate transmission over long telephone lines. Professor David A. Huffman has been studying the synthesis of a class of signals that have applications to communication and radar systems.

Professors Walter A. Rosenblith, Moise H. Goldstein, and William T. Peake and other members of the Communications Biophysics Group have continued their interest in the analysis of biologically significant patterns of activity. During the past year these studies have included work on the coding of sensory stimuli in the activity of single neurons (Dr. Nelson Y. Kiang and Dr. George L. Gerstein), on the electroencephalograms of identical twins, and on the characterization of cursive writing (Professor Murray Eden). Professor William M. Siebert has re-examined existing models for Békésy's data on the dynamic behavior of the cochlear partition and has formulated a promising model of his own. Together with some colleagues from the digital computer group at the Lincoln Laboratory there was organized under N.S.F. sponsorship a three-week training conference on Computer Techniques for Senior Biological Scientists.

Professor Jerome Y. Lettvin is developing a testable hypothesis on the relation between geometry and function in single neurons, and Walter H. Pitts, together with Robert C. Gesteland, has made substantial progress in characterizing the properties of single elements in the olfactory system.

Professor Patrick D. Wall and others have developed methods for distinguishing various skin sensations in relation to the location and quality of the stimulus.

The ninth International Congress of Linguistics, which is expected to attract up to 900 participants, convenes at M.I.T. and Harvard from August 27 to August 31, 1962. The meeting has been organized by Professors Morris Halle and William N. Locke.

In addition to his world-wide lecturing, Professor Roman Jakobson is devoting much of his time to various publications and at the present time has thirty-one in press.

Professor William F. Schreiber and his group are investigating the fundamental properties of image transmission systems with a view toward reduction in the channel capacity required for monochrome and color picture transmission. Another goal is an understanding of the relation between the objective parameters of imaging systems and the subjective reaction of human observers to the output images. The principal tool used is computer simulation; for this purpose, equipment has been built to make computer tapes from pictures and vice versa.

Research on sensory aids under the supervision of Professor Samuel J. Mason has yielded interesting results on shape recognition and on the bit rate achievable by tactile stimulation.

Work has been initiated by Professor Edward Arthurs on parallel computation. Results to date include a theoretical demonstration that computers constructed from "slow" elements may be designed to process information at arbitrarily high rates, and various design techniques have been evolved for achieving this serial-parallel interchange.

The mechanical translation group, headed by Dr. Victor H. Yngve, completed a manual for the COMIT programming system. The manual is now in use at more than a dozen computer installations.

The total number of thesis research projects supported by the Laboratory from its inception at the close of World War II through June, 1962, is slightly more than 1,500. These divide approximately as follows: 300 doctorate, 600 master's, and 600 bachelor's. The number of thesis projects completed during the past year is: 13 doctorate, 38 master's, 17 engineer, and 51 bachelor's. Approximately 110 faculty members participated in the research program of the Laboratory and the total personnel count averaged about 700 during the year.

HENRY J. ZIMMERMANN

School of Humanities and Social Science[1]

A year ago I reported some numbers concerning the size and range of activity of the School of Humanities and Social Science. Since figures of this kind had not been reported for some years at least, they highlighted the extensive growth of the School over the past fifteen years.

No comparable *coup* is possible in this report. All the trends continue favorably but there are no sensational breakthroughs to recount, only quiet processes of consolidation and growth. The numerical changes (indicated in Tables I and II) are modest and are provided more for the record than to make any spectacular new point.

The faculty remains at about the same size. Last year those of faculty rank numbered 91; this year they are 98. Teaching staff below faculty rank numbered 44 a year ago; now they are 46. In the previous year the faculty met 7,982 undergraduates who were registered in one or another of our subjects; this year the number had increased to 8,351, an increment of 4.6 per cent. The yearly load this remains comparable to that of a liberal arts college of some 1,000 students.

A year ago I reported an increase of one-eighth in the undergraduate enrollments of our subjects since 1955-56 and noted that most of this was because undergraduates in science and engineering were electing more of our subjects than the minimum curricular requirements would demand. The trend continued in 1961-62 (Table I).

[1]This is an extensively abridged version of the full report which can be obtained on application to the Dean of the School of Humanities and Social Science.

Table I. Registration in Humanities, Languages, and Social Science Undergraduate Subjects, 1961-62

	Fall Term		Spring Term	
Freshman Core		910		883
Sophomore Core		880[1]		818[1]
History	84		182	
Philosophy	319		298	
Literature	324		321	
Music	144		237	
Total Humanities electives		871		1,038
Economics	635[2]		728[2]	
Political Science	227		182	
Labor Relations	78		75	
Psychology	259		296	
Total Social Science electives		1,199		1,281
Modern Languages[3]		121[4]		202[4]
Visual Arts[5]		86		60
Thesis		3		32
Total		4,070		4,314
Public Speaking		11		6
English Composition		20		8
Humanities Senior Seminar for Course XXI Students		33		29
Science Writing		11		15
Elementary and Intermediate Modern Language		624		386
Grand total		4,769		4,758

[1] Includes registration in special social science core: 184 in fall term, 183 in spring term.
[2] Includes registration in 14.01 (382 in fall term, 367 in spring term) and other subjects (253 in fall term, 361 in spring term).
[3] Exclusive of 1,010 registrants in elementary and intermediate languages.
[4] Includes undergraduates in graduate linguistic subjects.
[5] Taught by faculty of the School of Architecture and Planning.

Table II. Majors in the School of Humanities and Social Science*

	UNDERGRADUATES			GRADUATES			
	Social Science	*Humanities*	*Total*	*Social Science*	*Humanities*	*Total*	*Grand Total*
1955-56[1]	40	19	59	52	—	52	111
1956-57	38	32	70	69	—	69	139
1957-58	41	67	108	74	1[3]	75	183
1958-59[2]	46	75	121	81	1[3]	82	203
1959-60	38	64	102	105	2[3]	107	209
1960-61	35	93	128	114	—	114	242
1961-62[4]	55	88	143	129	7	136	279

* As registered in the second term of each academic year 1955-56 to 1961-62 (omitting freshmen)

[1] Course XXI initiated.
[2] Graduate degree in Political Science initiated.
[3] Special program in teacher training.
[4] Graduate degree in Linguistics initiated.

Table II offers a different measure of growth, as revealed by our undergraduate and graduate major registrations since 1955-56. As before, this does not include freshmen, since many first-year men are not committed to departmental programs and some of the commitments are not firm. It is especially characteristic of the students in our fields that we have many newcomers as late as the junior year. We show second-term registrations because they are more stable.

Undergraduate Majors

Table II shows a steady increase in the number of our undergraduate majors. The 59 of six years ago, of whom 40 were in economics, have increased to 143 divided among economics, political science, and humanities and most of this gain has been due to the introduction of new major offerings. The increase was noticed most sharply at first in the humanities, due in part no doubt to the novelty of the new opportunity afforded by the programs in Humanities and Engineering or Science (Course XXI), but also I am sure because of the energy, imagination, devotion, and singleness of purpose with which Professor Roy Lamson has directed this effort. A year ago I deprecated the fact that though we had admirable undergraduate majors in economics and political science, they did not seem to attract enough students. This year shows a sharp increase in the number of undergraduate majors in the social sciences (60 per cent). The absolute numbers can stand to be much greater. The present total of 55 could legitimately be expanded to 60-75 in each of economics and political science and soon as many in psychology. Thus the present number of 55 in the social sciences, though the largest for years and notably larger than a year ago, could appropriately be multiplied fourfold. Therefore it seems to me appropriate to repeat what I said on this score a year ago: "On the basis of what they offer in the way of preparation for modern life, our social science undergraduate options are underpopulated. They should, if well understood by the M.I.T. students, have registrations that compare favorably with those in humanities. We have an obligation to see to it that they are understood, not only within our walls. The world can use many more economists and political scientists who have a solid understanding of science and engineering"—an understanding which has been rare indeed among social scientists up to now.

POLITICAL SCIENCE

In his first annual report as Chairman of the Political Science Section, Professor Lucian W. Pye says, "In the last few years we have been producing an increasingly impressive group of majors in political science. Some of our best graduate students have come out of our own undergraduate program. Significantly, all of our graduates who have chosen to go on to graduate school or to law school have been admitted to the best institutions in the country. Indeed, these students have done so well in their graduate work that now some of the leading graduate schools are seeking out our graduates.

"The character of our undergraduate political science majors has been changing in recent years. We still have a few students who come to us because they have made a mistake in believing that they had an aptitude for work in the physical sciences or in engineering. More recently, however, the majority of those concentrating in political science are men who have done superior work, mainly in physics and mathematics, and who could clearly have had fruitful careers in the physical sciences, but who have found that they prefer the kinds of intellectual or human problems basic to the social sciences. It is our expectation that some of these students who are well grounded in scientific procedures and who have an imaginative command of mathematical manipulations will in time move rapidly to the forefront of those who are innovating new methods in the social sciences.

"We might observe here that in the past many of the people who have come to the social sciences from earlier training in the physical sciences or in mathematics have not always been able to make creative contributions to knowledge. Indeed, many became mere technicians capable only of handling the data relevant to problems conceived by others. No doubt this was largely because they were men who lacked the creative spark and would not have been effective scientists even if they had remained in the physical sciences. This pattern will clearly be broken as we get a higher calibre of man who is creative in a scientific sense."

PSYCHOLOGY

At the present stage of its development, the central concern of the Psychology Section has appropriately been the building of a new and stronger faculty, the developing of a research program, and the beginning of graduate instruction. Up to now these concerns, and the maintenance of a modest program of good general undergraduate courses for all M.I.T. students who elected them, have been all the faculty of psychology could manage; and even this has often tested their energies and loyalties. But the future must be different. Of this, Professor Hans-Lukas Teuber, Chairman of the Psychology Section, has the following to say: "Our concern with the development of a graduate curriculum has not detracted from an equally active reconsideration of undergraduate teaching. Even if we had permitted ourselves to be distracted, the undergraduates themselves would have brought our attention back to these questions by their insistent and increasingly pressing inquiries about the prospects for an undergraduate 'major' in psychology. A decision in this matter will probably have to be reached sometime in the coming year."

The question Professor Teuber raises about undergraduate majors in psychology can, it seems to me, have only one answer in the long run. We must have undergraduate majors in psychology as soon as we can do it without prejudicing on the one hand the burgeoning graduate program or on the other our obligations to offer some experience in psychology to M.I.T. undergraduates whose major interest lies elsewhere.

ECONOMICS

The undergraduate majors in economics remain small in number, and I sense nothing to suggest that our eminent faculty of economists has any intention to expand on this particular front, or, indeed, should have.

COURSE XXI

Although I have no doubt that we will see a substantial growth in the quality and quantity of our undergraduate majors in the social sciences in the years ahead, Course XXI is clearly our most significant undergraduate achievement at the moment. Despite its success, it is still not well comprehended throughout the country or even in parts of M.I.T., so I do not hesitate to quote from the report of its director, Professor Lamson, who says: "Course XXI continues to attract good students who are genuinely seeking a balanced education; for a few this is a terminal collegiate experience, but for most it is a preparation for further studies in science, engineering, or the humanities. Through its alumni, now about one hundred, the Course is becoming better known in graduate schools, and the students who have gone into industry seem to have in their careers a mark of the Course itself."

The five years have witnessed an increase from 66 to 84 students in the Course, of whom 36 were seniors and 30 juniors in the spring of 1961-62. A considerable number come into the Course only at the junior level (the 16 sophomores of last year's class grew to 30 juniors), but there are few switches thereafter. We need expect no important change in the totals next year, when we will exceed the 25-per-class we postulated when we initiated the program.

As the Course is stabilizing, and subject only to inevitable yearly fluctuations, it appears that the quality of students is also stabilizing at something near to or slightly above the M.I.T. average. An unusual number of stragglers in the junior class weighs that class down, but averaging the more typical sophomores and seniors, the following emerges: 26 per cent are in the first one-quarter of all M.I.T. undergraduates, 56 per cent in the first half, and 78 per cent in the first three-quarters. The performance is so marginally better than the all-M.I.T. performance as to seem hardly worth mentioning; actually, it is significant. One of the risks a program of this sort runs in a technological institution is that it may collect low-standing students who seek to be refugees from the ardors of science or engineering. Such students are unlikely to do well in Course XXI, and we would rather have none of them; but undeniably we do get some and will continue to do so. This, however, makes the average performance of the Course XXI students even more impressive. The danger of becoming a refugee course seems to me to have been passed.

It must be conceded, but not necessarily with chagrin, that Course XXI, at least to this point in its short history, would have been thin indeed were it not for the School of Science which is contributing 72 of our 84 present double majors. Of the 72, 26 are from the life sciences, 21 from physics, 16 from mathematics, and six from chemistry. Single students from mechanical engineering, metallurgy, and chemical engineering, and even the seven from electrical engineering do not alter the general picture. Either the curriculum of Course XXI appeals more to science than to engineering students, which I should not find surprising, or it is easier for science students to work out the required dual program, which is also quite possible. Probably both forces are at work. This does not seem to me to be a matter for any concern, at least to those who are charged with the direction of Course XXI.

Professor Lamson is often asked what Course XXI students do later on. It is too early, of course, to give any long-term answers, after only six years of an expanding experiment. But Professor Lamson's report throws some tentative light on the question. "Five classes, numbering 100 students, have graduated from the Institute with a degree in Course XXI. Thirty will receive their degrees this year. The 70 graduates who have had a little time to find their professional paths represent an interesting diversified group. Some 28 (or about 40 per cent) have continued graduate study in various fields, 13 in the humanities, 15 in scientific or related fields. English literature leads with seven graduate students. Law school, medical school, and the armed forces account for six students each (about 9 per cent for each). Thirteen went into industry; two are with the federal government; and seven are in teaching, three in college and four in secondary schools. We have no accurate knowledge of nine." (See also Table III).

Of this year's 36 seniors, 30 were graduated in June. Thirteen have been admitted to graduate schools at Chicago, Wisconsin, Pennsylvania, Harvard, Stanford, Tulane, and elsewhere in such a range of fields as psychology, history, economics, philosophy, English, anthro-

Table III. Distribution of Graduates of Course XXI

GRADUATE STUDY

English literature (7) (1 also in industry; 1 teaching)
Philosophy (5) (1 also teaching)
History of science (1)
Political science (1)
Social psychology (1) (also teaching)
Anthropology (1)
Theology (1)
Physics (1) (also in industry)
Biophysics (1)
Electrical engineering (1)
Industrial design (1)

CONTINUING STUDIES AT M.I.T.

Sciences (5)
Linguistics (1)
Architecture (1)

OTHER

Medical school (6)
Law school (6)
Armed Forces (6)
Industry (13)
Government (2) (1 U.S., 1 Foreign)
College teaching (3) (also graduate study)
Secondary school teaching (4)
Unknown (9)

pology, business, engineering, education, and theology. Nine are going to medical schools. Others will continue advanced work at M.I.T. in architecture, industrial management, and science. Three are going directly to industry, one to the Navy, one to science teaching, one to advanced work in music, and one to the theater, hopefully as a producer.

"In 1960-61 the Humanities Senior Seminar (21.05) had the advantage of a distinguished guest, Aldous Huxley, Carnegie Professor of Humanities (Visiting), whose lectures formed the basis of the first half of the Seminar in the first term. Professor Huxley's participation, though brilliant and stimulating, brought the pressure of large numbers of observers of the Seminar and some consequent loose organization. This year we decided to experiment with concentrating on a single period and institution, The Royal Society in the seventeenth century. On this institution and period our staff lectured and dealt with assigned reading, while students chose topics of interest in literature, history, philosophy, and the history and philosophy of science on which they prepared bibliographies and a short report. The exercise was designed to introduce them to the impact and influence of the new science and to open up problems of the relations of science, philosophy, literature, and history. In addition, it made an exacting demand on their abilities to seek and interpret source material at a level beyond that of the course paper. In short, it served as a brief excursion into intellectual history and as training for the thesis to come. As a second part of the Seminar, the staff lectured on the problems of study and research in literature, history, philosophy, history of science and technology, and linguistics. The term was concluded with a symposium on 'Scientific Organization, Its Place and Influence,' which ranged over the subject from the seventeenth century to the present. The participants were Professor Cyril S. Smith; Professor Giorgio D. De Santillana; Professor I. Bernard Cohen, Professor of the History of Science at Harvard University; and the staff of Course XXI. The symposium showed the various ways in which groups of scientists, both privately and in institutional or governmental organization, have served and influenced their society, from The Royal Society to the United States Atomic Energy Commission. The demands of the first term put students on their own with occasional reporting of papers to search out their thesis topics, prepare bibliographies and plans, and select their supervisors.

"The second term of the Humanities Senior Seminar is really accomplished through independent study, thesis supervisors, and a series of oral reports on theses given before the Seminar, supervisors, and any members of the staff who wish to attend. This year we concentrated the reports into a single month. The students were allowed a total period of forty minutes each, twenty minutes generally given to presentation and twenty minutes for questions. Attendance was not required but 'expected,' and indeed most students attended and took part in the questioning up to their own presentation, and then tended to stay away. Some students attended most of the reports and provided useful criticism. They themselves have proposed required attendance at all reports in the fields of their own theses. Of the 31 theses submitted, eleven were in literature, five in history, nine in philosophy, six in the history and philosophy of science or engineering.

"On the basis of the experience of the past three years, the Humanities Senior Seminar will attempt to provide an educational experience of greater depth and preserve at the same time its 'training' for the thesis. In addition it will try more thoroughly to expose to students the major problems of and approaches to the study of literature, history, philosophy, and history and philosophy of science, that they may avoid considering their study as having any terminal quality. We are privileged to have as a new member of the Seminar next fall Professor Howard Mumford Jones who will be visiting as Carnegie Professor of Humanities. He, with Professors De Santillana, Huston C. Smith, and Lamson, will conduct the Seminar on 'Revolution, Romanticism, and Order (1789-1848)' using a two-hour session on Mondays for the whole group and splitting into three or four groups on Wednesday afternoons.

Professor Lamson has worked tirelessly to increase the understanding of Course XXI externally, but he is the first to say that more needs to be done. Perhaps the most difficult levels are those of secondary school students and their parents, who do not tend to think of M.I.T. as a place in which study of this sort may be pursued, much less well pursued, and graduate schools in nontechnical fields, many of which continue to suffer from the prejudice of ignorance as to what M.I.T. is really like in 1962. Some ground has been gained by meetings at the various learned societies. Every time one of our students applies to a graduate school, we attach a descriptive statement about the Course. This has evoked interest, even amazement, and in the end our best advertising will be the performance of our product. On the record to date we can be optimistic, but the process will naturally be slow.

The record of Course XXI is a good one. Most of the needed improvements can be achieved by a dedicated leader and a cooperative faculty. There are, however, two material changes which the administration should try to effect. The better our students become, the greater their stretch, the more inadequate our library collections become. We cannot expect to correct this entirely in our own stacks, for the range of interests is too widespread and the number of those with each interest too small. At least for the most advanced students we must make imaginative explorations of alternatives, and this applies to some other interests of this School as well. The other material need may seem a frill, or trivial, but it is not. There is no other group of undergraduates at M.I.T. of anything approaching comparable size which does not have a common meeting ground and place for discussion in the form of a lounge. Course XXI students probably need this resource more than most by the very nature of the interdisciplinary and individualistic design of their curricula. We provide it, for example, for the smaller number of graduate students in political science and the equal number in economics, and the time has come to provide it for a group which has no common laboratories or drafting rooms. The need for the lounge is urgent. It requires first, the allocation of space which the Department has been quite unable to secure, and then the raising of funds. I think the latter will not be hard, but there is no point in trying to secure them until there is space on which to spend them. So far as Course XXI is concerned, this is a matter of high priority. There could be no more fitting memorial to the memory of Henry Greenleaf Pearson.

Graduate Study

Another look at Table II will show that the increase in graduate registration has been of the same order as that of undergraduate majors and represents a total expansion of 150 per cent over six years ago. In 1955-56 practically all the students were in economics. The current 129 graduate students in the social sciences consist of 84 in economics, 42 in political science, and three in psychology. The latter two groups are expected to grow further, the last substantially. The new graduate registration in humanities is the consequence of the first year of the new doctoral program in linguistics. This too will grow substantially. The 136 graduate students are, almost without exception, candidates for the Ph.D., since we are reluctant to encourage master's or special programs in this School.

Each of these graduate programs is an eminent one; all are important to us.

ECONOMICS

The graduate program in economics has been deliberately designed by a distinguished faculty to do outstanding work over a limited part of the full spectrum of economics. It can hardly be debated that the faculty and its program is world-famous and that the selectivity it is able to apply in choosing from among the many applicants for admission is almost fabulous, perhaps the highest for any department at M.I.T. and certainly always among the highest. Since our general policy at M.I.T. is to do some important things with distinction rather than to cover the water front less well, this departmental achievement deserves nothing but praise. The numbers are now essentially stable, the program is always under critical review.

POLITICAL SCIENCE

The next oldest of our graduate programs is in political science, and here I quote Professor Pye's annual report. "Without question our greatest strength lies in our dynamic graduate program. During the year we had the satisfaction of observing the extremely satisfactory performance of our first graduates as they began their professional careers.

"As more of our graduate students become involved in thesis research, the fundamental character of our program becomes increasingly apparent. For example, our relative strength in the study of the underdeveloped areas and of foreign politics is highlighted by the fact that this year we had students working in Turkey, India, the Ivory Coast, and Australia, and we are about to send out students to Nigeria, Thailand, Iran, Finland, and France. Probably no other political science program in the country has such a high proportion of its graduate students working in foreign areas. It is also striking that our students have turned to such a wide variety of countries.

"I believe that it is safe to conclude that we have been notably successful in realizing our objective of developing a sophisticated program of work on the underdeveloped areas which is not built around any particular geographic areas. In striving to avoid a single-area focus we have, however, come against a problem which we foresaw in our planning, and this is the fact that most foundation fellowship programs are geared to training people in area studies. Our candidates are thus placed at some disadvantage when competing against students who have received a concentrated, and what we feel to be dangerously narrow, program of area rather than discipline training. It was this problem which we had in mind when we sought and obtained our major grant from The Carnegie Corporation for fellowships in political development. If the demand continues at the current rate for a year of research abroad, as we hope it will, it will be more difficult to provide the necessary fellowship funds.

"This raises the general problem of scholarship funds. If we are to realize fully our potential as a leading political science program in America, we must be able to compete on favorable terms with the other outstanding graduate schools in providing financial assistance. It must be recognized that our graduate program does not receive the support which comes from being associated with large research laboratories or an extensive undergraduate program which can be heavily staffed with teaching assistants. This means that we must depend very heavily upon direct funding of fellowships and assistantships.

"With respect to the other fields of our graduate program, the time has arrived for us to devote our energies to building up the fields of defense studies and public policy and science. Only as we round out our programs in these areas will we be able to realize the full dimensions of our initial planning.

"I am happy to report that with the arrival of Professor William W. Kaufmann we are now beginning to develop a major program in defense studies. As we begin our development of this field, it is appropriate for me to state briefly our general objectives. We are genuinely concerned that the nation needs a larger supply of well-trained defense analysts of the first order of technical competence who also have a real understanding of public affairs and the broad perspective necessary for mature judgment. It is our observation that most people professionally concerned with defense problems have come to their understanding of these weighty problems of national security through one of the two main avenues of intellectual development. One group consists of those who have been students of the history of war, of international relations, and of the social uses of violence. The other group has an engineering background and learned about the problems of defense through their concern with issues in the development of weapons systems and the contemporary revolution in military technology. Often those trained in these two traditions of the political and the technical have not been able to appreciate the full relevance of each other's knowledge. It is our prime objective in the years to come to train people who will be fully at home in both traditions. More specifically, we want to produce a new generation of defense analysts who will have on the one hand a firm grasp of the historical and political significance of the tremendous revolution in the military realm which has colored all international politics during the last seventeen years, and who will have on the other hand a complete command of the most sophisticated techniques of operations research.

"Our objective cannot be realized simply by adding further subjects to the curriculum. We shall also have to build up a well-rounded research program to help define the field. We will also have to raise further fellowship funds to be reserved for those contemplating serious work in this area. We are now at the stage of drawing up the necessary plans for such an over-all program of development.

"The second area which must now receive top priority of assistance in development is that of science and government. In this area, under the leadership of Professor Robert C. Wood, we are also at the stage of drawing up an over-all plan for development. Next year Professor Wood will be on leave of absence in order to concentrate on the problems of this field. During the past year we have explored plans for a possible intern program which would bring to M.I.T. for a year or more of study civil servants and government officials concerned with problems in government and science."

LINGUISTICS

Next in seniority among our graduate undertakings is the program in linguistics. Last year I was happy to be able to report that the faculty and the Corporation had approved Ph.D. study in linguistics, some of the most important modern applications of which have had their genesis at M.I.T. Professor William N. Locke, head of the Department of Modern Languages, reports that seven students were admitted in 1961, six of whom will continue in 1962. They will be joined in September by nine new students, several of whom have already had graduate work in linguistics elsewhere. This has resulted inevitably in an expansion of advanced linguistics subjects from the three of 1960-61 to nine in 1961-62 and to sixteen projected for 1962-63, with dissertations yet to come. Much of the present teaching responsibility has been assumed by existing faculty with corresponding diminution of undergraduate teaching. This in itself has required additional faculty, but the graduate faculty, too, will have to be expanded as was prophesied in the various investigating reports that preceded the establishment of the degree.

Professor Locke reports that during the year he and Professor Morris Halle, Secretary General and Secretary, respectively, organized the meeting of the Ninth International Congress of Linguists which is to be held at M.I.T. and Harvard in the last week of August, 1962. Of the six major addresses at the Congress, two are to be by M.I.T. faculty members, Institute Professor Roman Jakobson and Professor Noam A. Chomsky and a third by Professor Jerzy Kurylowicz of Cracow, Poland, who will be Visiting Professor in the Department in the fall term of 1962.

The rapid growth of graduate work and the fact that the Ninth International Congress of Linguists came to M.I.T. show the esteem in which our work in linguistics is held, mainly as a result of the quality of the research in linguistics that has been coming out of M.I.T. for the last decade. The linguistics group in the M.I.T. Center for Communication Sciences—Research Laboratory of Electronics, consisting of about a dozen researchers, is the main focus of this work. During the past academic year research was conducted on logical and mathematical foundations of linguistic theory; grammar of English, Mohawk, Hidatsa, Russian, Old Church Slavonic, Latvian, and Hindi; evolution of language with special reference to its primary mechanism; phonetics; perception of language; language learning by children and by adults; history of linguistics; and semantics and the philosophy of language.

It is clear, as Professor Locke has said, that the "healthy growth which the Department is experiencing will bring with it demands for new faculty and additional facilities. A solution will have to be found immediately for the question of library facilities, as they are completely inadequate both for linguistics and for foreign literature." Professor Locke's last comment is correct; but is not unamusing, coming as it does from our Director of Libraries who is having to meet the problem he mentions on many other fronts as well.

PSYCHOLOGY

When Dr. Kurt Lewin was Professor of Psychology here in the years 1944 to 1947, we had a rather special kind of graduate program in psychology at M.I.T., but this lapsed some years ago. Last year I reported our gratification that Professor Teuber had decided to join our faculty. He came in the expectation that the psychology program which he was to direct would have graduate students, and we have moved expeditiously to establish what is the newest of all the graduate programs in this School. The development is complex, and I must quote at considerable length from Professor Teuber's annual report.

"During the course of the academic year 1961-62, the Psychology Section has gone through several further stages in its metamorphosis towards a Department of Psychology. Foremost among these events was the completion of plans for a doctoral program in psychology and the unanimous approval of these plans (in March, 1962) by the Institute faculty and Corporation. Of nearly equal importance were the actual initiation of graduate instruction (through the development of a graduate proseminar); the selection and admission of ten graduate students for 1962-63; the progress in reconstructing a building for psychology; and the expansion of faculty research and teaching activities in several new directions.

"Considerable thought and discussion went into the plans for the graduate program. It was agreed that we should concentrate our efforts in a few areas of great promise; accordingly, the graduate work is being centered around three focal points, each represented by correspondingly active research projects carried by members of our faculty and staff. These three areas are physiological psychology (especially studies of the relationships between brain and behavior); experimental psychology (with particular stress on studies of perception); and social-developmental psychology (with emphasis on early stages in the acquisition, by children, of social attitudes and values, of logic, and of language).

"A radical feature of the new doctoral program, in all three areas, is its reliance on learning-by-doing rather than learning-by-listening. The main burden of graduate instruction will be carried by a triple sequence of informal seminars and laboratories which will take the place of the usual program of lecture subjects. The only required subject is a proseminar which all incoming graduate students are asked to attend throughout their first year in residence. This proseminar was organized for the first time in 1961-62; it covers, with heavy reading assignments, the major themes of modern psychology —from biological foundations to social phenomena. The proseminar was attended by three special students who had entered the prospective graduate program in the fall of 1961, at their own peril, expecting to have their status converted into that of regular doctoral candidates upon formal approval of the program by the Institute faculty and Corporation.

"This approval was obtained without dissent by the Institute faculty at the monthly meeting in January, 1962, and its action was, in turn, confirmed by the Corporation at the quarterly meeting in March, 1962.

"The timing of the review process made it impossible to send out formal announcements of the new doctoral program at the beginning of 1962. Nevertheless, our Section had received by February, 1962, all together 59 inquiries and applications from prospective graduate students. After a protracted screening procedure, seven of these applicants were granted admission to the graduate program for the fall of 1962. Together with the three students already aboard, this brings the graduate student body for the first year of official operations to ten in all. Our present plan is to admit six to eight students in each of the three subsequent years, until the total number of students in the graduate program will have reached 25-30. Our hope is thus to maintain a faculty-student ratio of one-to-two, or at most one-to-three. These students are eagerly awaited by our faculty who look upon them as junior partners in research and teaching.

"The impending arrival of graduate students has increased the urgency of our building program, a program already made mandatory by the pressing need for laboratory space on the part of our psychology faculty. The extensive remodeling of the former Cenco Building (a three-story structure at the corner of Ames and Amherst Streets, immediately adjacent to the main campus) has progressed at an accelerated pace. In December, 1961, we obtained a matching grant from the National Institutes of Health (under the program for health research facilities) which provides $252,000 towards the total expense of $652,000 for the conversion of this structure into a psychology research building. Additional funds are needed for the equipping of this building, but there is every hope that the main phases of the renovation will be finished by mid-August, 1962, in time for the arrival of our first group of 'official' graduate students in psychology."

The research activities of the Psychology Section, give or take the normal extensions and shifts of emphasis, have continued to be centered around the three focal points previously described; but the branching out has produced a closer interrelation between these three principal efforts. The studies are described in greater detail in progress reports from the laboratories.

Table IV. Percentage Distribution of Undergraduate Electives in Humanities, Languages, and Social Science by Fields, 1956-57 to 1961-62*

	1961-62[1]	*1960-61*	*1959-60*	*1958-59*	*1957-58*	*1956-57*
Literature	15.7 (13.3)	18.6	20.2	18.1	19.8	20.5
Philosophy	15.0 (12.7)	15.9	12.8	11.6	11.5	8.3
Economics	15.0 (28.0)	12.4	12.5	12.7	11.2	9.9
Psychology	13.5 (11.4)	13.2	15.0	13.9	14.1	17.1
Political Science	9.9 (8.4)	11.1	9.5	9.8	10.9	12.1
Music	9.2 (7.8)	7.8	8.3	8.9	9.7	11.2
Modern Languages[2]	7.9 (6.7)	5.5	5.1	3.9	3.2	3.7
History	6.5 (5.5)	7.0	8.4	10.5	11.1	8.6
Labor Relations	3.7 (3.2)	4.0	4.2	5.0	4.3	8.6
Visual Arts[3]	3.6 (3.0)	4.6	4.0	5.6	4.3	—

*Omitting registrations in the underclass *required* core subjects 21.01, 21.02, 21.03, 21.04, and the partially required subject 14.01, Economic Principles I

[1] Percentages in brackets are of a total which includes registrations in 14.01.
[2] Exclusive of elementary and intermediate languages courses; includes undergraduates in graduate linguistics courses.
[3] Taught by faculty of the School of Architecture and Planning.

Student Preferences Among Our Electives

As in earlier years, I present (Table IV) a comparative analysis of the distribution of undergraduate electives which reveals the trends of student taste over a number of years. Most of the changes this year are not striking. Except for economics, part of whose registration is due to its being required for a degree in some departments, literature remains the most popular single field, but its lead is diminishing.

Economics has shown a startling gain in the free elective area, while philosophy shows a small decline. Political science has not maintained its gains, but no trend is perceptible. On the other hand, history and labor relations continue on a long-standing downward trend which will bear examination. Modern languages show a quiet but steady growth. The visual arts have fallen off but again it is too early to say whether this means anything. Short-term changes, even spectacular ones, should not be taken too seriously. For example, a year ago I called attention to the steady decline in music registrations ever since 1956-57. This year, with no change in the faculty, only minor changes in the offerings, and no special effort at recruitment, the registrations in music shot up by almost one-fifth. It is hopeless to try to understand these large, almost capricious shifts in student fashion; we must deal as best we can with the staffing problems they impose, as we do not approve of the imposition of quotas in our free electives. Moreover, it must be remembered that even the program with the fewest registrations, the visual arts, served 146 students. But we should watch long trends, and these are evident, it seems to me, in labor relations and in history.

New Social Science Core

A year ago I reported on the desirability of establishing an underclass core subject in the social sciences and on the effective work that had been done in this matter by Associate Professors Alfred D. Chandler, Jr. and Robert E MacMaster, both historians in the Department of Humanities. The core continues to be successful. But a year ago the report also said that this core should become the responsibility of the faculty of social science as soon as possible, that we had authorized a new senior appointment to bring this about, and that we had established a finding committee under Professor Ithiel de Sola Pool. The committee has been working hard, but as this report goes to press I cannot yet announce the result of its efforts.

Other Departmental Comments

DEPARTMENT OF ECONOMICS

Professor Ralph E. Freeman, Acting Head of the Department of Economics during Professor Robert L. Bishop's leave of absence, has made some interesting remarks in calling attention to the rise in enrollments in the social sciences: "The over-all undergraduate enrollment of 2,455 in the Department's subjects is about 4 per cent higher than last year, and it equals approximately two-thirds of the M.I.T. undergraduate population. Since the numbers of Course XIV majors remain comparatively small, the great majority of our undergraduate enrollment comes from the Institute at large; so the figures imply that a sizable fraction of all M.I.T. undergraduates is taking at least one semester subject in the Department during any given academic year. Within the Department, economics accounts for 54 per cent of undergraduate enrollment, which is somewhat higher than last year even in percentage terms; psychology is second, with 22 per cent; political science at 16 per cent has recorded a slight percentage decrease over last year; and industrial relations at 7 per cent shows a downward trend.

"Graduate subject enrollments reflect primarily the comparative numbers of graduate students registered within the Department, even though there is a sizable minority of students from other departments in some of our subjects. Thus the Ph.D. program in political science has just completed its fourth year, so the 18 per cent increase in its subject enrollments represents partly a filling up of the pipeline. Over that four-year period, the numbers of equivalent full-time political science graduate students have increased from 14 to 34; in economics the change has been from 75 to 80. The 10 per cent increase in subject enrollments in that area since last year reflects in part an increase in outside enrollments, mainly from the expanding graduate programs of the School of Industrial Management."

POLITICAL SCIENCE SECTION

The faculty of political science was substantially strengthened by the addition of Professor Kaufmann, who will be developing our program in defense studies. He is introducing into our curriculum four new courses in defense analysis, and he will be developing a significant research program in the Center for International Studies.

Another significant addition to our faculty strength has come through the receipt of the Arthur and Ruth Sloan Chair for African Studies. Until we are able to make a major appointment to this chair we shall seek to enrich our program with visiting professors. Last fall Ezekiel Mphahlele, a leading African author originally from the Union of South Africa and Nigeria and now with the Congress of Cultural

Freedom, delivered a series of public lectures under the auspices of the Sloan Chair. During the spring term we had Dr. Michael A. Banton from the University of Edinburgh as a visiting associate professor. Professor Banton will continue with us through next fall.

With the promotion of Robert C. Wood to professor and the arrival of Professor Kaufmann, all the major fields in our program have the leadership of full professors.

During the year the Political Science Section, in conjunction with the Center for International Studies, organized and presented a course on non-Western societies for the four colleges in Western Massachusetts: Mount Holyoke, Amherst, Smith, and the University of Massachusetts. This was a cooperative effort in which the Political Science Section was happy to be able to provide for liberal arts colleges the kind of specialized education which is generally available at universities. The fact that the Political Science Section was invited to organize the course is testimony to the way others see us as a major teaching center.

PSYCHOLOGY SECTION

Our work in psychology has suffered a severe blow from the decision of Professor Roger W. Brown to accept an invitation from Harvard and to return to that institution where he had spent the early years of his academic career. This loss in the area of social and developmental psychology was compounded when Assistant Professor Wallach accepted a call to Duke University.

"While we regret these departures, we are happy to report the appointment of four new staff members. The first of these is Dr. Herbert D. Saltzstein from the University of Michigan, who will join us as assistant professor. He will divide his time between participation in Professor Donald G. Marquis' research program in social psychology in the School for Industrial Management and the teaching of personality theory and social psychology in the Psychology Section. His main research interests concern the socialization process in normal children —their acquisition of values. A second new appointment—also on the level of assistant professor—is that of Dr. Wayne A. Wickelgren from the University of California in Berkeley. His interests lie in the study of language and logic and in mathematical approaches to concept formation. In addition, two of our current research associates, Drs.

Joseph Altman and Chorover, are expected to join the regular psychology faculty beginning July, 1962.

"Last but not least, we look forward to the arrival (as visiting professor for 1962-63) of Dr. Richard Held, Professor of Experimental Psychology and Chairman of the Department of Psychology at Brandeis University. Professor Held's research program deals with the problem of the evolution and maintenance of sensorimotor coordination, as seen in experiments involving the deliberate disarrangement of normal relations between the world and the perceiver, through the wearing of distorting or inverting spectacles. He has recently extended these studies to work with very young animals raised under conditions of unusual sensory input and to systematic observations of human infants, both normal and abnormal. In this way his work parallels that of several other members of the Section who are also engaged in studies touching simultaneously on the three areas of our principal concern: the work on physiological (and comparative) psychology, the work on perception, and the work on early development.

"The year under review has seen the beginnings of the hoped-for collaboration with other departments and schools within the Institute. Professor Marquis and Associate Professor Edgar H. Schein of the School of Industrial Management have participated actively in our graduate proseminar by conducting several of the seminar sessions on social psychology. We are also looking to them, and to others among their colleagues, for help in our continuing search for a suitable social psychologist to fill a senior academic position in the Psychology Section.

"Cooperative arrangements with the Center for Communications Sciences have led to our joint sponsorship of Professor N. Stuart Sutherland from Oxford for a year's visit and to the organization in the spring term of a graduate seminar on pattern recognition mechanisms, conducted jointly by Professor Sutherland and Associate Professor Murray Eden of the Department of Electrical Engineering. Professor Sutherland's work has dealt with problems of pattern recognition in man and machine; he has spent part of his time at M.I.T. on collating data gathered over the last several summers at the Marine Biological Station in Naples, Italy, where he has been engaged in a systematic program of experimentation on pattern perception in the octopus.

"There have been equally fruitful contacts with the linguists in the Center for Communication sciences, particularly Professors Chomsky and Morris Halle, who have offered to take an active role in training our graduate students for research careers in psycho-linguistics. Similarly, there have been further contacts between our physiological psychologists and a number of other members of Professor Walter A. Rosenblith's group, contacts that are likely to lead in the future to the joint sponsorship of graduate students. Cooperation with members of the Biology Department has included the joint work of Professor Ronald Melzack with Professor Patrick D. Wall as well as repeated contacts on the part of Professor Teuber and his associates, especially Drs. Joseph and Elizabeth Altman and Stephan L. Chorover, with Professor Francis O. Schmitt, with whom they share an interest in the possible molecular bases of memory. It is apparent that contacts of this sort will grow in frequency and scope as the psychology program itself gets further along in the next few years."

It would be idle to pretend that the resurgence of psychology at M.I.T. has been achieved without pain and stress. Psychology covers a very wide spectrum, and at the extremes of the range psychologists may have less to say to each other than some at one end may have to say to scientists and engineers (and philosophers) and some at the other end may have to say to sociologists and novelists (or even poets). Almost every band of this range interests or ought to interest someone at M.I.T., from the most quantitatively minded industrial manager to the airiest architect. When Professor Teuber came to us as head of the Section, we agreed with his conclusions that we could not do everything at once and that we ought to begin by doing something very well. I see no reason to regret that decision or to seek to change it. It was, moreover, to be expected that the first thrust should be in directions in which Professor Teuber's own skills were well known. This has caused some to feel and a few to say that we were going to let "social psychology" wither away. This is by no means the case. Social psychology means different things to different people, but if there are aspects of it which are languishing, nothing prevents those concerned with such a lag from pushing forward on their own, since the Psychology Section does not contain or direct all M.I.T.'s psychologists. In my opinion the Psychology Section is well on its way to becoming the department it openly aspires to be. As Professor Teuber says: 'The birth pangs may have been unexpectedly severe, but also less protracted than one might have feared. Considerable work remains to be done, but we have no regrets about the rigorous limitations we have imposed on our enterprise by means of the 'three-prong' approach to graduate training and research. Most of all, we want to persist in stressing the central importance of *uncommitted research* on the bases of man's behavior; no matter how persuasive the arguments in favor of early application of present psychological knowledge, the first duty of an academic department is to generate new knowledge, so that it can be applied sooner or later, when the need arises. In that sense, psychology at M.I.T. will be academic rather than applied and autonomous rather than ancillary. This is not to deny that practical day-by-day needs often engender new and lasting insights, nor that cooperation across fields is not an essential source of advances in methods. Yet there has to be a core of essentially free investigators who can follow their own curiosity into basic study of the behavior of human beings, their early development, their ability to perceive and talk about their perceptions, and their manifold ways of interacting with one another.

"We could have approached this task of building psychology at the Institute in quite a different way: We could have tried to gather an impressively large group of psychologists from all the schools of the Institute and from the various allied laboratories, inviting them to conduct the business of graduate training from wherever they happened to be. Whether such a large combination would have been viable is hard to tell, but we have chosen a different route: the building of a core which we hope will possess sufficient attraction for those with similar or complementary interests to join us in research or graduate teaching, or both. Such a structure has to be permitted to grow—it cannot be forced. But we believe it is in the making."

DEPARTMENT OF HUMANITIES

The Philosophy Section in the Department of Humanities has suffered from the decision of Professor John B. Rawls, its Chairman, to accept a professorial appointment at Harvard, which we congratulate since he will be an adornment to that faculty. We shall miss him. On the happier side I can report two new senior appointments in philosophy. Dr. Hilary Putnam came to us from Princeton at the beginning of the year, following a year at Oxford. A graduate of the University of Pennsylvania with his Ph.D. from U.C.L.A., Dr. Putnam has achieved a considerable reputation in the philosophy of science, language, and mathematical logic; he came as Professor of the Philosophy of Science. From time to time he will teach mathematics as well. Dr. James F. Thomson, Fellow and Tutor in Philosophy at Corpus Christi College, Oxford, one of the leading men of the Oxford school and a scholar who understands science and especially modern psychology and physiology, will join us in September, 1963, as Professor of Philosophy. Thus the Philosophy Section, now under the chairmanship of Professor Huston C. Smith, continues to grow in numbers and quality, especially as it can also coopt the interest of such men as Professor Chomsky in linguistics. It has now reached close to the critical size and shape which would justify proposals for a Ph.D. program in this field. It is a field which would seem particularly appropriate for M.I.T., at least with respect to major aspects of contemporary philosophy. Moreover, we also have historians well informed about historical philosophic systems. All of this was set forth by a distinguished *ad hoc* advisory committee which I described in last year's report. We continue to inch towards the goal they set.

The success of the administrative change by which we created a Philosophy Section last year has encouraged us to section all the work of the Department. There has been a Music Section for a long time, under the direction of Professor Klaus Liepmann. To this and the Philosophy Section, we have now added a Section of Literature under the chairmanship of Professor Carvel Collins and a Section of History under the chairmanship of Professor Chandler. This means that every member of the Department should have a closer liaison with the others in his field, that young members should be able to get more specialized advice, that new appointments should receive closer and more professional attention, that curricular revisions should also profit, and that morale should rise. Against these advantages lies the risk of separatism. We think the gains will outrun the risks. The chairmen of the sections, together with Professor Lamson, director of Course XXI, and Professor Howard R. Bartlett, head of the Department, will constitute the new Policy Committee for the Department.

A year ago I discussed at some length the gnawing problem that all general education programs have to face up to. It centers around the presumably sad future that lies ahead of the young man who dedicates himself to teaching in general education, clearly the least comfortable road to academic distinction and reward. Indeed, it is hardly a road at all. It should not be if, in the teaching, the young man neglects to advance his scholarly achievements. But the competition between these two things is severe. I therefore argued that ways must be found to permit able young men to resolve this dilemma or else, in the end, no sensible and able young man would have anything to do with general education. One way I thought would be to make it possible for these men to do serious scholarship during their trial period, which is usually the most demanding in teaching time, both because the younger staff ordinarily carry larger classroom loads and because they are less experienced and conscientious preparation takes longer. I suggested the establishment of a generous Young Professors' Growth Fund. It is a great satisfaction to be able to report only a year later that the Department of Humanities now has such a fund. Through the generosity of the Old Dominion Foundation, M.I.T. now has an endowment fund of $500,000. The income of this fund makes it possible for the Department of Humanities to establish a program of leaves of absence for non-tenure staff. In general, the fund will provide two one-term leaves for each young scholar in this Department who remains at M.I.T. for the approximately seven years before he reaches thirty-seven, the age of mandatory tenure decision. The relief from all duties, when combined with a previous or following summer, will offer two extended periods of uninterrupted time for research and writing. When necessary, some further funds will be available for travel and research expenses associated with the projects undertaken by those on leave. Both the requests for leave and for support will be submitted for evaluation to a small committee of the senior departmental staff. It is a program which has been received with enthusiasm and should in future be a decided asset both in recruiting new staff and in helping them to grow while they are with us.

The Department has had its usual complement of distinguished lecturers, of whom perhaps only a handful need be mentioned here. Dr. Henri M. Peyre, Sterling Professor of French at Yale University, inaugurated the annual Abramowitz Memorial Lecture to a capacity house on the topic "Albert Camus, Moralist and Novelist." Sir Ronald Syme, Camden Professor of Ancient History at Oxford, gave two lectures to the freshmen, "The Myth of Political Salvation" and "Roman Political Theory under the Early Empire." Gabriel Marcel lectured on "My Death and the Death of Others." A new and highly successful venture inaugurated and managed by Associate Professor Theodore Wood, Jr., was a series of poetry readings and discussions attended by about 350 students and guests. The sessions were all taped and subsequently broadcast over the M.I.T. f-m station, WTBS. Poets appearing in the series were James Merrill, Theodore R. Weiss, David Ferry, John Holmes, Maxine Kumin, Anne Sexton, and Samuel Albert. The last four appeared the same evening in a reading and mutual discussion group.

It is a pleasure also to report an example of successful interdepartmental cooperation on behalf of the humanities. In a belief that history of science is best served when it is held in close contact with the advancing front of research, Professor De Santillana and Associate Professor Jerome Y. Lettvin of the Department of Biology joined forces to give the subject 21.86, Problems of Modern Science in the Historical Perspective. Professor Lettvin's intense preoccupation with the historical background of modern biological theory made this collaboration an easy and highly successful one. Thirty students registered for the subject, and six of them wrote papers of such high quality that efforts are being made to have them published. We are deeply indebted to Professor Lettvin for his assistance.

Professor Howard R. Bartlett has given loyal and steady direction to the affairs of the Department of Humanities for 23 years. During this period major changes have occurred in the quality and scope of its work. At midyears he requested that he be permitted to lay down the administrative duties of Chairman as soon as we could find an appropriate successor, in order that he might devote the remaining years of his active life as a professor to research and teaching. Accordingly, a finding committee of the faculty was appointed under my chairmanship, comprised of Professors Bartlett, Chandler, Collins, Lamson, and Huston Smith from the Department, Professor Chomsky from the Department of Modern Languages, and Professor Elting E. Morison from the School of Industrial Management. We considered many possible candidates over many months, and at year's end we agreed unanimously that our best choice would be Dr. Richard M. Douglas, Associate Professor of History at Amherst College. I am happy to report that Professor Douglas has accepted our invitation and will come into residence as Professor of History and head of the Department in February, 1963.

Of Professor Bartlett no one is able to speak with more intimate knowledge than I. He has been a loyal and steady teammate through all the years in which we have worked together to enlarge and strengthen the Department; he leaves the Department in an excellent condition on which Professor Douglas can build; and it should be a source of gratification to all that he will continue with us in the role he played before he assumed the duties of Chairman in 1939, and that his wise and effective counsel will continue to be available to so many students in the classroom and out.

MUSIC

Our music program is strong because it relies quite as much on extracurricular as on curricular activities. This year's program was unusually rich, as Professor Bartlett reports: "The Humanities Concert Series had one of its most successful seasons since its inception. The Julliard String Quartet performed Beethoven's sixteen Quartets in a series of five concerts. Kresge Auditorium was filled for all performances.

"M.I.T.'s first Spring Festival of Music, organized on the suggestion of Donald F. Carpenter '22, was one of the outstanding events of the year. It took place at Kresge Auditorium on Friday and Saturday evenings, May 11 and 12, with capacity audiences for both evenings. The Choral Society performed the first concert and the Symphony Orchestra, Concert Band, and Glee Club the second concert. Included in the program were Tchaikovsky's *Fifth Symphony* and Randall Thompson's *Testament of Freedom,* with the composer as guest conductor.

"Ten Library concerts by soloists and chamber music ensembles, presented in the Hayden Memorial Music Library, included music ranging in scope from Bach and Corelli to Hindemith and Piston. Mr. Aksel Schiotz, baritone, performed the Schubert *Die Winterreise* at Kresge Auditorium on December 3."

There were many incidental concerts, serious and frolicsome, under many auspices. The organ recitals continued to prosper; there were twenty recitals at noon in Kresge, ten recitals on the baroque organ in the Chapel, and four major concerts in Kresge by André Marchal, Piet Kee, Donald McDonald, and Heinrich Fleischer. Ernst Levy returned to the campus for a piano recital under the auspices of the Baton Society.

The Glee Club, Symphony Orchestra, Concert Band, and Choral Society all had their usual distinguished seasons, including tours. One way to catch the flavor of these organizations is to indicate only a few of the works performed by one or another of them: Bach *Magnificat and Motet No. 1,* Beethoven *Symphony No. 3,* Brahms *Academic Festival Overture,* Bruckner *Mass in E Minor,* Copland *In the Beginning,* Hindemith *Apparebit Dies,* Ives *Sixty-Seventh Psalm,* Mozart *Eine Kleine Nachtmusik* and *Mass in C Minor,* and Purcell *King Arthur.* The Choral Society's season concluded with the group's third European tour, which included fourteen concerts in London, Paris, Berlin, and Munich. Highlights were a joint concert in Berlin with the Berlin Philharmonic Orchestra at the Free University and a concert in St. Eustache, Paris, with André Marchal.

DRAMA

A newer but now well-established effort, whose steadily greater success is another demonstration that we are right in thinking that the humanities must have a serious extracurricular as well as a classroom practice at M.I.T., is the dramatic work which continued to be directed with skill by Mr. Everingham. The fact that M.I.T. Dramashop was presented a Karl Taylor Compton Award at the end of the 1961-62 academic year indicates not only the high level of excellence but also the widespread undergraduate interest that has centered itself on the program of plays and evenings of theatre which comprised Dramashop's program during the year.

Mr. Everingham reports, "These activities began with a reading performance of Eugène Ionesco's *The Bald Soprano* for freshmen whose interest had been elicited by a Dramashop exhibit at the Activities Midway during Freshman Weekend. An all-day practical demonstration of basic theatre techniques such as building and designing sets and lights was given the following weekend for those new members, about fifty in all.

"During the fall term two evenings of one-act plays completely designed and produced by students were performed in October and November. These plays (Edward Albee's *The Sandbox* and *The American Dream,* and Harold Pinter's *The Room* with Samuel Beckett's *All That Fall*) were followed by a critique and coffee hour, were free and open to the public, and were played to standing-room-only houses.

"The major fall production, English author John Osborne's *The Entertainer,* performed in December, required a pit orchestra for the musical numbers and dances choreographed by Esther Brooks of the Cambridge School of Ballet to the original score of John Addison. The costumes were designed by Mrs. Helen Brumby and the play directed by the Dramashop director, Mr. Everingham.

"During the Christmas holidays, the Dramashop Celebrity Series sponsored two matinee performances of Ruth Brand's puppet theatre *Queen Muggly-Ug's Castle* for the children of the M.I.T. community between the ages of five and eleven.

"The spring term brought two more evenings of student-produced one-act plays in February and March, including Chekhov's *The Marriage Proposal* and Strindberg's *Miss Julie,* and Bertolt Brecht's *The Exception and the Rule* with Eugene O'Neill's *In the Zone.* And in April the Boston premiere performance of Eugène Ionesco's *Amédée, or How to Get Rid of It,* directed by Mr. Everingham, was staged as the major production and received critical praise from Boston reviewers."

Dramashop activities have been both stimulated and supported by the new subject in Theatre Arts (21.15) taught by Mr. Everingham in which regularly enrolled students are required to engage themselves in practical theatre work as a part of the course requirements. During the two terms of the past academic year, two directors, two designers, a property master, three stage managers, two set designers, and several actors and lighting technicians from this subject fulfilled major assignments in Dramashop productions. One student directed and acted in the one-act performance of Brecht's *The Exception and the Rule* as partial fulfillment of the thesis requirement in Course XXI, the subject of which was *Bertolt Brecht: Four Didactic Plays.* The production of the play comprised one chapter of his thesis.

"It is hard to estimate the exact participation in Dramashop activities, but a reasonable guess is that approximately 125 students were actively engaged. The mailing list of students who attend performances is between 800 and 900."

DEPARTMENT OF MODERN LANGUAGES

Aside from the graduate work in linguistics, which is the most noticeable new development, the Department of Modern Languages has continued to expand its work in literature and languages along lines discussed in past years. Humanities in French has remained an exciting undertaking with more qualified students than can be accommodated in a single section. It is hoped to have two freshman sections next fall. Professor William F. Bottiglia has successfully inaugurated an advanced subject on Dante (23.87 and 23.88) in Italian and expects to offer this subject regularly from now on.

Industrial Relations Section

This year marks the twenty-fifth anniversary of the founding of the Industrial Relations Section at M.I.T. The Section is not only the oldest section in the Department of Economics and Social Science but is one of the oldest attached to a university in the United States. Princeton's Industrial Relations Section was the first, and there may have been one or two others, but M.I.T.'s Section was one of the few established before World War II, and for this we are indebted to the late Professor W. Rupert Maclaurin. Today there are some thirty-five industrial relations sections or institutes in United States universities. While the Section is administratively part of the Department of Economics and Social Science, it counts among its members those in the faculty of the School of Industrial Management who have been identified with industrial relations work at M.I.T. over the years. Thus, Professors Douglass V. Brown and Douglas McGregor (who was Director of the Section for several years prior to 1948) remain identified with the Section as does Howard W. Johnson, Dean of the School of Industrial Management. Professor Charles A. Myers, head of the Section, reports: "No particular events are planned to celebrate the twenty-fifth year. It is appropriate to note that the Section continues its basic contributions to M.I.T.'s teaching and research programs, to the greater Boston community, and to the industrial relations profession nationally.

"The participation of Professors Myers, Douglass V. Brown, and Abraham J. Siegel on various national study groups such as the C.E.D.'s Independent Study Group on National Labor Policy (of which Professor Robert M. Solow was also a member) and the Presidential Railroad Commission were particularly noteworthy in the year under review.

"The graduate student group emphasizing industrial relations as a part of the M.I.T. doctorate in industrial economics is still one of the largest groups in any American university. There were eleven such students in residence, and a number of others are completing their doctoral work while engaged in teaching positions at other universities. Our 'alumni group' is bringing increasing distinction to M.I.T., since some of our former students now hold professorships at such universities as Chicago, Columbia, California (Berkeley), Case, Tulane, Minnesota, Pennsylvania, Illinois, Michigan, Michigan State, and Rutgers. Those who complete their doctorate this year are accepting positions at Carnegie Institute of Technology, University of California (Los Angeles), and the University of Michigan.

"The undergraduate subjects in labor relations and labor economics have not maintained their enrollment at the level reached immediately after the war, when nation-wide strikes and other labor difficulties attracted students' attention to labor relations problems. The drop in enrollment is further explained by the increasing offerings available under the third- and fourth-year humanities and social science electives.

"Despite these developments, there were 70 students in four sections during the fall term and 72 during the spring term. A new third subject for advanced students in labor relations was offered during the spring term for twelve students, including several freshmen under the new Undergraduate Seminar Program initiated this year."

Of the Industrial Relations Section, now entering its second quarter-century, it is fair to say that it is often easy to overlook the quiet effectiveness of any established enterprise in the roseate glamor of new ones. The variety of activities reported by Professor Myers demonstrates again, if demonstration were needed, the vigor of the Section, even though the size of the section staff is at least one-third less than it was prior to 1955. The number of reprints of articles growing out of its research, published in the Department Reprint Series, now totals over 75, and this is in addition to books and textbooks. The research has been infused into our teaching program at the undergraduate level, in the executive programs, and for economics doctoral students. I mention these points because the impression may have arisen that the interests of the Section are too much outside M.I.T. Nothing could be farther from the truth, for even the outside activities have contributed to the standing of the Industrial Relations Section and have served to attract students and visitors. Writing this report as I do on a terrace in Kashmir, having just come to these faery mountains from the torrid plains of India, I can give personal and first-hand testimony to the esteem in which Professor Myers is held on this great subcontinent. It is much the same in other parts of the world, and among the number of peripatetic envoys of M.I.T.

he certainly deserves a high place as a fine representative of his field, his Department, his School, and his institution.

Center for International Studies

The other, larger, and newer research operation in this School is the Center for International Studies which celebrates its tenth anniversary this year. It has been a decade of solid and continuing accomplishment and has provided a large contribution to education at M.I.T., to public policy, and to new knowledge, especially in the fields of economic and political development, international communications, the Communist bloc, and American military and foreign policy. Its Tenth Annual Report, 1961, just published as an independent document, is comprehensive and interesting. It is available upon request to the Center and eliminates the necessity of any extensive exposition here.

However, it may be appropriate for someone who has not been directly involved in the program of the Center to do some stocktaking at the end of the decade. It is now more than ten years ago that our summer study project TROY, under my chairmanship, completed its report to the Department of State. Dean Acheson and James E. Webb had requested a study of some electronics problems surrounding the effective operation of American overseas broadcasting activities. We acceded to this request on the condition that the scope of the inquiry could be much broadened. It was a distinguished team which was assembled, including the late Clyde Kluckhohn, Edward M. Purcell, Martin Deutsch, the late Francis L. Friedman, John R. Pierce, Lloyd V. Berkner, Alex Bavelas, Jerome B. Wiesner, Jerome S. Bruner, Elting E. and Robert S. Morison, Max F. Millikan, and a few others. Some of our suggestions were no doubt foolish, some were ephemerally successful, and one or two may have had long-range effects. But possibly the most important long-range result and certainly the most important for M.I.T. was the conviction reached by some of the group, and held with particular passion and persistence by Professor Millikan, that it was not in the national interest to condemn to a short-term life a project of the scope we had built. It touched on many aspects of governmental information services, involved consideration of the total image of the United States as it might exist in the minds of foreigners, the values, interests, prejudices and daily expressions through which people filter the information they receive. "A survey of the academic resources of the Boston-Cambridge area revealed a wealth of individual talent in the relevant social sciences but no research organization able to mobilize it. The Center was formed, originally under the joint sponsorship of M.I.T. and Harvard, to fill this need for research on important problems in the social sciences that did not seem to be receiving sufficient attention."

Although the Center has never had to overcome any serious opposition at home and has enjoyed the steady encouragement, for example, of the President of M.I.T., it is certain that it would never have been air-borne and would never have hung up such a distinguished flight record had it not been for the determination, persuasiveness, and all-around skill of its first and only Director, Professor Millikan, strongly supported by his frequent partner, Professor Rostow.

The Center is primarily a research institution, although it properly does not seek to conduct research alone or in an educational or action vacuum. It is a part of the School of Humanities and Social Science, although from time to time it has coopted faculty members from other schools and no doubt would be happy to coopt more. It has a position of considerable autonomy with its own director who, although a member of a department, is vis-à-vis the Center equivalent in rank and authority to a department head—though his responsibilities are quite different. The Center defines its own research programs and seeks its own research funds, subject of course to prior approval by the Dean and the President which it has never been necessary to withhold. It organizes conferences on its own, holds seminars, determines its publications policy. Like a department, it has a distinguished Visiting Committee. In all of these matters it has wide latitude, and its performance has justified its freedom.

But the Center does differ from a department in very important ways. It has no faculty of its own, nor can it have. Anyone on the Center staff who holds faculty rank or permanent tenure must achieve it through one of the regular departments. This applies also to salaries and promotions. The Center may propose but it cannot dispose. Proposals must be approved by the appropriate departmental faculty, recommended by the appropriate dean, approved by the Budget Committee, the President, and the Corporation. Since the tastes of the top people in the Center are not different from those of the faculty, this has occasioned no difficulty. On the contrary, the existence of the Center has vastly strengthened the permanent faculty. As an outlet for research it has made M.I.T. more attractive to some of our people, and it has been an active recruiter of personnel, permanent as well as transient. The Center has been wholly or partially responsible for the endowment on a permanent or wasting basis of at least three new professorial chairs in the social sciences at M.I.T., matched in part by other new chairs created from general funds. But these funds are managed by the Institute, not by the Center, and although the Center's recommendations for incumbents have always been accepted, this is not automatic. Moreover, although the Center raises most of the funds it spends, saving some administrative assistance provided by the general funds of the Institute, it is required to follow the same budgetary procedures as any department of M.I.T.

The Center's most recent report lists 21 M.I.T. men of professorial rank as being members of its administrative or research staff. Six of these were professors of long standing at M.I.T. well before the Center was even a dream. All were in the School of Humanities and Social Science. Four more have been appointed in this School quite independently of Center funds, although certainly the Center was one of the inducements for them to come. Two are in other schools, one in Industrial Management and one in Engineering. This leaves nine of the 21 who would probably not now be here had it not been for the existence of the Center. Five senior men of this School, quite explicitly, came to our faculty via the Center—Professors Paul N. Rosenstein-Rodan, Ithiel D. Pool, Daniel Lerner, and Everett E. Hagen, and Harold R. Isaacs. Each began with only a Center connection and was later joined to the faculty. It need hardly be stated what a large contribution these five men have made to the growth of social science here, particularly but not exclusively political science.

It is clear, then, that one of the striking and beneficial features of the Center's life has been the degree to which it has been integrated into the academic community and the degree to which it has helped to build a strong faculty. In addition to its good taste in people, the opportunity the Center offers for support of and reinforcement of research through collaboration has had a major effect.

Anyone who holds a faculty appointment at M.I.T. has an obligation to teach. Those who are also attached to the Center for research may have all their research time paid for from Center funds, but the teaching time is always part of a departmental budget. This also applies to reverse transfers which are made when some nonfaculty member of the Center teaches. Nonetheless, the teaching done by members of the Center is economical of cost in terms of its quality.

This leads to a second major difference between the Center and a department. It may design and propose subjects to be taught, but these can be added to the curriculum only on approval of the department and the appropriate Institute faculty committees. Its staff may assist with graduate theses and graduate students may work in the Center, but the Center grants no academic credit or academic degrees.

There is an important third difference. Departments operate under budgets made up in part of grants and other short-term funds but also entailing substantial appropriations from general M.I.T. sources, all of which are allocated by the Budget Committee. Except for some administrative support, the Center is essentially financed by short-term external grants for generally defined research purposes. This places a compulsion on the Director and his associates to be assiduous in the search for new funds, a search which really never ends. On the one hand, the Center's distinguished record of past performance may facilitate this. On the other hand, there is the unfortunate propensity in many American quarters to find it always more exciting to support new untested ventures for brief trial runs than to invest further support on a group which has distinguished itself in the trial.

This national tendency in less aggravated form does not simplify the problem of Professor Millikan and his associates, even though two large foundations have displayed an outstanding consistency of support. No single thing could help the Center for International Studies and the social sciences at M.I.T. more in general than a base of permanent funding for a minimal research program on which more temporary structures could expand or contract.

On the side of recent substantive performance I prefer to refer the reader to the Center's annual report, published separately. The end of the Center's report explores the research philosophy which has gradually merged over the ten years of the life of the organization. It adds up to a concern with the *process* of change rather than a description of what a society is or has been like, with the internal dynamics of states, and with policy orientation, all in the context of the conviction that multidisciplinary research is most fruitful in this field. It has been a serviceable policy and should continue to be for a long time to come.

Canning the Humanities

More than ten years ago I sat for a while on a committee which was worrying about the impending shortage of teachers in the humanities. At one point I suggested that we had to look at the potential resources of film, radio, and television. I was thinking in very primitive terms, involving only elimination of duplicated manpower. Perhaps, I thought, *Julius Caesar* might get a better interpretation than it was obviously getting in many schools. Perhaps even it might result in not reading *Julius Caesar* or *Silas Marner* at all. But I certainly was not dreaming in the sophisticated terms which were applied later by the Physical Science Study Committee with such powerful effect to entire revision of content and method, of books and tools, so that almost overnight the teaching of physics was revolutionized. But even my tiny suggestion was hooted down. The consensus was voiced by a much beloved and admired colleague, now deceased, who said (and it settled the question), "But you can't can the humanities."

In one sense, of course, Sidney Painter was right. Over thousands of years men have been trying to determine the answers to some very fundamental and recurrent questions. The answers have never been found. The questions ask: What is love? What is truth? What is justice? What is beauty? What is right? and so on. Operationalists may dismiss them as "meaningless," but they cannot be dismissed so easily. In the end each of us has to arrive at some working definition that will suit him, that he can live with; and our society has to have some kind of understanding as to answers, too. It does not help that we cannot find the universally acceptable answer in any formula or in any book. Science helps us no more than theology. But the questions do not vanish.

All we can do is to think as well and as clearly as possible. Over the years a few men—not very many, really—have thought about such questions more profoundly than others, and they have written these thoughts down more powerfully. Sometimes they have done it in prose, sometimes in verse, sometimes in an epic, sometimes in a novel or a play or an essay, a history, or a biography, sometimes even in an epigram. Occasionally the discourse has been advanced by a painter or a sculptor. That it has been advanced directly by an abstract art like music, I am less sure.

But it is the works of these men which offer us the tools that will sharpen our own thinking better than the works of littler men. Sometimes the works have other dimensions, sensuous dimensions, emotional dimensions. They are beautiful or ugly, pleasurable or painful, and they may be different things to different people. About the very greatest of these works there is no dispute whatsoever. It is only about minor men that we debate. So what is most important to take from the humanities has been worked out quite well and does not change much; and it is hard to imagine a revolution in which, for example, Plato would be discarded in favor of Bertrand Russell or Shakespeare in favor of Tennessee Williams or Leonardo da Vinci in favor of Robert Motherwell.

Behind all this work there is of course a body of information. Since any work is strengthened by the strengths of the reader or the viewer, it is obvious that you can get more out of Dante, for example, with some information than with none (you probably need less information for Sophocles than for Dante, which may mean that Sophocles was the greater artist; but that is another question). Information helps to appreciate and understand the works of the humanities but one cannot list a few pieces of information that are critical and make another larger list of the superfluous.

In this sense the humanities cannot be canned. There is no ready way to choose and purvey information. There is no substitute, absolutely no substitute, for the direct encounter. There is no one living whom you ought to allow to stand between you and Plato or Sophocles or Shakespeare or any other of the great debaters. There is no royal road or short cut or abridgment. It is not important to be able to state two or three formularized conclusions that Plato reached. The important thing with him or with Aquinas is the argument. You have got to enter the argument yourself. This means you have to read and then to think. And this is going to take time. To this extent, then, the humanities cannot be canned or even short-circuited, and the tests of retention suitable to the rapid reading of *Ben Hur* or of *Life* are not applicable.

But this, of course, is a superficial view. You will never read unless you want to. And you may easily be introduced to these things in a way which will never make you want to. Even Shakespeare can be destroyed by a Dry-as-Dust. This is what humanists had better be wary of. If they take their established ways as the only good ways, just because they can be reasonably sure what is the best material, they may be marching on the road to defeat.

I do not know that anything can be done to aid us to do a better job. I do know that we cannot say without trial that nothing can be done. I think we may have a pretty good idea of what ought to be taught in the humanities despite our disagreement in detail. But how we can be so sure we know how to teach it puzzles me.

Long ago Socrates was probing the reasons the oracle might have had for saying to Chaerephon that there was no one wiser than his friend. He settled the question as the embarrassed Athenians learned from the *Apologia* by examining politicians, poets, and technicians in that order and finding them all almost entirely deficient in wisdom. Of the poets, he observed, "The very fact that they were poets made them think that they had a perfect understanding of all other subjects, of which they were totally ignorant." Later, in the twentieth century, Ortega y Gasset applied this comment more generally to all specialists. It is a warning we can all heed with profit.

In the ancient battles of the books, and in some of their recent writing about science, some humanists have betrayed the arrogance of the Greek poets; and if sometimes the roles have been reversed, I cannot think of more than one or two examples where scientists have said as stupid things about the humanities as humanists have often said about science. But it is time all this bickering stopped and time that claims about who is bright, who is useful, who is worthy were muted. All these depend on definitions. What we can be sure is that everyone ought to till his own vineyard well.

A vineyard needs roots, and good care of these is essential. But the roots are meaningless if the grapes are not ripe, well plucked, well trodden into wine. We do well about our roots. And if our angelic feet have become too soft to tread our grapes, other tougher feet may enter the vat. They may not necessarily be the feet of fools; nonetheless, we may not like what they squeeze out. Yet we cannot blame anyone save ourselves, for the grapes are rich and should not rot unpressed.

Film, sound, television, radio, and other devices have great potential power, and it is absurd to ignore them because their use has so often been debased or trivial. All the use has not been debased or trivial. Bernard Knox's films on *Oedipus* are a lot more exciting than many of the lectures on the play that are being given every year throughout the country, conceivably even better than we ourselves are doing with *Oedipus*. There are other examples.

Perhaps the humanities cannot be canned. But someone is likely to try to can them. And if in default and through inaction the humanists in the end do not like the container or the contained, they will have only themselves to blame for having "left it to George."

In closing, let me report that the faculty of this School continues to travel extensively and that many of them could write reports from quite as exotic places (if any place is exotic any more) as the surface of the Dal Lake where mine is being written. As one of the "offenders," I naturally believe in this travel. It is bound to widen our personal horizons, to increase the quality of the goods on our academic shelves, and I see nothing to suggest that the store is not being well kept by those who at any moment are not away. Aristophanes to the contrary, it is not such a bad thing to "traverse the air and contemplate the sun," and one need not become a Strepsiades thereby.

JOHN E. BURCHARD

School of Industrial Management

The year just past marks the tenth in the School of Industrial Management's lively operation. In the shadow of M.I.T.'s Centennial, ten years is hardly a major anniversary. Birthdays like these, however, afford a good vantage point from which to review the past and to anticipate the future, and an annual report is an appropriate place for such stocktaking. M.I.T.'s concern with management began, of course, long before the founding of the School, and, in that sense, 1952 does not mark the beginning. Sixty years earlier, President Francis A. Walker had pressed for the teaching of business management to engineering students and had organized a small faculty, including such bright stars as Louis D. Brandeis, for that purpose. Then, beginning in 1914 and for almost forty years thereafter, Course xv was the regular vehicle for providing education in engineering and business to M.I.T.'s undergraduates. During this period, many of M.I.T.'s most distinguished sons made their reputations as managers and business leaders. The gift of Alfred P. Sloan, Jr., in 1952, however, was the landmark in establishing a new level and a new scope to management education at M.I.T., and much of the story of management education at M.I.T. has occurred since then. In the past ten years, over two thirds of our Master's degrees in industrial management have been awarded; 80 per cent of our Sloan Fellows have had their remarkable year of study at M.I.T.; all of the Senior Executives have come through; and our first Ph.D. candidate has received his degree. More important than these numbers, however, the School has produced a style that now makes its own imprint on M.I.T. and its community. Increasingly, the concern for developing imaginative, analytical managers has become a part of M.I.T.'s own thrust in the world. It is this fact that is probably the most notable one that emerges in any ten-year review.

This School is committed to educating enterprise managers—men who have the will to manage and to risk, who can deal with complex systems, who have insight into themselves as well as others, who understand the total environment in which they live, and who continue to learn. It oversimplifies the task of educating men such as these to differentiate business education into quantitative or non-quantitative alternatives or between liberal and technical emphases. We want to produce men who are solidly based in the pertinent disciplines and who can think about the whole problem in management terms, from the whole range of technical data to the human element. We want them to be able to reach decisions. At his best, our young graduate has this ability to move decisively and responsibly in an increasingly complex world. This task of educating men for management is our first purpose, but there is a second concern, equally important, that drives the School. We want to conduct research that produces new understanding and better solutions to management problems, and these results must be communicated to a broader audience. The net effect of these education and research goals should have their impact on other schools and on management operations in general.

Although no one year provides a base to measure the effectiveness of the School in reaching such broad goals, the year just past offers, I believe, an opportunity to take a sighting on the spirit and accomplishment of the School, its faculty, and its students. This report, therefore, is devoted to a review of the major programs of the School, its teaching efforts, and its research record. The highlights of the year can be summarized under the following headings:

1. The substantial growth and strengthening of the faculty in several key areas.

2. The expansion of the Master's program based on a continued increase in the number and quality of our applicants.

3. The establishment of the Sloan Fellows Professorship in Industrial Management by the alumni of the Sloan Fellowship Program.

4. The inauguration of a major new research project in the management of technologically based enterprise supported by the National Aeronautics and Space Administration.

5. Further evidence of the School's research productivity, including the appearance of several major books in the field of management by members of our faculty.

6. The granting of the first Ph.D. in Industrial Management in our doctoral program.

7. The triennial Convocation of Sloan Fellows and Senior Executives, held as one aspect of the continuing education program of the School of Industrial Management.

8. The effective continuation of our M.I.T. Fellows in Africa program.

9. Further progress in our sponsorship of the first graduate school of business in India in the Calcutta Institute of Management.

These and other events of importance occurring during the past year are reported briefly in the following paragraphs.

Education for Management

The teaching program of the School of Industrial Management continues to be characterized by four distinct levels of students engaged in the study of management, each level contributing in its own way to the richness and variety of the total environment of the School. The first of these, the graduate program, is essentially the main line of the School of Industrial Management. Students here, typically in their mid-twenties, are about to enter their first assignments as managers of organization. The second group, the undergraduates, continue to bring enthusiasm and high potential to the study of management, and their purpose is to prepare themselves for a first entrance into the world of business. The third group of students, the Sloan Fellows, are those young executives already selected for the combination of personality, drive, and ability that leads to early recognition in management, who now seek a broader grasp of the whole range of ideas entering the management function. Finally, the Senior Executives represent those men already in key positions who need to take stock of the progress and problems in several fields of business analysis.

THE MASTER'S PROGRAM

The Master's Program in management continues to grow both in number and in the quality of its students. This year we showed the largest increase of any of M.I.T.'s graduate schools, in point of fact twice the increase of the next school. Behind this increase is the fact that our applications for graduate work for the coming year will total approximately 400 as against 360 a year ago, 314 in 1960, and 251 in 1959. I note one other statistic of importance. Currently, over 60 per cent of our accepted candidates have said they will indeed come to M.I.T. next fall. This percentage of final acceptances is significantly higher than the School's usual 50 per cent acceptance rate and indicates, I believe, that an increasingly higher value is being placed on the M.I.T. opportunity. These numbers of applications are more significant when one takes into account the increasing quality of our students and the generally higher standards for admission. Let me illustrate. In the fall semester of the year just past, six of our first-year students in the graduate program had 5.0 averages (the maximum obtainable) as compared to one student attaining this average last year and two the year before. More important, 52 of the total group in the first year had 4.5 or better this year compared to 33 last year and 28 the year before.

We are continuing our experiments in curriculum strengthening in the Master's Program. The Program has always had a strong analytical bias in the first year. We seek to build the students' understanding in the basic fields supporting management—in economics, psychology, statistics, and history. We then move on to the business functional fields for further application, synthesis, and integration—in accounting and finance, production, marketing, and industrial relations. In approaching this, we have always been willing to assume, given our entrance requirements, a basic mathematical competence on the part of our students. We are no longer willing to assume this. We therefore began the development during the year of a foundation course in mathematics for managers in our first year. We will continue with this development on a required basis in the coming year. This will make, we believe, more efficient the business applications that follow. We have also continued to develop our course work in management information systems, in industrial dynamics, in systems management, in international management problems, and in other fields.

On the debit side, we remain unsatisfied with our progress in resolving the thesis problem. The faculty is convinced that the thesis—which we, almost alone of the major schools of business, still require—offers great opportunity for individual work and achievement on the part of the students. We now have plans to encourage earlier exploration and attack on the thesis by the students, and, hopefully, progress is in the wind on this point.

There are other problems; but taken as a whole, the Master's Program is certainly a positive one, perhaps the strongest such program available, certainly a high-grade terminal program in the preparation of the managers of the generation to come.

THE DOCTORAL PROGRAM

The Ph.D. Program continues to meet our expectations. We now have eighteen men actively involved as doctoral candidates, and we will add ten more in the coming year. The first of our doctoral candidates was awarded his degree this June, the first doctoral degree ever awarded in industrial management in this country. The program is attracting attention nationally as one of the best, and certainly most rigorous, preparations for management research and teaching. The faculty has responded to the program with the creative development of doctoral seminars that expand the opportunity for the doctoral student in our particular environment. This year we had over sixty applications for the program, and the general quality of these applications was high indeed. A basic problem remains: to find ways to support the doctoral candidate and his family during the roughly two years of intensive work that he is required to spend beyond the Master's Program. The average age and typical family responsibility of these candidates make some kind of support necessary, and we have not wholly solved this problem. In general, however, the second complete year of operation of this program has convinced the faculty of the relevance of its contribution to the management scene, and in a few years our men should be in a position to make a real contribution to management teaching and research in this country.

At the same time, our Sloan Internship Program, on which I reported in detail last year, seems to be filling a highly useful purpose in the field of business teaching. This year six able young professors, typically at the start of their teaching careers, spent a year in preparation in the midst of our faculty. We have selected another group for next year from a range of excellent applications.

THE UNDERGRADUATE PROGRAM

The classic Course XV continues to roll along at a slightly slackened pace from preceding years, although the rate of decline has sharply lessened. Our total undergraduate registration, however, is increasing, based on the enrollment of out-of-Course undergraduates, many of them involved in the "Management Minor." We are convinced that there is strength and interest in our undergraduate students that is well worth caring for. The several Undergraduate Seminars offered by members of our faculty this year, the spontaneity of the undergraduate Industrial Management Association, and the quality of the "Management Minor" men all support the fact that work in management for M.I.T. undergraduates still makes a great deal of sense. We have not yet found the best way to organize this work, but we are working hard to find it, and we are optimistic.

EXECUTIVE DEVELOPMENT PROGRAMS

Sloan Fellowship Program. The Sloan Fellowship Program paces the general field of management development as a kind of hallmark in terms of the quality of its participants, the concept of its educational process, and the rigor of the program itself. This year forty-three young executives from the United States and abroad participated in the Sloan Fellowship Program. All of them were awarded the degree of Master of Science in Industrial Management at the conclusion of their year of study and upon successful completion of the Master's thesis. Their year was again marked by four very effective field visits. In the late summer, they examined a number of manufacturing plants. In early December, the group met with key executives in leading industrial and financial firms in New York City and again had the privilege of meeting with Alfred P. Sloan, Jr. In the spring, the Sloan Fellows held useful sessions with senior government officials in Washington. Once again, at the conclusion of the academic year, the group traveled to England, France, Germany, and Italy for meetings with influential representatives of government and industry. This latter trip was first undertaken two years ago with the aid of a grant from the Sloan Foundation. Subsequent events in the rapid development of the Common Market have substantiated the relevance of that first close look at new competitive currents in the world of trade and business. All these sessions outside of our classrooms in Cambridge add to the Sloan Fellows' faculty, in a sense, many distinguished men here and abroad who contribute much to their understanding of the management process. Indeed, one characteristic of the Sloan Program is that remarkable association which develops between the Sloan Fellows and their professors, embodying a partnership in constructive and enthusiastic pressure for new knowledge and understanding.

An important event in the year for the Sloan Fellows was the Executive Development Convocation in May, to which all present and former Sloan Fellows and members of the Program for Senior Executives were invited. They returned, over three hundred strong, to share in a stimulating two-day discussion centered around "Management Decisions in a Changing World." The nature and dimensions of change were outlined in a series of papers contributed by William B. Murphy, Dean George R. Harrison, and Professors Douglas M. McGregor, Max F. Millikan, and Robert M. Solow. Participants in the Convocation were greeted by President Julius A. Stratton, and at the conclusion of the opening day Dr. James R. Killian, Jr., outlined some of the changes in higher education around the world. Important to the participants was the presence of Alfred P. Sloan, Jr., who spoke on the relationship between education and business and then, in a remarkable extemporaneous comment, emphasized the importance of the individual in producing ideas that mean human progress. It turned out to be, happily enough, a kind of birthday party for Mr. Sloan, who celebrated his eighty-seventh birthday that same month. A second full working day of the Convocation saw twenty members of the School's faculty leading seminars in which the implications of change for many areas of business responsibility were discussed. The strong interest in the Convocation as an opportunity to share ideas with faculty and their colleagues reinforces our conviction of the importance of this kind of stimulus to the continuing self-development of our executive program alumni.

Contributing greatly to all these events was the new Director of the Executive Development Programs of the School, Peter P. Gil, who replaced John M. Wynne upon the latter's appointment as Associate Dean of the School. Mr. Gil was appointed to the post of Director on February 1, coming to M.I.T. from the Centre d'Etudes Industrielles in Geneva, Switzerland. His experience and fresh point of view in this field should help us to continue to progress in the executive program field.

The Society of Sloan Fellows, composed of the growing body of alumni of the Sloan Fellowship Program, attained one of its major objectives this year. By means of pledges of continuing support, the Society has established the Sloan Fellows Professorship of Industrial Management, and it was Dr. Killian's privilege to make this announcement at the final banquet of the Convocation. Professor McGregor was appointed by the Institute as the first holder of this new professorship. The founding of the Chair is important in itself, but it gains new perspective as a symbol of the relationship between the Sloan Fellows and the School and as a mark of appreciation to the man who made the Program possible.

One final note on the Sloan Fellowship Program: strong as the program is, the need for constant review of its basic concept and its operational performance is a necessity. For this reason, I have appointed a faculty committee under the chairmanship of Professor Stanley Jacks to consider and evaluate every aspect of the Sloan Program. We will perform our trail-blazing function in this field, as in others, only by continued introspection and appraisal of this most important program. The report of this committee will be at hand in another year.

Program for Senior Executives. This program continues to be a useful and important segment of the School's activities, involving the presence on the campus of some forty-five senior corporate executives each year. Built around four core seminars—control of the financial resources of the firm, management of its human resources, and its economic and institutional environment—the program gives its executive participants a broad exposure to changing concepts of management away from the continuing pressure of everyday decisions. Major American and foreign corporations are finding it increasingly useful in the development of their executives. The Program for Senior Executives is now in its sixth year, and approximately 220 men have passed through this experience which, at its best, makes a significant impress on the thinking and action of the participant. It is time to raise again, however, the question of other ways in which this School can make an important contribution to the education of advanced executives. We now have the Sloan Fellowship Program and the Program for Senior Executives, in a different context we contribute in the same way to the development of Indian executives, and we sponsor a Greater Boston Program for executives in Boston and the surrounding area. It may well be, however, that a new pattern beyond this group of efforts so effectively pressed could now begin. With America's executives having by and large been exposed to general management programs, it may well be that new patterns of individual association of executives with a faculty can be planned. We hope to have progress to report on this score in another year.

The Greater Boston Executive Program. Twenty-two managers from Greater Boston firms again took part in this course, offered one day each week for 15 weeks each spring. With concentration on the human and financial resources of the firm and its economic and institutional environment, the Program continues to be useful in meeting part of the needs of Boston-area business. The interest of these men in their continuing self-development is remarkable, with each of the groups voluntarily organizing sessions with members of their faculty each succeeding year after their own graduation.

ENROLLMENT

The graduate program continues to show an increasing number of students. In the year just past, approximately 200 students were enrolled, again an increase of about 25 over last year. This number includes both the men who are involved in the full two years of work and the men who because of prior credit and advanced studying can complete the work in two or three semesters. It is likely that we will increase this number slightly once again in the coming year.

At the undergraduate level, 62 men received the Bachelor of Science degree in Course xv in June of this year as compared to 45 a year ago, and the total number of degrees awarded in all three semesters during the year increased to 77 as compared to 62 a year ago.

Enrollment in Industrial Management Subjects (Man-Courses)

		Course xv	*Other*	*Total*
1959-60	Fall	905	171	1,076
	Spring	860	192	1,052
	Total	**1,765**	**363**	**2,128**
1960-61	Fall	936	203	1,139
	Spring	970	243	1,213
	Total	**1,906**	**446**	**2,352**
1961-62	Fall	1,124	224	1,348
	Spring	1,027	283	1,310
	Total	**2,151**	**507**	**2,658**

School of Industrial Management

The growing number of students involved in undergraduate and graduate study in the School, represented by the increased number of individual registrations in subjects offered by the School, are shown above. The increase experienced in these three years is likely to continue.

The enrollment in the Sloan Fellowship Program continued at the three-group level with a total of forty-three men. The Senior Executive group remains constant at a few more than twenty in each of two sessions of the year.

Management Research

Last year I spoke again of our continued effort and some progress in the field of research. This year, it is a pleasure to point to evidence of fruition of some of these efforts as well as continued enthusiasm and work on the part of our faculty. One does not weigh quality by the number of works produced, but it is encouraging to see some twelve books of importance as well as many articles appear as publications by members of our staff. The books included among the publications listed at the back of this report, range the full scope of our four major research streams: the quantitative analysis of management decision-making; the behavioral studies of organization, motivation, and human purpose; the environmental study of business and management; and the business functions themselves. The subjects involved are not trivial, and, in sum, they indicate the snowballing of our productivity in these fields. The following brief review can hardly be complete, but it does indicate the breadth of the work now under way.

One of the main streams of research in the School is that complex of problems relating to the effective development, control, motivation, and leadership of a productive organization which we call the organization studies field. Typical of the range of research reported here are the continuing projects of Professor Edgar H. Schein, who is carrying forward his long-term research relating to the impact of large industrial organizations on individual attitudes, values, and behavior. His earlier research on the effects of "brain washing" tactics in the Korean War, which sharply challenged a number of widespread beliefs about the susceptibility of American soldiers to such tactics, may well prove to be the definitive work on the subject. Professor Warren G. Bennis has been experimenting with some new ideas about curriculum and teaching methods for executive training programs while on leave at the Nestlé school in Lausanne, Switzerland. Professor McGregor has been involved for the fourth year in an extensive action-research project on organizational change in a large company. Plans are now under way for extension to the rest of the company. Professor Harry Levinson of the Menninger Foundation of Topeka, Kansas, spent the year as a visiting member of the organization studies faculty this year and brought a stimulating research point of view to the School with his extensive background in the field of executive mental health. Professor Bernard J. Muller-Thym has continued his theoretical studies of the organization of advanced technically oriented companies. A primary event in providing stimulus in the organization field was a two-year grant of $447,000 from the National Aeronautics and Space Administration in the spring of 1962 to support research in the management of technologically based enterprise. This project in research management, under the direction of Professor Donald G. Marquis, will help to create a major center of research and, eventually, teaching in this field. Projects already undertaken range from problems in control of evaluation of project research, through the analysis of the interface of government-industry relationships, to the career growth problems of the scientist and science managers in organizational settings. Over a period of time, we fully expect this grant to build basic strength in the faculty and the student body of the School and of M.I.T. as a generating source of new ideas in organizing the better management of complex systems.

In the more precise fields of management research dealing with the application to management problems of mathematics, simulation techniques, and systems approaches in general, good progress is noted. A most specific milestone in industrial dynamics research was the publication of Professor Jay W. Forrester's book on the subject in November, 1961; however, new work is going ahead in growth dynamics problems as well as a continuation of what has been called steady state dynamics, dealing with the fluctuations of inventory, employment, sales, and possibility as experienced in more mature industries and companies. Professor Edward B. Roberts' completed monograph on the dynamics of research and development is an important indication of progress in the growth dynamics area. Of real importance has been the continued growth of the highly competent junior staff in this field.

Our interest in computer applications and development in general was served by the appearance of Professor Martin Greenberger's book, *Management and the Computer of the Future.* The work of Professor Greenberger in the quantitative approach to management problems, of Professor Edward H. Bowman in operations and decision programming, of Professor Ronald A. Howard in systems problems, and of Professor Barnard E. Smith in quality control problems all proceed with interest and good potential. The full availability this year of our own Sloan Building computer, an I.B.M. 1620, to supplement our use of the M.I.T. Computation Center, greatly facilitated the research efforts of students and faculty alike.

In a real sense, however, the application of advanced quantitative techniques is now the commonplace in connection with research in almost every functional field. In the field of finance and its related areas, for example, I can note the work of Professors Daniel M. Holland and Paul H. Cootner on the relation of risk to rate of return, Professor Myles M. Dryden on capital budgeting decisions, Professor Holland's book on dividends under the income tax, Professor Edwin Kuh's completed study on capital theory, Professor Myron J. Gordon's work on the investment financing and valuation of the firm, and Professor Andrew C. Stedry's work on budget and control situations. This generation of research, based in large part on quantitative applications, applies equally to other applied fields of management.

In the environmental field, broadly defined, I note the appearance of Professor William L. Letwin's book on American economic policy, which becomes a basic piece in our graduate education program. In the field of public policy, Professor Douglass V. Brown and his Economics faculty colleague, Professor Abraham Siegel, were mainstays in producing the Committee on Economic Development study group report on "The Public Interest in the National Labor Policy." In the business functional fields, there continues to be new work under way, of which Professor Gerald B. Tallman's work on the new distribution systems characterized by the discount department stores is an example.

We will see, I believe, an increasing amount of research now in international management questions, and in this sense I note with pleasure that Professor William P. Travis' thesis, soon to be published, "On the Theory of Commercial Policy," received the David A. Wells Prize in the Harvard Department of Economics this year. Here also should be noted the work of Professor J. Daniel Nyhart in entrepreneurship development in Africa and the study on Tanganyikan industrial development by Professor Tallman.

In the development of new methods in teaching, the members of the faculty have been active as always. The marketing game, developed over the past few years by members of the marketing staff, including Professors Tallman, William F. Massy, Henry J. Claycamp, and Arnold E. Amstutz, was extensively tested during the year, and plans for its modification and further use are under way. We have an exciting and potentially valuable tool in the marketing game, but its full development is not yet at hand. In the production field, Professor Donald C. Carroll is experimenting with the development of a similar simulation supplement to student learning.

One of the most interesting developments in teaching methodology comes out of the application of group dynamics principles to "sensitivity training" for arriving Sloan Fellows and newly appointed M.I.T. Fellows in Africa. This work, under Professors McGregor, Schein, and Warren G. Bennis, promises to be useful in developing better insights for the individual's effectiveness in working with others. We expect to extend this work. In another way, Professor Zenon S. Zannetos has been experimenting with programmed instruction in both accounting and statistics; this is also going on in other fields. Finally, in several areas the use of tutorials is increasing; this seemingly expensive way of relating student and teacher on a one-to-one basis may actually prove more efficient in terms of results.

I wish to add four comments of different sorts which affect the research situation in the School. First, we have had an influx of outstanding young men as assistant professors in the School. Nine were here for the first time this year, and a few more will join us in the coming year. This group, plus a few replacements at more senior levels, is a major addition to faculty research strength, and we can expect the results to be apparent in the coming years. Second, the doctoral program in industrial management has indeed shown evidence of aiding our research strength. Third, on the hardware side, the computer installed last July in the basement of the Sloan Building has proven to be of immense use in providing student and faculty with an easily available tool of analysis and a spur to interest and achievement in certain fields. Fourth, the *Industrial Management Review,* noted last year, is now a first-class—if small-scale—contributor to the stream of advanced management research information in this country, and the interesting thing here is that it is largely based on our own faculty research reports and findings.

In all, I believe we have demonstrated in this year a real ability, as opposed to a high potential, to produce important research. We do not forget the mainspring function performed over the past several years by the Sloan Research Fund in this regard.

Student Research. The thesis requirement in the degree programs of the School has given our students research opportunities beyond the ordinary and has provided them with an excellent vehicle for working closely and individually with faculty members. Research assistantships, typically under grants from the Sloan Research Fund and increasingly from other funds, have produced a research environment for our graduate students, especially, that is encouragingly productive. Now the availability of assistantships under the N.A.S.A. project and, in a smaller way, under the risk-and-return project sponsored by the American Telephone and Telegraph Company have made feasible student research on a summer- as well as an academic-term base. This bodes well for the future.

As usual, two student theses were selected for special mention during the year. The E. P. Brooks Prize for the best Master's thesis was awarded to Romulo H. Gonzalez for his thesis "Solution of the Traveling Salesman Problem by Dynamic Programming on the Hypercube." The Industrial Management Association Prize for the best undergraduate thesis was awarded to Adolfo J. Facussé for his thesis "Social and Economic Development in Central America." Last year I mentioned a hope that I could report the title of our first Ph.D. thesis in industrial management in 1962. I can do so: it is "Federal Urban Renewal Program: A Financial and Economic Analysis," by Martin C. Anderson, who is our first candidate to be awarded the degree. Once again, our students were awarded a number of fellowships in support of their graduate work during the year: six Ford Foundation Fellowships, four N.D.E.A. Fellowships, one Lord Heyworth Fellowship (the Lipton Tea Company), one Eastman Kodak Fellowship, and one United States Steel Fellowship.

Special Programs

THE SCHOOL OF INDUSTRIAL MANAGEMENT OUTSIDE THE UNITED STATES

At present, three programs occupy our energies and concerns in the underdeveloped areas—two in India, one in Africa. For each of these programs this has been a year of reasonable opportunity and achievement. In India we saw the completion of our second successful advanced management program for Indian executives held in Kashmir in July and August of 1961, and we planned and prepared to carry on the third of these programs in the summer of 1962. The 1961 faculty group was made up of Professors Sidney S. Alexander, Gordon, Houlder Hudgins, Howard W. Johnson, and McGregor of M.I.T. and John R. Coleman of the Carnegie Institute of Technology. In addition to the Kashmir sessions for thirty-two top Indian executives, the faculty also conducted a reunion conference for the previous year's group in Bombay. The 1962 faculty, now actually in session, is composed of Dean John E. Burchard, Professors Thomas M. Hill, Letwin, Charles A. Myers, and Carroll L. Wilson, and Associate Dean John M. Wynne. The All-India Management Association as the sponsors of this enterprise, and the Ford Foundation, who financed the dollar cost of this as well as of the Calcutta Institute described below, assure us that this program is having a major catalyzing effect on Indian management development in general. The participating faculty members, now numbering seventeen from M.I.T. alone, have each time been impressed by the competence and devoted involvement of the participating executives and by the productive possibilities of further communication with this group. Of greater importance in the long run, however, was the initial year of the School's active sponsorship of the Calcutta Institute of Management. It can hardly be said that this Institute, which we hope will be the first real graduate school of business in India, is yet operating, but some important progress has been made. Professor Hill, assisted by other American faculty members, undertook the critical assignment of developing plans and laying the groundwork in Calcutta in collaboration with the newly appointed Indian director of the Institute, K. T. Chandy, formerly Vice Chairman of Hindustan Lever. A nucleus of Indian faculty is now being appointed. The acquisition of land and the building of classrooms and hostel accommodations are now financed, and plans for the first short-term programs are under way. Only time will tell whether this Institute can play a critical role in the preparation of talent and the development of research so badly needed in India, but now at least a start is assured.

In Africa a different kind of project also reports progress. Here we see the extension and continuation of the work directed by Professor Wilson, previously reported, in which eight M.I.T. Fellows in Africa joined the original seven in serving two-year terms in a variety of managerial and technical administrative posts in seven countries of mid-Africa. Seven of the Fellows have had duties involving the selection and administration of suitable programs of major technical and financial aid for their assigned countries, two have held posts in ministries of finance, two are currently working in ministries of commerce and industry, two are working in law posts serving as principal architects in the development of new institutional arrangements for business and government, and the others are in the investment posts. The remarkable achievement of this program has demonstrated clearly that young management graduates can perform in major responsibilities for operational results in foreign governments; they have been accepted, and they have matured rapidly and effectively as representatives of this country. Next year ten more men will take up similar posts from Sierra Leone to Tanganyika. These new appointees will meet with the other M.I.T. Fellows and with M.I.T. faculty members for a ten-day conference in August, 1962, in Evian, France. Like the conference held in the summer of 1961 in Uganda, this conference should serve to help the Fellows explore problems in a broader framework and to help us all to understand the implications of their discoveries to management in general. The first of the M.I.T. Fellows appointed in 1960 will then return "home" for short terms as researchers in the School. They deserve a salute, these modern pioneers, for their achievements.

These international programs are more and more becoming logical extensions of the School's interest in management and administration. Far from being a one-way street, they afford faculty members and, indirectly, our students an invaluable opportunity to see contrasts and thus to see more clearly an approach to our own management problems as well as theirs. These programs represent difficult and often hazardous work, but they also offer opportunity for new learning.

SHORT-TERM PROGRAMS

In the 1961 Summer Session, members of the faculty once again conducted successful two-week efforts which served to communicate new ideas in industrial dynamics and marketing planning and strategy to both corporate managers and to professors from other institutions. The School also took responsibility for a day-long session in "Planning Organizational Change" held in Chicago, and for several shorter sessions on other topics. In addition, the School and its faculty served as hosts in the endless visitations of individuals and groups that have become a demanding part of the daily schedule in American universities.

THE INDUSTRIAL MANAGEMENT REVIEW

The *Review* is still a modest undertaking, but its excellent 1962 record promises a future that deserves its mention once again. The editors of the *Review* in 1962, chosen on the basis of their standing in the first-year class, were John V. Olszewski, Michael Roemer, Fred I. Steele, Charles H. Greer, and Emery G. Olcott. The editors now publish two issues each year and distribute over 1,500 copies to libraries, schools, and private subscribers.

The Administration of the School

THE ADVISORY COUNCIL

I wish to report with appreciation the continued activity in the service of the School of our Advisory Council under the chairmanship of Alfred P. Sloan, Jr. This distinguished group of men were on call for opinion and advice, they contributed their ideas in meetings and convocations, and they met in a full-day session in May, as usual, for specific consideration of the School's plans and programs.

INTERNAL ADMINISTRATION

I take pleasure in reporting that John M. Wynne, for the past three years Director of the Executive Development Programs, was appointed Associate Dean of the School on February 1. He brings experience and strength to the post, and every program of the School should show benefit. As previously noted, Mr. Gil replaces Mr. Wynne as Director of the Executive Programs. Completing our administrative group, Mr. Arthur L. Singer, Jr., becomes Assistant Dean, a post he holds jointly in this School and in the School of Humanities and Social Sciences. He will provide administrative support especially for the research management projects.

STAFF CHANGES

Last year I noted the arrival in 1961-62 of nine assistant professors, each of whom has now added new strength and scope to our teaching effort. I now wish to note with satisfaction the arrival for the coming year of several more key additions to our staff. These include: Dr. Franco Modigliani of Northwestern University, one of this country's outstanding management economists, who is appointed Professor of Industrial Management; Dr. John D. C. Little of Case Institute of Technology and Dr. William M. Evan of the Bell Telephone Laboratories, Inc., appointed Associate Professors; and Dr. David E. Berlew of Wesleyan University, James S. Hekimian of Harvard University, Dr. Gordon M. Kaufman of Harvard University, and Dr. Herbert Saltzstein of the University of Michigan, appointed Assistant Professors. We look forward also to continued association with Dr. Robert L. Dixon, Professor of Accounting at the University of Michigan, who will serve again as Visiting Professor of Accounting. We will also have with us during the coming year Dr. Lionello A. Lombardi, staff mathematician with Olivetti, who will serve as Visiting Associate Professor of Industrial Management, and Robert K. Greenleaf, on leave from the American Telephone and Telegraph Company where he is Director of Personnel Research, who has been appointed a Lecturer in the School.

At the same time, I record with regret the departure of several members of our faculty: Professor Eli Shapiro, who leaves a permanent impress of his work here at the School both as a Professor of Finance and as Associate Dean; Associate Professor Myron J. Gordon, whose work in accounting has been outstanding; and Assistant Professors Stuart E. Dreyfus, Chadwick J. Haberstroh, Thomas M. Lodahl, Richard B. Maffei, and William F. Massy. All will be missed. We are sure that each of them will make important contributions in their new assignments.

I take great pleasure in reporting the following promotions: Douglas M. McGregor was appointed Sloan Fellows Professor of Industrial Management. Edwin Kuh was appointed Professor of Finance and Economics, and Daniel Holland was appointed Professor of Finance. Paul Cootner and Herbert Goodwin were appointed to the rank of Associate Professor. Arnold Amstutz, Daniel Nyhart, and Edward Roberts were promoted to the rank of Assistant Professor of Industrial Management.

Staff Activities and Awards

M.I.T.'s faculty rightfully is asked to perform a variety of duties in a world larger than M.I.T. itself. These duties include advisory responsibilities, to governmental and other public posts, to other university and educational systems, to professional societies, and to business corporations. The members of the staff of the School of Industrial Management carry their share in this responsibility, as will be evident from even a brief review of the list of professional activities and awards at the back of this volume. In addition to those formal assignments which are compiled there, I report the following contributions by members of our staff: Professor Travis was appointed a senior staff consultant on a Harvard economics research project and served as an assistant to the American delegate to the United Nations consultative group on the social and economic consequences of disarmament. Professor Brown served as a member of the study group set up by the Committee on Economic Development on the public interest in the national labor policy. Professor Cootner served as a consultant to the Treasury Department on problems involving depreciation practices. Professor James C. Emery was on leave during the year to serve on the staff of the Assistant Secretary of Defense working on management information systems problems. Professor Bennis also spent the year on leave, to be a member of the faculty at l'Institut pour l'Etude des Methodes de Direction de l'Enterprise in Lausanne, Switzerland. Professor Hudgins was appointed a member of Area I Economic Stabilization Board. Dean Johnson continued to serve as consultant to the Internal Revenue Service, while Professor Holland continued as consultant to the Assistant Secretary of the Treasury. Professor Haberstroh conducted two missions to Buenos Aires, one for the United Nations Bureau of Technical Assistance Operations in the reorganization of the Argentine Internal Revenue Service, and the second to participate in the O.A.S. Conference on Tax Administration.

Summary

In summary, this report has been a positive one, and it reflects the prevailing spirit of the School. A school of management is in some ways a curious academic amalgam. The best schools in the future will have in their faculties men who can hold their own and more with the first-rate researchers and teachers in the pure disciplines of the social sciences, the humanities, and the sciences; men of substantial achievement in the actual operations of business, who have an abiding interest in generalizing solutions; and men who like to live in both the world of theory and the world of action, but who do not compromise one for the other. The new trend toward academic centers to attack problems not divisible into separate disciplines had its start long ago in the business school context where "interdisciplinary" means men well trained in one approach choosing to understand the framework of others. Such a mixture runs the risk of being second-rate. It has been exactly that in other times in other places. But at its best, such a company of talent produces an excitement of new discovery and an atmosphere of the real world that attracts new faculty and students who are interested in tackling the complex problems of management and who want responsibility for achievement. We have at M.I.T., for many reasons, an exceptional opportunity to reach this goal.

This is not to say that we do not have problems. We do. It is reasonable to expect that we will always be pressed by our sister schools of business. This shows up today in the increasing interest by other schools in almost every one of our junior and senior faculty members. It is a fact that at a given time a hungry competitor can propose attractive terms to almost any single member of our faculty. We lose some colleagues this way. But this pressure has its good side. A post at M.I.T. is highly valued currency in today's academic bourse, and we can attract the best of the young men across the country. I believe we are holding the quality of our faculty very well.

Our second problem is one of facilities. The need for a library and research work center for our students and faculty is now intense. There is literally standing room only in our small library, literally no place for students to converse, literally no environment for encouraging students to discuss their work together. The dormitory situation is no better, especially for our married students, many of whom live in very substandard albeit high priced quarters. We need living facilities at the east end of the campus for our students and others, quarters where a more effective traffic of ideas can take place. We have plans to improve these situations substantially, and with major help we can solve the problem.

But if we have problems, we also know we are making progress. The School is strong and growing stronger. We do not lack for talent in our faculty or in our student body. A wise administration gives us support and the freedom to act. We have excellent working relationships with other departments and schools of the Institute. Businessmen of major rank in this country support us with their ideas and encouragement. The continued understanding and resolute help of the Alfred P. Sloan Foundation is a source of strength to encourage the best in men.

HOWARD W. JOHNSON

School of Science

The most noteworthy trend of the past year has probably been the continued increase in cooperative effort among research workers in various scientific disciplines. Artificial organizational barriers are increasingly broken down by the needs of mutual interdependence.

The Cambridge Electron Accelerator, an example of close cooperation between Harvard University and M.I.T., has recently been brought into successful operation and will greatly forward work in high-energy particle physics. The cooperation between our earth science departments and the Woods Hole Oceanographic Institution is increasingly productive. The strong and active interdepartmental laboratories, whose activities are reported in more detail elsewhere in this report, continue to be most productive. The two newest of these which will greatly affect the School of Science are the National Magnet Laboratory and the Center for Materials Science and Engineering.

An increasingly close working relationship is developing between members of the Center for Communication Sciences and certain members of our biology faculty. Another example of the advantages of cooperation is found in the earth sciences, where four well-defined groups, specializing in the solid earth, in the waters of the earth (in the Department of Geology); in the earth's atmosphere and in the earth's waters as they affect the atmosphere (in the Department of Meterology) are amalgamated in the Center for the Earth Sciences. A new offshoot of this activity is the Committee on Planetary and Space Science (COMPASS), discussed below. This is an example of the new groupings and organizational entities which are frequently needed to give strength to teaching and research activities.

New recognition is being given to the importance of applied mathematics by giving the group working in this field a certain degree of autonomy within the structure of the Department of Mathematics. An informal applied mathematics curriculum is being set up, soon to be listed in the M.I.T. General Catalogue. This will not be a new option but rather a sequence of selected subjects in which students primarily interested in the applied field will be encouraged to enroll. There has also been appointed a Committee on Applied Mathematics, of which Professor Chia-Chiao Lin is Chairman, to be concerned with undergraduate and graduate curriculum matters, research, and other topics related to the development of applied mathematics. In addition, an Applied Mathematics Subcommittee of the Mathematics Department Policy Committee is being formed, of which the head of the Department of Mathematics is to be chairman *ex-officio*.

There are, of course, many applied mathematicians in the various science and engineering departments of the Institute. These will continue their present departmental affiliations, but they will be encouraged to work as closely as they desire with the central nucleus of applied mathematicians in special committees, centers, and groups as need arises.

ENROLLMENT TRENDS

The number of students majoring in science curricula at the Institute continue to grow. In the Department of Biology the number of undergraduate majors has more than doubled at all levels in five years, resulting in temporarily overcrowded undergraduate laboratories. In mathematics, a larger department, the number of undergraduate majors has nearly trebled in five years. The number of students selecting chemistry as a major subject, which had diminished in recent years, is now again increasing. In physics, which has become one of the most populous departments in the Institute, undergraduate enrollment is approaching equilibrium through saturation.

The number of non-major enrollments in science subjects is again at an all-time high. The total number of roll cards in physics subjects approaches 6,500 per year, while in mathematics it now exceeds 8,000. To teach so many students in small sections and to maintain instructional quality demands constant attention to the expansion of the faculties of these departments.

In number of candidates for advanced degrees, all of the science departments show a healthy growth, and the shift in center of gravity of enrollment toward ever more advanced study continues. Two science departments—Meteorology, and Nutrition, Food Science and Technology—accept only graduate students, and enrollment in both is increasing. In the latter field especially, graduate enrollment can be expected to increase even more in the next few years as several new sub-disciplines become activated. In physics and chemistry, with more than 200 graduate students each, numbers are being held fairly steady by quota restrictions.

National statistics show that in the decade from 1948 to 1958 more Ph.D.'s in physics came from M.I.T.'s department than from any other single physics department in the U.S., although the Institute is designated second in the list as an institution, first place being occupied by all the campuses of the University of California taken together.

Post-doctoral study in science also is increasing. The Departments of Biology and Chemistry together now have 140 such workers, and the number is growing in all departments.

An even more desirable trend, now very noticeable, is the continuing improvement of the quality of the students entering science courses. This is particularly marked in mathematics, where an upgrading in the level of material considered in certain courses has been made possible by improved student preparation. The effects of recent reforms in secondary school science teaching are already noticeable in the quality of the product received in the universities, and M.I.T. has benefited particularly as a result of its selection program.

There is some indication that our admissions policy may be operating to select an undesirably large proportion of theoretically inclined students, with no compensating mechanism to insure the inclusion of those with marked experimental aptitudes. Some departments have reported a paucity of graduate students with adequate natural skills in the experimental aspects of science to act as laboratory instructors. This matter is being studied by the Admissions Office, and the science departments are following the analysis closely.

TEACHING AND CURRICULA

The current rapid growth of all the sciences and their increasing proliferation into sub-disciplines requires that frequent attention be given to desirable changes in course content and to new sequences of course specialization. From time to time new curricula must be arranged, at first informally through recommendation of selected electives and later by faculty action.

As a case in point, oceanography is a discipline only recently introduced at the Institute. It overlaps the boundaries between geology and meteorology, and it has profited markedly from the fact that these two previously separate disciplines are now joined in the Center for Earth Sciences. Twelve students specializing in oceanography are now majoring in the two departments, and, in fact, one-fifth of all applicants for graduate status in meteorology desire so to specialize.

Planetary and space science is another example of a field which may well give rise eventually to a formal curriculum, and the problem of how this rapidly expanding area is to be coupled with the earth sciences has been the subject of much discussion. Professor Raymond Hide has led a group concerned with arranging a series of informal meetings attended by staff members from such departments as Geology, Meteorology, Mathematics, Physics, Aeronautics and Astronautics, and Electrical Engineering. A Committee for Planetary and Space Science, designated COMPASS, has developed from these meetings.

A preliminary brochure is in preparation to set forth the views of the committee members on such matters as a special graduate curriculum, colloquia and seminars, thesis research, and graduate student support. Plans are now being made for the further development of space science in directions other than those originally envisaged by the members of COMPASS, and a Space Science and Engineering Committee has been established under the chairmanship of Dr. Charles H. Townes, Provost, to correlate Institute activities in this important field.

The Science Teaching Center, whose activities are detailed in a later section of this report, has made especially noteworthy progress during the past year. Under the leadership of the late Professor Francis Friedman, an able and active staff continued pedagogical research; the results are proving quite as interesting and important as those coming from more common types of scientific investigation. Dr. Friedman's untimely death will be felt by all his colleagues, but especially will his leadership in this important activity be sorely missed in years to come.

Professor Nathaniel H. Frank has been on leave from his duties as the head of the Physics Department during the past year so that he might contribute his skills and experience to the Science Teaching Center. He has now been charged with assisting all of the science departments in utilizing the developments coming from the Center.

The Department of Physics is planning to make available a new experimental version of first-year physics, 8.01, which Professor Frank will teach in parallel with the usual version. The new approach arises from the basic conviction that no effort must be spared in leading the student to the fundamentals of physics through his own experimental experience, whenever possible, rather than by assertion. One of the great contributions of the Science Teaching Center has been the demonstration (as was earlier done by the Physical Sciences Study Committee for physics in the secondary schools) that this is possible in many more cases, and much more effectively, than had been thought.

Two films, designated to make the freshman directly aware of the experimental evidence for the quantum theory and relativity, have already been completed. One, dealing with experiments performed with the linear accelerator, shows most convincingly that there is indeed an ultimate speed limit for electrons as their energy is increased. The student can observe pips on an oscilloscope which show that as the time required for passage of particles is increased their speed lags behind proportionally, and the relativity effects become obvious. Soon every M.I.T. freshman will be able to carry out such experiments with his own hands in the laboratory.

The importance of removing the apparent dichotomy between classical and modern physics before the beginning student becomes aware that any has existed is becoming increasingly obvious. The results achieved by Professors Jerrold R. Zacharias, Friedman, Frank and their collaborators show that many of the previous barriers to progress in understanding physics are completely removable, and these results are of the utmost importance. More on this important subject will be found in the report written by Professor Friedman shortly before his death in July.

The Science Teaching Center has been given no mandate of responsibility for the teaching of science at M.I.T.; this is a function of the various science departments. It is, however, providing a wealth of new pedagogical method and material which the entire School is finding useful and suggestive.

RESEARCH ACTIVITIES

Although many research activities and achievements are listed below in the reports of the various department and laboratory heads, these give only a selection of typical projects which in turn represent only a small fraction of those in progress.

In all, more than 500 research projects are being carried on in the School of Science, and they cover an extremely broad range of subjects. When classified according to the energetics of the processes involved, they range from the more than 10^{20} volts of some cosmic rays down to millionths of a volt in certain life processes. It is difficult to mention a field of modern fundamental scientific activity, directed to the understanding of natural phenomena, which is not represented at M.I.T. Yet the list is kept very carefully pruned, and many topics, such as taxonomy, systems of classification and other more descriptive aspects of science, are excluded in favor of direct attacks on the understanding of phenomena.

Marked in many fields of science is the growing need for new methods of data reduction, capable of distilling from large masses of accumulated quantitative material the essential content in a form to make this readily assimilated by scientists. Thus the vast array of temperature, pressure, wind velocity, and other readings which comes daily into a meteorology laboratory needs summarizing and correlating before the trained meteorologist sets to work on it. Similarly, workers in the high-energy laboratories need automatic methods of reducing data obtained with bubble chambers, scintillation counters, and the like. This problem of eliminating the non-essential and boiling down information to more readily assimilable form by automatic means is becoming critical in many laboratories today, and it is receiving much attention from data reduction and computer specialists.

SPACE AND FACILITIES

The School of Science finds itself in the midst of an Institute building program which will contribute markedly to its effectiveness and make possible proper housing of our expanded activities in all the scientific fields.

The new Green Building, future home of the Center for Earth Sciences, is now actively rising and will soon dominate the campus scene from its eminence of twenty stories. We hope that this building will be occupied early in 1964.

The crowded situation in the Dorrance Laboratory, occupied by the life sciences, has become almost intolerable in the past few years; it has been partially ameliorated by construction of new laboratories on the eighth floor. A number of new staff members of the Department of Nutrition, Food Science and Technology are being accommodated in temporary space, and it is hoped that more extensive laboratories can be set up in the Daggett Building shortly.

These particular space problems will be solved within two years, however, when the projected Center for the Life Sciences Building, an extension of the Dorrance Laboratory, is to be completed; construction will begin in the fall of 1962. When this new Center is occupied the space allotted to the two departments will be more than doubled.

Plans for a new building for chemistry, required to correct current overcrowding and to permit moderate expansion during the next ten years, are now being drawn. As a temporary expedient, the space allotted to the department has been increased by approximately 20 per cent by the provision of laboratories for nuclear chemistry near the Nuclear Reactor and by improvement of certain basement space. This problem will not be completely solved, however, until a new building for chemistry, projected for the space in front of Building 6, is available.

With the continued increase in enrollment and staff in mathematics, space problems in this department are still pressing. It is hoped that when the new chemistry building becomes available it will be possible to assign to mathematics some of the space now occupied by offices and classrooms for chemistry; in anticipation of this a rearrangement of offices in mathematics is being made so that staff concerned with a particular sub-discipline, such as applied mathematics, may have neighboring offices.

The needs for space in the School of Science will also be helped when the new Center for Materials Science and Engineering is completed. The Physics Department, already overflowing the Karl Taylor Compton Laboratories completed in 1957 and its original space in Eastman, is eyeing the possibility of a new building in the not-too-distant future.

PERSONNEL

The increasing intermixing of faculty and students from various institutions which is made possible by the fellowship programs now available from various foundations and the federal government is clearly very valuable. The temporary interchange of faculty members is aided by the Institute's educational leave policy, under which up to 10 per cent of the faculty members of a given department may be considered for educational leaves in any given year. Thus as many as twenty members of the faculties of the science departments may be absent at any one time for study abroad, teaching at other institutions, or carrying out special research activities elsewhere. These are usually temporarily replaced by visiting professors and lecturers coming, in turn, from other institutions and activities.

Detailed changes in faculty appointments are listed and discussed elsewhere in this report, and I have already referred to the important assignment of Professor Frank in furthering the utilization of the results of the Science Teaching Center.

In August the Institute sustained a tragic loss in the death of Professor Francis L. Friedman of the Department of Physics. Professor Friedman, who came to M.I.T. as an instructor in 1946, had made unusually important contributions to the work of the Department, both in research and teaching. He was an expert in nuclear and theoretical physics and in cosmic ray shower theory, and he exerted great influence as a major figure in the Physical Science Study Committee, which reshaped science education in American secondary schools, and as Director of the Science Teaching Center at M.I.T. A person of extraordinary qualities of spirit and intellect, Professor Friedman will be greatly missed.

Professor William W. Beuchner, who has been acting head of the Department of Physics since March 15, 1961, has now succeeded Professor Frank as head. Professor Beuchner brings to his new post an extensive background of teaching, research, and administration at M.I.T. An alumnus of the Institute, he has been continuously associated with the Physics Department since receiving his doctorate here in 1939. He played a leading role in the development of the Van de Graaff generator and its associated ion sources. His first administrative experience was as Associate Director of the High Voltage Laboratory, and he was later appointed Director of the M.I.T.-O.N.R. generator when it was established in 1951. Under his direction this laboratory facility has become one of the foremost of its kind in the world.

Professor Nevin S. Scrimshaw has completed his first year as head of the Department of Nutrition, Food Science and Technology, and he has already greatly enlarged the activities of the Department. His first report as Department Head appears below.

No discussion of personnel at the Institute would be complete without reference to the very important Visiting Committees of the Corporation, which meet at stated intervals with the various departments and with the administrative officers concerned. Not only do these committees make important contributions to the improved operation of the departments, but they provide a very important strengthening of morale to the deans, to the department heads, and to individual faculty members. The willingness of their members to furnish their valuable time to the aid of the departments is greatly appreciated.

EXTRA-INSTITUTE ACTIVITIES OF THE DEAN

The Dean of the School of Science has during the past two years visited a number of South American and later several Central American universities on behalf of the Science Improvement Program of the Ford Foundation. In the summer of 1962 he again visited universities in Argentina and Brazil in connection with university science equipment loans to be made by the Inter-American Development Bank.

Despite the considerable handicap of unstable political situations in several of the more important South American countries, rapid strides are being made in many of the universities, particularly in the science faculties. Observation of the development of science teaching and research in such environments throws much light on matters affecting policymaking and planning in our own School of Science.

GEORGE R. HARRISON

Department of Biology

In September, 1961, we initiated the new joint curriculum in the Life Sciences, which includes basic studies in mathematics, physics, and chemistry and a core curriculum in biology. The latter emphasizes basic concepts and theories of biology and is designed to prepare students especially for graduate work in medicine, nutrition, food science, biophysics, biochemistry, physiology, and microbiology. This new undergraduate curriculum in Course VII promises to become one of the important programs in the School of Science; it is already the School's fourth largest Course in terms of numbers of students.

A new Biology Seminar was given this year by all the faculty of the Department to introduce first-year graduate students to our various research programs. Another new subject, Biological and Neurological Control Systems, was offered for the first time by Dr. Lawrence Stark. It carries graduate credit in either biology or electrical engineering and is designed to explore servomechanisms of living organisms with special reference to the nervous system and sense organs. This subject is already serving to bring research workers in the Center for Communication Sciences and the Department of Biology closer together.

The number of students at all levels, including undergraduate, graduate, and postdoctoral, has more than doubled in the past five years. The same is true of the research program of the Department. Although such growth is most gratifying, it has also brought with it certain problems. For example, the tripling in number of students enrolled in the undergraduate laboratories has resulted in very serious overcrowding. The faculty assigned to teaching undergraduate biology is no longer large enough to cope with the problems which have arisen, and additional instructors are needed, especially for laboratory subjects. It is expected that the problems of overcrowding will be alleviated when the new Center for the Life Sciences building is available in another three years.

NEW LABORATORIES FOR CELL BIOLOGY

During the past year the new laboratories for cell biology were opened on the eighth floor of the Dorrance Building. These laboratories are partly occupied by Professor Eugene Bell and his associates who are exploring problems of growth and development in embryos and in cells grown in tissue culture. They are shared by Professor James E. Darnell and his group who are investigating protein biosynthesis in polio virus grown in tissue culture and, in collaboration with Professor Salvador E. Luria, are beginning studies of viruses which produce cancer in mammals.

NEW FACULTY

Both the student body and the academic staff profited greatly from having three visiting professors in the Department during the academic year. They were: Professor Alex Keynan from the Hebrew University; Professor John Platt from the University of Chicago, and Professor Donald Glaser, Nobel Laureate, from the University of California. In addition, Professor Corrado Baglioni of the Institute of Molecular Biology in Naples taught the undergraduate subject in genetics and participated in the research program on hemoglobin biochemistry.

RESEARCH

In biochemistry, major attention has been devoted to problems of biosynthesis. Professor Gene M. Brown has discovered how precursors are put together in the living cell to make thiamine, nicotinic acid, and folic acid. The enzyme reaction involved in folic acid formation is blocked by the sulfur drugs which suggests a mechanism by which these antibiotics can arrest bacterial growth. Professor John M. Buchanan has studied the role of folic acid and vitamin B-12 in the synthesis of the amino acid methionine from homocysteine. He has discovered that certain steps in this reaction are blocked by the anti-cancer drug, azaserine. Professor Bernard S. Gould has established the fact that ascorbic acid plays a role in wound healing by being directly concerned with the biosynthesis of collagen. His group has discovered a major building block, RNA-hydroxyproline, in tissues where collagen is undergoing rapid synthesis. Dr. Francis O. Schmitt and his group have evidence that fibrogenesis involves the polymerization of tropocollagen monomers through interaction of terminal peptide chains. Professor Vernon M. Ingram has continued his chemical and genetic analysis of human abnormal hemoglobins and has related these abnormalities to substitution of one amino acid for another in the peptide chain of hemoglobin. This substitution appears to result from the mutation of the hemoglobin gene. Professor Phillips W. Robbins has studied the polysaccharide antigens of the cell membrane of *Salmonella* bacteria. He has found that the chemical composition is modified in a dramatic fashion as a result of infection of the bacterium by a virus.

Professor Cyrus Levinthal has found 150 mutations which affect the physical, chemical, and enzymatic properties of the bacterial enzyme, alkaline phosphatase. It appears that some of the gene mutations are so profound that the phosphatase protein has totally different immunological, electrophoretic, and enzymatic properties. In the normal bacterium the production of this enzyme is repressed by the presence of inorganic phosphate which is the normal end-product formed by this enzyme. Such feedback mechanisms for the control of enzyme production seem to be quite general in microorganisms. Professor Alexander Rich has demonstrated by means of x-ray diffraction techniques that DNA and RNA can form mixed two-stranded or three-stranded helices. This may provide insight into the way in which the code of the DNA is handed on to RNA in the nucleus of the living cell. By means of electron microscopy, Professor Cecil H. Hall has studied the conversion of the fibrinogen molecule to fibrin during the process of blood clotting; he has also shown that one of the very small viruses has an icosahedral shape with a shell of protein molecules surrounding a core of nucleic acid. Professor David F. Waugh has continued his studies of the colloidal properties of blood and milk. Of special interest is his finding that the key reaction in the clotting of milk to form curds and whey, brought about by the enzyme rennin, is the hydrolysis of kappa-casein by the rennin, thereby disrupting the colloidal system of the milk and leading to the formation of a clot. In recognition of this work, Professor Waugh was awarded the Borden Prize by the American Chemical Society.

For the first time, Professor Jerome Y. Lettvin and his colleagues have succeeded in recording electronic impulses from single receptors of the olfactory mucosa. This work makes possible an interpretation of the sense of smell in terms of the stimulation of specific receptors by different odiferous chemicals. In its studies of cutaneous sensation, Professor Patrick D. Wall's group has found that information from the sense organs is transmitted as a space-time pattern of nerve impulses resulting in a coding of information prior to its arrival in the central nervous system. Original work on the very small cells of the spinal cord has shown that they are generators of slow potentials of the dorsal root of the cord, and it is believed that these same cells are responsible for modulating activity in the central nervous system. These studies are rapidly resulting in information on the roles of convergence of nerve cells onto other nerve cells and the mechanism by which relay stations in sensory pathways act as filters.

Professor Boris Magasanik has elucidated certain aspects of the metabolic regulation of the synthesis of proteins and of RNA. The repressive effects of catabolic products on the synthesis of enzymes which catalyze the formation of such products has been demonstrated in many microbial systems. The same type of approach is now being applied to an exploration of the regulation of the synthesis of ribosomes of the cell cytoplasm. Professor Luria has studied the function of genes introduced by viruses into their host cells and has thereby clarified the mechanism of virus infection. This study shows how gene regulation can affect normal and abnormal reactions in the living cell. The way in which viruses carry genetic information among cells appears to have special significance to the cancer problem. There appears to be a strong possibility that in cancer cells some genes escape normal regulation because of their location in virus-like elements.

IRWIN W. SIZER

Department of Chemistry

The number of undergraduate majors in chemistry who received the B.S. degree in June, 1962, dropped to 13, but last year's record was continued in that all of these students are continuing study as candidates for advanced degrees in various universities. The number of undergraduate chemistry seniors next year will increase to 37, the largest group in many years. Since all of these men will do a senior thesis next year, the research space in the Department will be severely strained to accommodate them in addition to the group of faculty, doctoral candidates, research associates and postdoctoral fellows engaged in research.

CURRICULUM

Two new graduate subjects are being introduced into the curriculum beginning in the fall term of 1963. Advanced Organic Chemistry Techniques, to be taught by Professor Glenn A. Berchtold, will be concerned with modern techniques for organic research, including spectroscopy, mass spectrometry, and chromatography; application of modern techniques to the purification and determination of the structure of organic compounds also will be discussed. This subject has been added because of the recent extensive growth in the use of instrumental methods in organic chemistry.

Special Topics in Nuclear Chemistry, to be offered for the first time next fall by Professor Glen E. Gordon, will provide doctoral candidates in nuclear chemistry with a thorough background in all of the important aspects of that field. The content of this new subject will change on a three-year cycle.

PERSONNEL

President Kenneth S. Pitzer of the William Marsh Rice University was the tenth Arthur D. Little Visiting Professor of Chemistry during part of the fall term of 1961. His lectures on "Selected Topics in Physical Chemistry" dealt with intermolecular and intramolecular forces as related to molecular conformations, internal rotations, and equations of state for fluids and with additional topics of current interest including the thermodynamic and spectroscopic properties of marginally metallic systems such as solutions of alkali metals in ammonia and in fused alkali halides.

Professor Ernst Berliner of Bryn Mawr College was a guest of the Department as a Guggenheim Fellow during the spring term of 1962 and participated in seminars and delivered lectures in physical-organic chemistry.

Professor John S. Waugh was on sabbatical leave during the 1962 spring term and spent two months at the University of Moscow. Professor John C. Sheehan also was on sabbatical leave during the 1962 spring term, visiting universities and lecturing in England, Israel, and Japan.

Professor Nicholas A. Milas has reached the retirement age but will continue as Lecturer in the Department; Professor Walter H. Stockmayer has resigned his faculty appointment to join the Department of Chemistry at Dartmouth College.

New appointments for the fall term will include those of Dr. James L. Kinsey to be Assistant Professor of Physical Chemistry and Dr. David K. Roe as Assistant Professor of Analytical Chemistry. Dr. Kinsey completed graduate work at Rice University and has since studied at the Universities of Uppsala, Sweden, and California, Berkeley. Dr. Roe, who comes to M.I.T. from the Shell Development Company, completed graduate work at the University of Illinois and held a National Science Foundation postdoctoral fellowship for work at the Max Planck Institut für Metallforschung in Stuttgart, Germany.

FACILITIES

The extreme shortage of research space in chemistry will be somewhat relieved in the summer of 1962 with the completion of laboratories for research in nuclear chemistry adjacent to the M.I.T. Reactor. These laboratories, being constructed with the aid of National Science Foundation funds at a total cost of about $475,000, will provide approximately 10,000 square feet of space, increasing the research space in chemistry by about 13 per cent. The National Science Foundation has also provided funds to aid the program of remodeling space in the basement of Building 2 for research laboratories in physical chemistry and mass spectrometry. The cost of this project is expected to be $140,000, and these laboratories will increase research space in chemistry by approximately 7 per cent.

RESEARCH

Active research programs are being conducted by thirty-one faculty members of the Department. In 1962, participants in these programs included 202 doctoral candidates, 70 postdoctoral fellows, and 14 seniors. The doctoral candidates and postdoctoral fellows continue to perform a most important function in teaching as well as in research.

Some of the important accomplishments in research during the year were the following:

Professor Klaus Biemann and his research group have continued to explore the applicability of mass spectrometry to the elucidation of the structure of complex organic compounds. Major emphasis has been on amino acids and alkaloids. As a result, the structures of four new amino acids occurring in plants or antibiotics were established. The mass spectra of various alkaloids proved very valuable and permitted the determination of structure of about fifteen indole alkaloids. This new technique makes it sometimes possible to arrive at the structure of an alkaloid if only as little as a few milligrams is available, and the procedure is of particular interest for the investigation of all of the alkaloids occurring in a given plant. Further efforts have been made to extend the use of mass spectrometry to compounds of very low volatility and to extremely small samples. It has been possible to obtain very useful spectra with a series of nucleosides and of free amino acids, sometimes using only a fraction of a microgram. In addition to these specific problems, the mass spectra of polyfunctional organic molecules in general are being determined and interpreted to extend our knowledge of the basic principles of organic mass spectrometry.

Work on the low-temperature elastic constants of single crystals is being carried out under the supervision of Professor Carl

W. Garland. Results on both zinc and cadmium have established the similarity of bonding in these highly anisotropic hexagonal metals and have made possible a more detailed interpretation of their thermodynamic properties at low temperatures. Recent measurements of ultrasonic velocity and attenuation in ammonium chloride near the λ-point have provided new information concerning this order-disorder transition; a lattice-dynamical interpretation of these results is in progress. In addition to the above investigations, related work is being carried out in low-temperature calorimetry. Measurements of the heat capacity of crystalline linear polyethylene have been completed in the liquid helium range.

Professor John S. Waugh and his students have been using nuclear magnetic relaxation as a means of studying molecular dynamics. In gases they have been able to obtain information about the part of the force between two molecules that depends on their relative orientation. They have studied molecular motions in crystalline solids, especially those involved in the establishment of ferroelectricity. They are using nuclear magnetic resonance as a tool for studying self diffusion in liquids over unusually wide ranges of temperature and pressure, in an effort to provide severe tests of current theories of transport processes in fluids.

Professor Berchtold and his students have investigated various reactions of enamines. This class of compounds reacts with ketene by a cycloaddition mechanism to produce substituted 3-aminocyclobutanone derivatives. These products are in many cases relatively unstable and undergo ring opening to the mono-enamine of β-dicarbonyl compounds. These latter products can be treated with excess ketene to form α-pyrones containing a carbonyl substituent in the 5-position. In some cases the α-pyrones can be obtained directly from the simple enamines by treatment with an excess of ketene. This sequence has merit for the synthesis of a number of α-pyrones.

Research by Professor Gordon and his students includes development of computer methods for a Monte Carlo calculation of nuclear-reaction probabilities, including fission-spallation competition, and least-squares analyses of complex radioactive growth and decay curves and beta-particle energy spectra. Results from the Monte Carlo calculations indicate that in the astatine region level densities at the fission saddle point are normal, whereas those for nuclei resulting from neutron emission are depressed under the influence of the nearby

82-*p* and 126-*n* closed shells. A new isomer, 62-sec Sc^{42m} has been discovered and Ca^{42} levels formed in its decay studied. The latter studies are quite important for theoretical calculations on the coupling of $f_{7/2}$ nucleons, as Ca^{42} has two $f_{7/2}$ neutrons outside the Ca^{40} core. Current work involves further studies of nuclear level densities, decay-scheme studies on short-lived antimony fission products, range and energy measurements on fragments from thermal-neutron and photofission, and determination of excitation functions for heavy-ion-induced nuclear reactions.

Professor Gordon G. Hammes and his associates have been concerned with studying the kinetics of fast reactions in enzymatic and related model systems. The relaxation methods being employed allow measurement of time constants as short as 10^{-9} seconds. This past year the enzyme glutamic-aspartic transaminase was investigated with the temperature jump method. The time range covered was from a few microseconds to about one second. This is the first time such fast rates have been studied in biological systems. At least eight discrete intermediates have been identified for over-all reaction and, in addition, spectral information about many of these intermediates was obtained. Continuation of this study should disclose an even more detailed mechanism for enzymatic transamination.

The reactions of metal ions with amino acids, peptides, and other biologically interesting compounds were also studied. The rate constants were found to depend greatly on the groups coordinating the metal; for example, if a charged group is bound to the metal, subsequent reaction with another ligand occurs faster than if a non-charged ligand is initially attached to the metal. All of these results are consistent with the theory that the rate controlling step is the release of a water molecule from the inner hydration shell of the metal ion. These systems should prove useful as models for more complicated ligands such as proteins and polynucleotides which are currently being investigated.

In addition to the above project, attempts are being made to study fast conformational changes in macromolecules with the temperature jump and ultrasonic attenuation measurements. The results obtained may help provide an explanation for the tremendous catalytic efficiency of enzymes.

From a study of carbanions, Professor Herbert O. House and his students have found a new method for the production of five-, six-, seven-membered cyclic ketones from the appropriate ω-halo esters *via* the intermediate phosphorus ylids as well as a convenient procedure for the direct formation of the useful organic base, triphenylmethylpotassium, from triphenylmethane and potassium. These studies have also led to a procedure for measuring the rates of reaction of simple ketones with Grignard reagents which is providing information useful in determining the mechanism of this reaction.

Other studies have led to convenient syntheses of azabicyclic ketones analogous to those found in naturally occurring alkaloids. Studies of the chemistry and physical properties of these azabicyclic ketones are providing a useful measure of the importance of interactions between functional groups nearby in space as a factor for controlling the stereochemistry and reactivity of these functions. Among the results of these studies are a very convenient procedure for removing methyl groups from quaternary ammonium salts and a simple procedure for determining the relative stereochemistry of alcohol and tertiary amine functions within the same molecule.

ARTHUR C. COPE

Department of Geology and Geophysics

During the past year further progress was made in bringing more closely together the varied instructional and research activities in the several earth sciences. More students than ever before registered in the oceanography subjects and carried on thesis research. The freshman electives offered in astronomy and earth science together attracted about 20 percent of all freshmen. In spite of this freshmen interest, however, sophomore registration in Course XII fell to six students, the lowest since World War II. However, this decline in undergraduate geology enrollment, which was nationwide, did not affect the size of our graduate group, which remained at 65—essentially the same as in 1960-61.

DEPARTMENTAL ACTIVITIES

The fourteenth Summer School of Geology was held at the Nova Scotia Centre for the Geological Sciences near Antigonish, Nova Scotia, with Professor William H. Dennen as Director. Professor Walter L. Whitehead, who directed the School for its first ten years (1948-1957), served as resident Lecturer, and Professor Donald J. MacNeil, Chairman of the Department of Geology at St. Francis Xavier University in Antigonish, again acted as Lecturer and as our local representative.

Twelve M.I.T. juniors participated in the program which consisted largely of field work near the Centre. Although the student group exceeded by four the number of the preceding summer, lower sophomore registration in Course XII forced upon us the decision to discontinue the School because of excessive operating costs. Consequently, Course XII undergraduates of the Class of 1964 will receive their required summer field training in 1962 at the Indiana University Field Station near Caldwell, Montana, (for geoscientists) or at the Woods Hole Oceanographic Institution (for oceanographers).

For the twelfth summer we participated in the Student Cooperative Program of Geophysical Service Inc. of Dallas, Texas. This cooperative plan, started originally as a joint venture by M.I.T. and G.S.I. for training exploration geophysicists for the petroleum industry, has now greatly broadened in scope. As in all previous years, the program was organized and managed by Dr. Cecil H. Green '23, Honorary Chairman of the company and member of the M.I.T. Corporation.

Two Course XII juniors and nineteen other students from fourteen other colleges worked as field assistants on seismic and gravity crews. Before going to their field assignments, the students spent a week in Dallas attending a series of more than forty short lectures delivered by professional geologists, geophysicists, and geochemists. M.I.T. was represented by Professors Peter Elias and Robert R. Shrock, both of whom participated in the orientation program.

Recognizing that four distinctly different though closely related sciences are now included in our departmental instruction and research program, we created four committees to guide these programs and to supervise thesis research. These committees met regularly with interested students to discuss their academic work and thesis research. They also formulated policy and brought their recommendations to our regular monthly staff meetings. By this arrangement, each undergraduate and graduate student in Course XII came under the direct supervision of the committee involved with his field of interest. Staff members served on the committee or committees that represent their fields of interest and were thus able to exert their influence wherever they felt policy should be revised.

School of Science

The problem of how the earth sciences are to be coupled with planetary and space science, and how this latter rapidly expanding new area of science is to be organized and supervised at M.I.T., came up for much discussion during the year. Professor Raymond Hide took the leadership in arranging a series of informal meetings, the outcome of which is described in the report of the Dean of the School of Science.

PERSONNEL

Professor William F. Brace was awarded an extension of his Guggenheim Fellowship and continued study of the behavior of rocks and minerals under various temperatures and strain rates. The second term was spent investigating certain folded mountains in Europe.

Institute Professor Martin J. Buerger spent the spring term as Visiting Professor of Crystallography at the Institute of Physics and Mathematics, University of Chile in Santiago, under the auspices of U.S. Aid to Chile.

Professor Roland D. Parks was on leave to serve as Lecturer in Mining Engineering at the University of Assiut in Egypt. This assignment involved participation in the educational exchange program of the Department of State. Professor Parks delivered a series of lectures at the University of Assiut and assisted in organizing a program of instruction in mining engineering at that institution.

Dr. Raymond Hide, a member of the Physics Department of Kings College, University of Durham, joined our staff as Professor of Geophysics and Physics in January, 1962. His areas of special interest are the earth's magnetic field and the fluid dynamics of planetary atmospheres and oceans.

Dr. Dayton E. Carritt, formerly at the The Johns Hopkins University, joined our staff as Associate Professor of Chemical Oceanography. He divided his time equally between M.I.T. and the Woods Hole Oceanographic Institution and initiated several subjects in chemical oceanography. Next year he will be full-time at M.I.T. during the academic year and at Woods Hole during the summer.

Dr. Joseph L. Gillson, retired Chief Geologist of the du Pont Company, became the first William Otis Crosby Lecturer. He delivered a two-term series of lectures on his special field of industrial minerals. The lectureship was established by Irving B. Crosby '18 in honor of his father, a member of the Class of 1876 who was the fifth professor of geology at M.I.T. and the third chairman of the Department of Geology.

RESEARCH

The past year was typical in the number of degrees granted—ten Bachelor's, five Master's, and six doctoral. It was one of much increased activity in staff and student research. As in recent years research consisted chiefly of experimental and theoretical investigations of the physical nature, chemical composition, and geological age and history of the earth's crust and mantle. Two major research programs were added during the year, one in oceanography and one in the hydrodynamics of rotating fluids.

Professor Buerger continued investigation of the crystal structure of a dozen minerals, using x-ray diffraction with a precession camera and a single crystal counter diffractometer and treating the data on the I.B.M. 7090 computer. Professor Brace investigated the behavior of rocks and minerals at low confining pressures under both laboratory and field conditions. Professor Hide initiated a major program in the hydrodynamics of rotating fluids, using a newly prepared laboratory in Building 20. In our Geochronology Laboratory Professors Patrick M. Hurley and Harold W. Fairbairn, using an array of mass spectrometers, continued investigations of variations in radiogenic isotopes in minerals and rocks both recent and ancient. One noteworthy result of this program was the formulation by Professors Hurley and Harry Hughes of a new concept of continent formation. Professor William H. Pinson expanded his investigation of tektites and meteorites, utilizing a new laboratory developed for the purpose in Building 24. The Cabot Spectrographic Laboratory under the direction of Professor Dennen increased its student research activities during the year and concluded a detailed investigation of the trace-element content of quartz. Professors Carritt and John W. Winchester initiated a major research program in the chemistry of sea water, using neutron-activation analysis. This program, supported by the Office of Naval Research, made it possible for several graduate students in chemistry to do their thesis work in our newly developed geochemistry laboratory in Building 20. Included in this program were studies of the following problems: abundance and distribution of rare earths in rocks and sea water; halogen ratios in sea water, rain water, and the atmosphere; stable calcium isotope abundances in minerals; and elemental fractionation in sea forms.

Professors Theodore R. Madden and Thomas Cantwell continued their measurements of the conductivity of the earth's crust, including use of natural electromagnetic fields for shallower conductivity structures, and also analyzed I.G.Y. data to determine the deep conductivity structure of the earth. Study was begun on the problem of the resonance character of the audio-electromagnetic signals due to the earth-ionosphere cavity. A study for the VELA UNIFORM project was also initiated to gain some insight into the possibilities of on-site detection of underground explosion sites by means of electrical measurements. These VELA studies involved laboratory and theoretical investigations of the cross-coupling properties of rocks and actual field measurements at underground blast sites. Professor Stephen M. Simpson, Jr., continued his study of ways for discriminating between seismic records from nuclear blasts and those of natural earthquakes, a part of the VELA UNIFORM project, and also investigated how high-speed computers might further be used on classic seismic problems. Professor Hughes coupled measurements of conductivity of minerals and rocks with theoretical work in thermodynamics and the physics of solids to gain a better understanding of the nature and composition of the earth's mantle and core. He collaborated closely with Professor Hurley in formulating a new hypothesis to explain how continents have been formed. Professor Ely Mencher initiated a program of field investigations of middle Paleozoic rocks in Maine in which he and his students cooperated closely with the United States Geological Survey and the Maine Geological Survey. Finally, a major program of oceanographic research was launched with Office of Naval Research support. This program, under the general direction of Professor Shrock, was organized with close cooperation of a number of scientists at the Woods Hole Oceanographic Institution, and much of the research that was started involved use of the facilities and supervision by staff members of that institution. The program henceforth will be under the supervision of Professor Carritt.

CURRICULUM, CONFERENCES, AND SYMPOSIA

Increasing interest in oceanography was indicated by the largest number of graduate students ever registered in this earth science at M.I.T. Several new subjects in oceanography were offered during the year, and all our oceanography subjects had larger student appeal than anticipated. To enhance our effort in this field, we held a one-day conference for local and Washington oceanographers in December; a second presentation of our research program was made on request to the National Academy of Sciences Committee on Oceanography in May; and in June we participated with the Woods Hole Oceanographic Institution in a two-day symposium on Modern Oceanography, the first day at M.I.T. and the second at Woods Hole, for the Industrial Liaison Office. All these activities were well received and should assist us in obtaining support for an expanded program in oceanography.

EARTH SCIENCES BUILDING

Although there was a token ground-breaking ceremony in December, 1960, actual work on the twenty-story Green Center for the Earth Sciences did not commence until a year later, in December, 1961, when preparations started for basement excavation and pile driving. Placing of the approximately 400 concrete-filled cylindrical steel piles was completed in early July, and basement construction started in late June as the last of the piles were being placed. It is hoped that the building will be ready for occupancy in 1963 or early 1964.

ROBERT R. SHROCK

Department of Mathematics

The number of mathematics majors again showed an increase during the past year. Last fall 258 undergraduates (sophomores, juniors, and seniors) were majoring in mathematics, compared to 210 the preceding fall and 90 in the fall of 1957. The corresponding figures for sophomores in mathematics are 105 last fall, 83 the preceding fall, and 35 in the fall of 1957. These figures indicate an increase in four years of 187 per cent in the number of undergraduate majors and of 200 per cent in the number of sophomore majors. Mathematics was the third-ranking department in the choice of majors by sophomores in the fall of 1961, and the Department stood fifth among all those at the Institute in the total number of majors, including undergraduate, graduate, and special students. Slightly over 50 per cent of the seniors graduating last year continued with graduate work. Professional opportunities for graduating seniors and for recipients of graduate degrees continue to exceed by a considerable margin the number of available persons.

During the year Professors Philip Franklin and Arthur P. Mattuck have worked closely with Professors Norman Levinson, Eric Reissner, Hartley Rogers, Jr., Gian-Carlo Rota, and George B. Thomas, Jr., in making revisions in the program of the first two years; the increased quality of the entering freshmen made possible many of these changes. The work on vectors given in the first year has been strengthened, and material on Green's theorem, the divergence theorem, and Stokes' theorem has been added; other material on vectors has been shifted from the second to the first year. These revisions will make possible a number of changes in the second-year program beginning next fall. Among these are the addition of material in linear algebra, a shift of the work in probability from the fourth term to the third term and an increase in the amount of work covered in differential equations in the fourth term. The Department feels that these changes will make the entire program much more valuable.

The two-term sequence in Advanced Calculus for Engineers (18.05 and 18.06), while still elective for most Courses, is taken by a large group of students throughout the Institute. For example, during the three terms of the past year (summer, 1961, and fall and spring, 1961-62), 838 students took 18.05 while 429 took 18.06. For some time the Department has been considering ways to give more unity to the topics covered in these two subjects and to make the subjects more useful and meaningful to those who need them. With this in mind a departmental committee consisting of Professors David J. Benney, Prescott D. Crout, Chia-Chiao Lin (Chairman), Levinson, and Reissner made certain recommendations, primarily to achieve greater coherence and unity in each term and better connection between the two terms, which will go into effect next year. Because of the wide interest in this subject, heads of the various Courses at M.I.T. were given an opportunity to discuss the proposed changes before they were placed in final form.

The number of freshmen entering with advanced placement credit continued to increase. Of last fall's entering class of approximately 900 freshmen, 195 took the advanced placement test in mathematics. Of these 156 did sufficiently well to receive advanced placement and degree credit, 72 for one semester and 84 for two semesters. In addition, another seventeen freshmen received credit at entrance by taking our own Advanced Standing Examination, nine for first-semester calculus, six for the entire first year, and one each for second-semester and third-semester calculus.

We also find that more students are taking advanced standing examinations in subjects beyond the first year. For example, in September and October, 1961, 112 students took our Advanced Standing Examination in third-semester Calculus (18.03), and 65 took the examination in Differential Equations (18.04). The entire group passed the 18.03 examination and 63 of the 65 passed the 18.04 examination. Of those taking the 18.03 examination, 46 were sophomores who had taken one of the special honors versions of calculus as freshmen; of those passing the 18.04 examination, 29 had also taken one of the honors versions.

For the past several years the Department's Visiting Committee and the Institute administration have given strong support to efforts to improve the mathematics collection in the Science Library. Since the position of Mathematics Librarian was established in 1960, rapid progress has been made in purchasing new material, replacing missing material, and binding back issues of journals. However, there is need for continued additional financial support for purchase and binding of journals and serials over a ten-year period, and adequate space for the collections housed in the Science Library is an urgent need.

RESEARCH

Professor Reissner is continuing his research efforts in the field of asymptotic solutions of the equations of shell theory and on deriving two-dimensional shell theory from three-dimensional elasticity theory.

Professor Lin is continuing his work on the hydrodynamics of superfluids (liquid helium II) which is based on continuum concepts without use of the extra notion of quantized vortex lines which have been proposed by physicists to account for experimental results in the field. At the moment, the central problem on which the theory is tested is the stability of superfluid helium between rotating cylinders.

Professor Kenkichi Iwasawa is continuing his work on the theory of cyclotomic fields, for which he has received the Frank Nelson Cole Prize in the Theory of Numbers, an award given once every five years by the American Mathematical Society.

Professor Warren Ambrose is working on general considerations about minimal surfaces of arbitrary dimension imbedded in Riemannian manifolds. This is a field in which the basic existence theorems have not yet been found; the problems of the moment seem to be partly in differential geometry and partly in partial differential equations.

Professor Isadore M. Singer is working on a new version of Cartan's infinite groups, including a classification of the simple and primitive ones, with some new results in the infinitely-differentiable, as opposed to the analytic, case.

Professor George W. Whitehead is studying the notion of orientability of manifolds relative to homology theories more general than the usual ones.

The research activities of other members of the Department are too numerous for individual mention, but the work of our faculty in the single field of analysis serves as an illustration.

Professor James G. Glimm has been studying group representations from the point of view of Mackey's theory of induced representations and investigating various related problems. It has developed that further analysis of the action of general locally compact transformation groups is possible than appeared likely several years ago.

Professor Sigurdur Helgason has been studying geometric function theory on symmetric spaces; he has worked out in considerable detail the significant case of a space of rank one and has found surprising differences between the so-called classical and exceptional cases. He has determined the functions admitting certain invariance features under the group of isometries on quadrics, and intends to apply the results to the study of spherical functions on symmetric spaces with an indefinite metric.

Professor Kenneth M. Hoffman has been studying the problem of endowing subsets of the maximal ideal space of a Banach algebra of functions with such analytic structures that the functions become analytic and has found a new class of abstractly defined algebras for which this is possible.

Professor Levinson has solved a random walk problem on a lattice having absorptive sites to obtain limiting forms in the one-dimensional case, the problem originating in the theory of luminescence from crystals. His long-term research continues, particularly in non-linear differential equations.

Professor Henry P. McKean, Jr., has obtained a very simple central limit type theorem for Kac's one-dimensional "caricature" of a Maxwellian gas. He has also obtained a necessary and sufficient condition that there exist a random time substitution mapping one process onto another. In the case of Brownian motion he has obtained a new proof of existence and continuity of local times.

Professor Daniel B. Ray, whose special interest is Markov process theory, has been completing work on two problems concerning sojourn times for Brownian motion. He has obtained an iterated logarithm type theorem for sojourn times of planar Brownian motion from which the exact Hausdorff measure of the path can be derived. He has also treated the density of sojourn times of linear Brownian motion stopped in a variety of ways, this density being a Markov process with the spatial variable as parameter.

Professor Rota has proved limit theorems for sequences of operators which unify and extend theorems pertinent to classical analysis, as in work of Calderon-Zygmund-Stein and work of Doob on martingale theory. His longer term work involves the interaction between probability theory and functional analysis and involves in particular the study of Markov and more general stochastic processes by the methods used in his current work, which uses a version of spectral theory drawing both from Doob's stochastic process theory and Neumark-Nagy's theorem of imbeddings of Hilbert spaces into larger spaces.

Professor Irving E. Segal has continued his work in the mathematical theory of quantum fields as well as the development of the relevant parts of functional analysis. He has shown that the set of global solutions of a non-linear hyperbolic partial differential equation can be given a type of measure as well as the structure of a symplectic differentiable manifold. These structures are expected to be instrumental in the mathematically precise development of the notion of quantization of a given field, although they have intrinsic mathematical interest.

PERSONNEL

During the year Professors Kenneth M. Hoffman, Louis N. Howard, Singer, and Gerald B. Whitham were on leave, Professor Hoffman at the University of California, Los Angeles, Professor Howard at Cambridge University, and Professor Whitham at the California Institute of Technology. Professor Howard held a Guggenheim Fellowship, and Professor Singer spent the year in Europe on an Alfred P. Sloan, Jr., Research Fellowship. Professor Marvin L. Minsky was on leave during the fall semester.

Professors Bertram Kostant of the University of California, Berkeley, and Reimar H. Lüst of the Max Planck Institute for Astrophysics, Munich, Germany, spent the fall semester with us as Visiting Professors. We had three visiting faculty members during the entire academic year, Professors Felix E. Browder of Yale University and Ekkehart Kröner of the Stuttgart Institute of Technology, Germany, as Visiting Associate Professors and Dr. Hubertus J. Weinitschke of Hughes Aircraft Company, Fullerton, California, as Visiting Assistant Professor. Dr. Jose Barros-Neto, Professor Robert J. Blattner, Professor Hazleton Mirkil and Dr. William F. Pohl spent the year in the Department as Visiting Fellows, Dr. Barros-Neto on a Guggenheim Fellowship and Professor Blattner and Dr. Pohl on National Science Foundation Postdoctoral Fellowships. Professors Blattner and Mirkil were on leave from the University of California, Los Angeles and Dartmouth College, respectively. In addition, Dr. Walter A. Strauss spent the spring semester in the Department on a National Science Foundation Postdoctoral Fellowship.

During the year Professor Bertram Kostant accepted an invitation to join our faculty on a regular basis and will return in the fall of 1962 as Professor of Mathematics. Professor Whitham received an invitation to remain at the California Institute of Technology on a regular basis and has accepted that invitation. Professor Minsky has requested a transfer to the Department of Electrical Engineering and will be a member of that Department beginning with the academic year 1962-63.

With the cooperation of the Department of Electrical Engineering, Professor Minsky will offer the graduate subject in Heuristic Programing and Artificial Intelligence with a joint listing by the two Departments (18.16 and 6.544). Professor Minsky has previously offered the subject in the Department of Mathematics.

W. TED MARTIN

Department of Meteorology

The closely integrated program of graduate education and research in meteorology and oceanography enjoyed a successful year. The space currently assigned to the Department does not permit significant expansion of the program and we have viewed with great anticipation the construction of the Green Center for the Earth Sciences.

The total number of graduate students was about the same as last year. The general caliber and academic promise of the applicants for admission has increased significantly, and we have taken advantage of this to raise our selectivity. About one-fifth of the applicants now indicate that they wish to work toward degrees in oceanography. The fact that few of our current applicants have had prior academic training or experience in meteorology or oceanography has caused us to orient the beginning subjects of instruction more in the direction of the physical and mathematical aspects, making a logical bridge into the earth sciences for students who have majored in the physical sciences. These subjects now also lead them directly into the areas in which our major research interests lie.

The predoctoral fellowship program supported by a grant from the Ford Foundation entered on its third year. All of the fellows enjoyed a successful year, and four new fellowship awards were made for the coming academic year. It seems quite certain that this program has played a major role in attracting students of real promise into our area, as many of them would not have considered graduate work in meteorology or oceanography had it not been for the fellowship program. It has been possible to offer assistantships to a number of the unsuccessful but well-qualified fellowship applicants. Thus the fellowship program has attracted considerably more capable students than the number who have been awarded fellowships.

The two-term sequence in physical oceanography which was established a year ago has been continued and strengthened. A number of students from other departments have joined those from the earth science departments in taking these subjects. This year a new problem subject in physical oceanography was given by Dr. Douglas L. Brooks, in which students worked on a variety of oceanographic problems using observational data taken at sea. The amount of data that must be treated to gain a real insight into an oceanographic problem percludes their assignment as home problems in a lecture course. It is believed that an opportunity to work with real oceanographic data is invaluable, and we plan to offer this course again next year.

Professor Reginald E. Newell has developed his lectures on the upper atmosphere into a regular graduate subject which will be offered every year. There is considerable interest in this subject by students from a number of departments. Knowledge in this area is accumulating so rapidly that it may soon be necessary to extend this subject to a two-term sequence.

As an experiment Professor George Veronis gave a subject on thermal convection under the auspices of the Department of Mathematics. It was hoped in this way to interest some graduate students in applied mathematics in some of the theoretical problems of convection in the atmosphere and oceans. The subject was well-attended and it is believed that it served its intended purpose.

Professors Jule G. Charney and Norman A. Phillips participated actively in the informal interdepartmental faculty Committee on Planetary and Space Science. It is the purpose of this group to develop interdepartmental graduate programs in the planetary and space sciences and to provide guidance to students interested in these areas. The Department intends to cooperate in this activity and will probably be responsible for much of the work in planetary fluid mechanics.

RESEARCH

The research activities of the Department are an intimate part of the graduate educational program. The research is supported by grants and contracts from five agencies of the federal government and one industrial association. There has been a continued trend toward increased support from the National Science Foundation and a decrease in the funds provided by the United States Air Force. In general, this shift of support has been accomplished without significant effect on the progress of the research.

Professor Hurd C. Willett has continued to investigate both the atmospheric processes and the variable solar activity that appear to be involved in long-period climatic changes. He recently has found a surprisingly strong correlation between total atmospheric ozone and an index of solar variability. This, together with strong evidence that the variation of ozone is related to certain features of the global atmospheric circulation, indicates that ozone may be an important physical link between solar variability and climatic change.

Professors Victor P. Starr and Newell have studied the large scale motions of stratospheric levels with the aid of special data collected during and subsequent to the International Geophysical Year. Rather surprisingly, it appears that there is a north-south oscillation of the air at these levels rather than an average northward flow. These results indicate that non-classical mechanisms must be invoked to account for the required poleward transports of heat, ozone, and radioactive debris. In another study Professors Starr and Newell have applied some of the concepts of momentum transport developed for studying the atmosphere to spiral nebulae. This has led to results which in some respects seem more consistent with observation than previous theories for the evolution of galaxies.

Professor Charney, in collaboration with Dr. Melvin Stern of the Woods Hole Oceanographic Institution, has derived an important theorem concerning the stability of internal jets in a rotating stratified fluid. The theorem, in which boundary conditions play a crucial role, establishes a close correspondence between this problem of great meteorological and oceanographic interest and the classic hydrodynamic studies of the stability of plane shear flow. Professor Charney is also exploring the non-linear interaction of three-dimensional point vortices. It is hoped that this type of study, by including the non-linear effects in a simple way, will shed some light on the behavior of large-scale flow patterns in the atmosphere over periods longer than two or three days. The technique is also applicable to the oceans, and has already been borrowed for this purpose by oceanographers.

Professor Phillips is continuing his work on the numerical integration of the meteorological equations of motion on a spherical earth. The refinement and extension of present numerical weather forecasting methods requires considerable work in this direction. A by-product of this has been a simple formal deduction of the "β-plane" representation of the spherical surface of the earth for meteorological purposes. This device was first introduced by Rossby at M.I.T. in 1939 but had never received any formal justification in the literature.

Professor Edward N. Lorenz and his group have been investigating the causes of the apparent limit of success of statistical methods for the prediction of the future state of the atmosphere. For this purpose he has developed a hierarchy of simple non-linear mathematical models of the atmosphere whose numerical solutions can be extended indefinitely into the future. Certain of these models execute variations resembling those observed in the real atmosphere, and the solutions possess continuous power spectra. In these models linear regression methods fail to give good predictions beyond short time periods, while slightly different intial states almost always eventually evolve into unrecognizably different states. Thus in the models there is a limit to practical predictability which is not approached by conventional statistical methods. The work represents an important contribution to our understanding of the limits of predictability of the real atmosphere.

Professor Frederick Sanders has continued his work on theoretical computations of large-scale vertical motions in the atmosphere which are too small to be measured directly but which are the basic cause of the formation of clouds and precipitation. A model for the transport and condensation of water vapor has been devised, in which the vertical motions play a crucial role. The model is being used to make predictions of large-scale cloudiness and precipitation up to three days in advance.

Dr. Hsiao-lan Kuo has been investigating the influence of the vertical shear of the mean wind on the structure of thermal convection. Constant vertical wind shear produces a stabilizing influence but, as the thermal instability increases, the convection can take place only in long bands which remain preferable to cellular convection even for very unstable stratifications. These results seem to provide a satisfactory explanation for the spiral cloud and rain bands that are characteristic of tropical hurricanes. A simple model of the hurricane has been formulated by an averaging process which eliminates the dynamical effects of these spiral bands but retains their important thermal effects.

Dr. Yoshomitsu Ogura has examined certain of the hypotheses usually made in the statistical theory of isotropic turbulence. He has demonstrated by numerical integration of the equations that one of these hypotheses permits the energy spectrum to assume negative values as time progresses. This clearly indicates that this hypothesis is not adequate to describe isotropic turbulence.

Professor Delbar P. Keily has continued to develop the electric probe instrument for the measurement of the size and number of natural cloud drops. The empirical calibration indicated that the response of this instrument was accurately proportional to the surface area of the drop over a wide range of drop sizes. He is now attempting to clarify the complex and interesting electrostatic processes that lead to this simple result. It is believed that when these processes are understood this type of instrument may have application to the identification and sizing of other types of atmospheric particulates.

Dr. Lewis D. Kaplan continued his work on the calculation of the flux of infrared radiation in the atmosphere as a basis for the preparation of tables and formulae for convenient evaluation of the flux divergence for meteorological purposes. His work was carried to the point where its completion is relatively straightforward prior to his departure from the Institute.

Under the general supervision of Professor Henry G. Houghton and the immediate direction of Dr. Harrison E. Cramer, the research group at the Round Hill Field Station has obtained extensive measurements of energy exchange processes occurring in the atmospheric boundary layer. Machine analysis of these observations has provided comprehensive information on the power spectra and cospectra of basic meteorological parameters responsible for the vertical fluxes of heat, momentum, and moisture. Results of this type are requisite for an understanding of a wide variety of atmospheric processes ranging from the diffusion of airborne contaminants to the thermal and frictional coupling between the atmosphere and the earth's surface. The program of observation and data analysis is continuing to permit extensions of the work to a wide range of time and space domains.

The Weather Radar Project, under the supervision of Dr. Pauline M. Austin, has obtained extensive data on mesoscale precipitation phenomena in the New England area. These radar data are being reduced to digital form for subsequent analysis at the M.I.T. Computation Center. Particular attention has been paid to the structure of squall lines and to hail-producing storms. It has been demonstrated that hailstorms may be identified through quantitative measurements of radar reflectivity and that the size of the largest hail stones may be estimated.

HENRY G. HOUGHTON

Department of Nutrition, Food Science and Technology

Although the name of the Department was changed from Food Technology to Nutrition, Food Science and Technology in 1960, the academic year 1961-62 was the first in which its scope and activity were expanded by a new Chairman and additional faculty members. Dr. Alfred E. Harper, noted for his work on dietary amino acid interrelationships, became Professor of Nutrition, and Dr. Donald M. Watkin was appointed Associate Professor of Nutrition to organize a research and teaching program in clinical nutrition. Dr. Jerome A. Uram, Assistant Professor of Food Toxicology, initiated investigative work and training in the safety of intentional and non-intentional food additives and of naturally-occurring toxic substances in foods. Gerald N. Wogan continued this program after the tragic death of Professor Uram in an airplane accident in Peru in February and has since been appointed Assistant Professor of Food Safety.

Early in 1962 the staff was further strengthened by the arrival of Dr. George Wolf, an expert on the use of isotope techniques in the study of vitamin metabolism, as Associate Professor of Physiological Chemistry, and of Dr. Louis C. Fillios, who specializes in purine and lipid metabolism, as Assistant Professor of Physiological Chemistry.

Assisted by the National Vitamin Foundation, the Department sponsored a highly successful three-day symposium in March on Recent Advances in the Appraisal of Nutrient Intake and Nutritional Status of Man. Key personnel from the food and drug industries and government agencies, as well as university scientists, attended this meeting.

Because of its new research and teaching programs, the Department has received an unusually large number of visitors during the past year. Staff members have also participated in many national and international conferences and advisory activities which have helped to make the expanded Department better known.

Formal training programs have been organized to encourage physicians and dentists interested in nutritional and metabolic research to add to their basic training in science and to qualify as candidates for a master's or doctorate degree in nutrition. Field training is available to qualified individuals through a cooperative arrangement with the Institute of Nutrition of Central America and Panama, Guatemala.

In cooperation with the Pan American Health Organization and the U.S. Armed Forces, the Department is offering a special two-year program leading to the degree of Master of Science in Food Science and Technology for veterinarians who serve as food-control officers in military and public health programs. As part of this program and the clinical nutrition training, Dr. John E. Gordon has been appointed Visiting Professor and Dr. A. Daniel Rubenstein has been named Visiting Associate Professor of Epidemiology; together they will offer a new subject in Epidemiology of Nutritional and Food-Borne Disease.

With the appointment of Dr. Leo Friedman, formerly Assistant Director for Research in the Division of Nutrition, U.S. Food and Drug Administration, to be Associate Professor of Nutrition and Food Safety, a degree program will be available in this discipline. To strengthen the Department's work with experimental animals, Dr. Paul Newburne has been appointed Associate Professor and Dr. William W. Carlton, Assistant Professor of Veterinary Pathology.

During the past year the departmental graduate seminars have emphasized during alternate weeks topics in human nutrition and in food science and technology and have made extensive use of visiting lecturers. Department members are encouraged to cooperate in major interdisciplinary projects rather than to limit their research to specific problems in their own fields. All specialties represented in the former Department of Food Technology have been retained, and several have been given even greater emphasis.

The number of graduate students accepted for the coming year has grown proportionately to the increase in staff and to greater financial assistance available from both government and industry. Undergraduates interested in nutrition and food science now take the life sciences curriculum, but they are encouraged to elect one or both of the introductory undergraduate subjects in nutrition and food science and to complete an undergraduate thesis in one of these fields. All other instruction is at the graduate level.

The encouragement and effective support of the administration and the cooperation of other departments have been major factors in the substantial progress made during the past year toward the goal of a broad multi-disciplinary department with competence in the major aspects of human nutrition, food science, and food technology.

NEVIN S. SCRIMSHAW

Department of Physics

The total registration in Course VIII has not changed markedly during the past two years; if our situation is now approximately at equilibrium, curricular planning will be much easier in the future than in the past, when the student population in physics continually increased at an unpredictable rate. In 1961-62 the total number of subjects taught by the faculty of the Department during the fall and spring semesters (excluding special problem subjects and thesis) was 55, and the total registration was 6,476. These figures are essentially the same as those for 1960-61.

THE UNDERGRADUATE CURRICULUM

No major changes were made during the year in our undergraduate program. A very successful experiment was carried out under the supervision of Dr. David H. Douglass, Jr., which may lead to future revision of our third-year laboratory subjects. During the spring term, sixteen juniors carried out a series of selected experiments in various research laboratories in place of the regular sequence in Experimental Atomic Physics II (8.10). The work on each experiment was supervised and graded by the research staff in the particular laboratory. Student enthusiasm continued high during the semester, and all the faculty involved felt the experiment was worthwhile and volunteered to continue to participate in it. During this first trial, the research areas to which the students were exposed were largely confined to various aspects of solid-state physics. We plan to continue this program in essentially the same form, although with the inclusion of some other areas of research activity in the Department, for another year. At the end of that time we shall decide whether to attempt to include such exposure to active research activities in the program of all Course VIII third-year students.

After consulting with the other departments involved, three undergraduate subjects which have been given for a number of years have been dropped from the Catalogue. Physics (8.00) and Elementary Nuclear Physics (8.055) have been taught for some time during the summer session, with registration limited to selected Naval and Coast Guard officers in Course XIII-A. Through a rearrangement of their programs, these students will in the future cover the necessary material in subjects offered during the regular academic year. The third-year elective subject in Solid-State and Molecular Physics (8.052), was developed at the request of several departments in the School of Engineering. While in the beginning, many Course VIII undergraduates also enrolled in this subject, in recent years those interested in this field have tended to register in the Quantum Theory of Matter (8.361-8.362) sequence, with the result that 8.052 has become entirely a service subject with the registration largely confined to Course VI students. The Department of Electrical Engineering has now developed an undergraduate subject in this area, so that there is no longer a need for the Department of Physics to continue to give 8.052.

We plan to offer a seminar in physics to approximately one hundred students of the entering class in 1962. This seminar will incorporate some of the ideas and techniques which have been developed in the Science Teaching Center. Professor Nathaniel H. Frank will be in charge of this new subject and will be assisted by some of the staff members who have been engaged in this activity. Under the direction of the late Professor Francis L. Friedman, the Center was greatly expanded during the past year. Professor Frank was on leave from administrative duties and Professors David H. Frisch, John G. King and William Bertozzi were relieved of teaching to collaborate in this work. Dr. Alan Holden of the Bell Telephone Laboratories, Professor James H. Smith of the University of Illinois, and Professor Anthony P. French of the University of South Carolina were on leave from their respective institutions and, as Visiting Professors of Physics, spent the year at the Center. Professor French will continue during the coming year in the same capacity. Other faculty members who have been involved to a greater or lesser degree are Professor Alan J. Lazarus, who has been in charge of 8.01 and 8.02, Professor Kenneth W. Billman, in charge of the first-year laboratory, and Professor John F. Cochran, in charge of the sophomore laboratory. During the spring term Professors Cochran and Holden collaborated in giving a freshman seminar subject which incorporated some of the ideas developed in the Center for teaching some basic concepts in solid-state physics.

GRADUATE STUDY

Our graduate subjects were examined this year by a reconstituted Graduate Curriculum Committee under the chairmanship of Professor Herman Feshbach. As a result of recommendations by this Committee, it was decided to drop some subjects and to give some others only in alternate years. In place of these, new sequences are being developed with the objective of providing a number of introductory graduate subjects, which most students will take, in the principal areas of physics, each such subject to be followed by a series of more specialized ones for students who wish to continue with a more advanced treatment.

This year our graduate examination procedure was somewhat changed. In the past, each student registering as a doctoral candidate was required to take a qualifying examination during the first term of such registration. Those failing this examination were required to become candidates for the Master's degree. An undesirable result of this system was that an increasing number of entering students registered as Master's candidates in order to avoid the test until they had taken several semesters of course work. It is now required that each entering student take, within the first few weeks of the fall semester, an examination which covers the major areas of physics at an advanced undergraduate level. The results of this examination are used for diagnostic purposes rather than as a filter and enable the student and his faculty registration officer to determine the most appropriate academic program in each case. Further registration as a candidate for any advanced degree is dependent on satisfactory progress in formal subjects and in research projects supervised by the staff. The nature of the written and the oral examinations for the Doctor's degree remains unchanged.

In the last report, attention was called to the problems of staffing the undergraduate laboratories with adequately prepared teaching assistants. The Department has now been authorized to appoint students as graduate assistants and to divide their assigned duties between teaching and research activities in any ratio which is appropriate from the point of view of the student's academic progress and the needs of the Department. This type of appointment will replace the previous ones of Teaching Assistants and Research Assistants and will be used for the first time in the fall term of 1962. A very important additional benefit of this new type of appointment has already been felt, since it has enabled our Graduate Admissions Committee to admit and to offer assistantships to well-qualified applicants much earlier than was previously possible when no offer could be made until the decision between Teaching or Research Assistant was made. The decision as to the proper division of a Graduate Assistant's activities between teaching and research can now be deferred until after a personal interview with the entering student just before the fall semester. We anticipate that this new system will work to the definite benefit of the Department's teaching and research activities and of the graduate students.

RESEARCH

The researches of the staff and graduate students continued at the usual high level of activity. The present research interests of the sixty regular faculty members are largely in various aspects of the fields of nuclear physics, high-energy and elementary particle physics, and solid-state physics, with roughly one-quarter of the staff working in each of these general areas. The interests of the other quarter cover a broad spectrum ranging from acoustics to the planetary and space sciences. There is a high degree of faculty participation in various interdepartmental laboratories such as the Research Laboratory of Electronics, the Laboratory for Nuclear Science, the Center for Materials Science and Engineering, the Spectroscopy Laboratory, the Computation Center, and the Operations Research Center. The variety and the scope of the researches of the staff are indicated in the reports of these laboratories and centers and by the lists of publications elsewhere in this volume.

During the year, the formation of the Center for Materials Science and Engineering and the first operation of the Cambridge Electron Accelerator were events of special importance to members of the Department. The first has been largely due to the leadership and initiative of Dr. John C. Slater, Institute Professor and Higgins Professor of the Solid State. Professor M. Stanley Livingston has been Director of the accelerator project since its inception; it now provides a unique facility for faculty and students interested in high energy phenomena.

A different type of facility, of importance to the entire staff, was obtained during 1961-62. Through the generosity of friends of the Department and the cooperation of the administration, it has been possible to furnish and equip a room for the uses of the physics faculty. This much-needed addition, to be known as the Karl Taylor Compton Room, occupies part of the lobby immediately adjacent to the Compton Lecture Hall, Room 26-100, which is used for the weekly colloquium as well as for the majority of the large physics lectures. With a department as large and as scattered geographically as this one, it is particularly important to have a centrally-located and well-equipped room which is always available for committee and departmental meetings and for various other professional and social affairs.

During the year Professor Victor F. Weisskopf continued on leave to serve as Director of CERN, the European center for nuclear physics at Geneva. Also at CERN on one-semester leaves of absence were Professor David O. Caldwell with a Ford Foundation Fellowship and Professor Kerson Huang as an Alfred P. Sloan Research Fellow. Professor Francis Low was granted a year's leave of absence to accept a Guggenheim Fellowship for work at the University of Rome. Also on leave for the year were Professors Malcom W. Strandberg and Arthur K. Kerman, at the Universities of Grenoble and Paris, respectively. During the academic year Dr. Samuel Schweber of Brandeis University served as Visiting Professor of Physics and was in charge of our regular two-semester sequence on Relativistic Quantum Mechanics (8.861 and 8.862), and also supervised the researches of several graduate students.

A number of the faculty will be on leave during 1962-63. Professor William P. Allis has been granted a two-year leave of absence to enable him to accept an appointment as Assistant Secretary General for Scientific Affairs of the North Atlantic Treaty Organization. Professor Rudolph W. Bauer will spend the year at the Livermore Laboratory of the University of California. Professor George W. Clark has been awarded a Guggenheim Fellowship and will do research during the second semester at the University of Milan. Professor Feshbach will be at the CERN Laboratory at Geneva for the entire year. Professor Livingston will be on leave during the first semester from his position as Director of the C.E.A. to enable him to visit various European accelerator installations. Professor Laszlo Tisza has been awarded a Guggenheim Fellowship and will spend the year on the faculty at the University of Paris. The leave of absence of Professor Weisskopf has been extended, and he will continue as Director of CERN for the coming year.

New faculty appointments effective July 1, 1962, include that of Dr. Robert A. Smith. Dr. Smith, who has been head of the Physics Department at the University of Sheffield, England, will come as Professor of Physics and will also serve as the Director of the Center for Materials Science and Engineering. Dr. Raymond Hide has been given a joint appointment in this Department and in the Department of Geology and Geophysics with the title of Professor of Geophysics and Physics. Drs. Richard H. Lemmer, Clive H. Perry, and John H. Wood have been appointed Assistant Professors of Physics. Dr. Marvin Goldberger, Higgins Professor at Princeton University, and Dr. Gerald Brown from the Nordisk Institut for Teoretisk Atomfysik will be Visiting Professors in the Department during the coming academic year. Dr. Murray Gell-Mann of the California Institute of Technology will spend the spring semester as Visiting Professor of Physics. The new position of Administrative Officer has been authorized and will be filled by Captain Edward S. Arentzen, who has retired from the U.S. Navy. Captain Arentzen was also, for the past four years, with the Department of Naval Architecture and Marine Engineering as Professor of Naval Construction.

After ten years in charge of the Department, Professor Frank has given up these duties in order to continue the work he has been carrying out in the Science Teaching Center and, among other things, to undertake an examination of the interdependence of the undergraduate subjects in the science departments and to assist in the area of the mutual interactions of the teaching of science and engineering.

Professor Buechner, who has been Acting Head since March 15, 1961, has succeeded Professor Frank as Head of the Department.

WILLIAM W. BUECHNER

Computation Center

In January, 1962, the International Business Machines Corporation replaced the Computation Center's 709 computer with the more effective transistorized I.B.M. 7090 computer. It has been the Center's experience that the 7090 operates at effective speeds approximately three times that of the 709. However, this increase in speed has been just barely sufficient to meet the growing needs of the faculty and students of M.I.T. and the cooperating universities and colleges of the New England Cooperative Colleges Program. During the month of May, which is usually the peak period at M.I.T., it was necessary to run the 7090 for over 400 hours for the use of these groups. This compares with approximately 300 hours' normal shift usage.

It is clear that with the increased popularity and use of computers and the parallel increase in the sophistication of that use, even the 7090 as it is presently used will very shortly become an insufficient source of computing power at M.I.T. Ways and means of increasing the computing facilities available for teaching and research at M.I.T. must be a major facet in our planning for the future.

It is very much the opinion of the members of the Computation Center that keeping pace with this demand requires not only faster and more efficient hardware but also great changes in the method in which the computers are used. The staff is constantly improving the procedures for the use of the computer and the vital systems programs which increase its potency. The big improvement, however, would come in adding input-output consoles and programming the computer so that several users could work simultaneously, sharing the high-speed capacity of the machine. For several years now the staff has been engaged in the initial phases of research and development with this goal of time-sharing in mind. At the moment the Center is running, during part of each day, a pilot model of such a system employing two electric typewriters as remote consoles. The experience gained in using this pilot model will be applied to an enlarged system which presently envisions at least sixteen remote typewriter consoles and telephone line connections to the PDP-1 computer on the second floor of Building 26 and the I.B.M. 1620 in the basement of Building 1. These hookups between the 7090 and the two smaller computers will provide the facility to simulate and thus experiment with more sophisticated types of remote consoles.

In addition to the development of time-sharing, the staff of the Center has been active in a number of aspects of computer science. For example, the group under Professors John McCarthy and Marvin L. Minsky has been working on programs in the area of artificial intelligence which will allow the machine to be used as a problem solver. Professor Herbert M. Teager's group has been involved in the development of devices, programs, and languages for graphic communication with the computer. Drs. Allen A. Goldstein and Phyllis Fox have continued to contribute in the area of numerical analysis. Beyond these few comments, it would be discriminatory to select only a few of the many research projects in which the computer plays an important part and on which the staff of the Center gave consulting assistance. Every department of the Institute now uses the facilities of the Center. More than two dozen regular M.I.T. subjects, graduate and undergraduate, plus more than one dozen courses at the other New England colleges use the computer as part of their instructional program. Special courses in programming are given just before the beginning of the fall term and occasionally during the year.

PHILIP M. MORSE

Cooperative Computing Laboratory

To meet the increasing computing requirements of a number of research laboratories at M.I.T., the Cooperative Computing Laboratory has been established with an I.B.M. 709 computer purchased at an educational discount; it is available to staff and students of the Institute for teaching, research, and administrative purposes. The initial cost will be amortized over a five-year period and the operating costs will be met by the laboratories who use the computer and who contribute at a rather low hourly rate.

The major objective of the Laboratory is to let members of the Institute have complete freedom in the way they use the computer. At present the operating time of the computer is divided fairly evenly between runs that are made by members of the Laboratory operating staff in the absence of the programmers and runs that are made with the programmers present. Teamwork is encouraged in which several users have access to the machine in alternation and on a basis of informal cooperation during some block of time which they reserve jointly. Real-time equipment attached to the computer allows one user to interrupt the execution of a program (that subsequently is completed) to perform some other operation. This equipment and visual display devices will be used mainly for "on-line" optimization studies. Time-sharing will be used for lengthy physical experiments that require intermittent interaction of observing devices and the computer. Analog-to-digital and digital-to-analog converters are attached to the input-ouput devices of the computer and are used, for example, in problems of musical acoustics.

The Laboratory is used by members of most departments of M.I.T. for theoretical calculations concerning the behaviour of matter and of man's environment, for the reduction of experimental data, for problems of design and simulation, and for teaching and administrative purposes. Theoretical calculations include quantum mechanical studies of solids, molecules, atoms, and nuclei; and meteorological and aerodynamic studies. Extensive calculations are performed on seismic data, on cosmic ray data obtained from satellites, and on crystallographic data for many materials.

The research staff of the Laboratory maintains an active program of research in computing science. Research topics include mechanized documentation—the use of computers to organize verbal and formal information to be printed without further keyboard action; the development of on-line optimizing methods; the development of formal and verbal systems of descriptive linguistics and of corresponding computer programs, and the application of these; the development of high-level programming languages; the mechanization of tedious algebra and analysis; the study of stylistic analysis; and some speculation concerning the mechanism of thought processes. The Laboratory staff is concerned also with the use of the computer as a teaching aid and the establishment of computational "laboratory" and reporting practices for the checking, recording, and reporting of high-speed computations that are comparable with the established practices of the experimental sciences.

MICHAEL P. BARNETT

Laboratory for Nuclear Science

In addition to the vigorous pursuit of its many-sided research program, the Laboratory for Nuclear Science has, during the past year, continued in a searching appraisal of its facilities as they relate to the projected program of research in low- and high-energy nuclear physics over the next decade. In carrying out this appraisal, which resulted in a proposal submitted to the Atomic Energy Commission in the summer of 1961, the research staff of the Laboratory and associated members of the Department of Physics faculty were fortunate in being able to call upon the advice and cooperation of the Laboratory's Visiting Committee. The plans which have thus been evolved for the future of the Laboratory have been discussed with the administration and with members of the Atomic Energy Commission; we have been gratified by their warm response and are assured of their hearty cooperation in carrying out these programs. As a result, we are now in the position of being able to see, with reasonable clarity, a sensible course of progress over the next few years.

Since the main conclusions of this appraisal form the backdrop against which our current proposals may be viewed in their proper perspective, it is useful to review them here: The Laboratory is now engaged in lively research programs on the forefront of both low- and high-energy nuclear physics. To continue on this course will require a program of both consolidation and expansion. Thus, we intend to concentrate our accelerator-based low-energy nuclear program in three areas—the Van de Graaff, cyclotron, and electron linac—and to direct our high-energy program at research with the Cambridge Electron Accelerator.

This consolidation allows also for the retirement of two of the Laboratory's major accelerator facilities—the 4-Mev. electrostatic (Rockefeller) accelerator and the 330-Mev. electron synchrotron. The former was retired as an L.N.S.-supported facility in July 1 of this year and transferred to the Department of Nuclear Engineering for use in experiments related to reaction and neutron physics. The synchrotron is expected to go into retirement with the appearance, we hope by 1965 or thereabouts, of the new facilities and research space.

On the other hand, continued pre-eminence in nuclear physics will require the addition of major new facilities to permit the natural growth of groups already prominent in their fields. There are four major additions, envisaged for initiation during the next five years: a 20 Mev. tandem Van de Graaff accelerator facility to broaden the range and scope of nuclear energy level studies now being carried on with the 8.5-Mev. accelerator; a 100-Mev. high-intensity electron linear accelerator facility to replace the present 18-Mev. accelerator and expand the breadth and scope of exciting new studies of nuclear and nucleon structure in which this Laboratory has been one of the pioneers; a High-Energy Research Center to bring together activities now scattered about the M.I.T. campus and to permit the required staging and assembling of apparatus for experimentation at the Cambridge Electron Accelerator and at the Brookhaven National Laboratory; and a data reduction facility, now well into the stage of prototype development, for analysis of the vast (and explosively increasing) quantity of film resulting from the application of visual techniques (bubble chambers, spark chambers, luminescent chambers, etc.) to the study of high-energy phenomena. It is proposed that this last facility be housed in the High-Energy Research Center.

To accomplish the growth envisaged and implied by these additions will require an expansion of laboratory personnel by a factor of almost two in the next five years. Correspondingly, it may be anticipated that the operating expenses of the Laboratory will need to be increased by the same factor of two, to approximately $6 million in 1966.

CURRENT RESEARCH

The research activities of the Laboratory may be classified under the categories cosmic ray and space physics research, high-energy and elementary particle physics, low-energy nuclear physics, theoretical physics, and nuclear chemistry. We summarize below the main accomplishments of these groups during the past year and the main aspects of their continuing research programs.

NUCLEAR CHEMISTRY

The Laboratory's program in nuclear chemistry continues and includes studies in nuclear inorganic chemistry, chemistry of the fission elements, and nuclear organic chemistry. A summary of this work of the chemistry groups is included, as usual, in the report of the Department of Chemistry.

COSMIC RAY AND SPACE PHYSICS RESEARCH

The past year has been marked by a number of significant—and in some cases rather striking—results in cosmic ray and space physics research. Data gathered in the satellite-borne gamma-ray experiment launched last year (Explorer XI) have been analyzed and preliminary results were reported at the International Congress on Cosmic Ray and Space Physics held in Kyoto, Japan, last September. While these results are still preliminary, they have already shown that the version of steady-state cosmology that postulates anti-matter as well as matter creation in our galaxy is untenable. In addition, the further results from this satellite and another yet to be built can be expected to give new evidence about the galactic distribution of cosmic rays and matter. Other results, on the densities and velocities of plasmas in interplanetary space and on the properties of ultra-high energy cosmic ray showers (up to 10^{19} ev.), were also highlighted at the Kyoto conference. A notable development, for example, has been in connection with cosmic ray showers induced by incident particles of extremely high energy. Although an event reported by the M.I.T. Agassiz group as early as 1957 gave strong evidence for the extragalactic origin of some cosmic rays, there has been a natural scepticism on this point. The large amount of data gathered subsequently at the Laboratory's giant air shower experiment at Albuquerque show that such events occur sufficiently regularly so as to be reasonably explainable only on that basis and gives considerable credence to the theory.

The program of the group, as in the past, continues along very broad lines. Studies are under way of rapid variations of cosmic ray intensities associated with solar phenomena using a μ-meson detector of exceptionally large area, and an experiment has recently been completed to study the ratio of K/π production by cosmic rays at energies exceeding 100 Bev. by measurement of the polarization of cosmic ray μ-mesons. Instrumentation for the group's collaborative air shower experiment at the Mt. Chacaltaya Observatory in Bolivia has been put into operation, and considerable data have been gathered on gamma ray induced air showers. In parallel with these experiments the group is carrying out theoretical studies on the nature of nuclear interactions at extreme cosmic ray energies and on the behavior of ionized gases such as those observed in interplanetary and intergalactic space.

A significant new technique for the detection of extensive cosmic ray air showers and for the accurate determination of the direction of the primary particles responsible for them has been demonstrated in a test conducted at the (Harvard) Agassiz Field Station. This technique, utilizing a pulsed image intensifier system to photograph the Cerenkov light emitted by the fast charged particles associated with the air showers, was developed in collaboration with a group from the University College, Dublin, and is planned to be used in conjunction with the Chacaltaya work.

For future research to follow the plasma probe and gamma-ray satellite studies, plasma probe instrumentation is being developed in collaboration with Lincoln Laboratory for the "Mariner" interplanetary probes, developed to explore the environments of Mars and Venus; and for the EGO (Eccentric Geophysical Orbiting) and IMP (Interplanetary Monitoring Probe) satellites which will make use of highly eccentric paths to achieve an extensive sampling of interplanetary space. Preliminary planning is also being undertaken in collaboration with Lincoln Laboratory and the M.I.T. Instrumentation Laboratory for the development of a new gamma-ray satellite experiment.

HIGH-ENERGY AND ELEMENTARY PARTICLE PHYSICS

The program of the High-Energy Group includes experiments utilizing the M.I.T. synchrotron, the accelerators at Cornell, Brookhaven, Berkeley, and CERN, the preparation of instruments and experiments for the 6-Bev. Cambridge Electron Accelerator, and the development of a precision encoder pattern recognition device (PEPR) for the analysis of data on photographic film obtained by the many visual detection devices now in use and under development.

Experiments completed and in progress at the synchrotron include investigations of pion photoproduction from hydrogen and deuterium, studies of the polarization of protons from the photodisintegration of deuterons, and a study of the cross section for positron-electron annihilation at positron energies in the 100 to 300 Mev. range using the high-Z bubble chamber developed in this Laboratory.

The synchrotron group has also carried out a search for the theoretically-predicted ω_o-meson (spin-1, isotopic spin-0) using the

1.2-Bev. photon beam of the Cornell synchrotron. This search, sensitive to ω_o-mesons of mass $\lesssim$ 500 Mev., has established an upper limit on the cross-section for their production which exceeds the previously established upper limits by a factor of $\sim$ 20.

A number of experiments have been carried out at the Brookhaven Cosmotron and A.G.S. These include a study of π^--p scattering in the region of the 900-Mev. ($T=1/2$, $J=5/2^+$) resonance, utilizing a cylindrical spark chamber; and a study of charge-exchange π^--p scattering in the same energy range, in which a heavy-liquid bubble chamber has been successfully operated with an internal liquid-hydrogen "finger-target." The analysis of data from these exposures has now been completed. In addition, some 250,000 pictures involving associated Λ°-θ° production in the 15-inch heavy liquid bubble chamber have been analyzed to determine the branching ratio of the neutral θ°-decay mode, in collaboration with groups at Brandeis, Brown, Harvard, and the University of Padua. The results of this experiment have determined the θ°-branching ratio with a statistical accuracy greatly exceeding that of previous experiments. Although planned primarily for the study of the θ°-branching ratio, the experiment yielded also, and more notably, strong evidence for a spin zero assignment of the recently discovered mass 546 Mev. "η" particle, whose properties are currently under intensive study. Measurements on the muon spectra from the $K_{\mu3}$ decay have also been carried out at the Brookhaven cosmotron, utilizing a "hodoscope" detector. The analysis has yielded accurate values of the lifetimes of some of the decay modes of the K-meson. Another experiment at Brookhaven, carried out in collaboration with groups from Brookhaven and from the Argonne National Laboratory, has utilized a spark chamber for the detection of Λ°-baryons whose spin direction had been processed in a strong, pulsed magnetic field. These observations have yielded data which, when analyzed, have determined the magnetic moment of the Λ°-hyperon to be -1.5 ± 0.5 nuclear magnetons. An extension of this experiment is now being developed with the objective of achieving a five-fold increase in the precision of the measurement of the Λ°-magnetic moment.

Other experiments, which plan to utilize the Brookhaven accelerators, contemplate the continuation of the bubble chamber work on charge-exchange π^--p scattering at a number of pion energies and the use of the cylindrical spark-chamber for the study of K^--p elastic scattering in the region of a reported resonance at $\sim$ 1 Bev./c.

Experimentation by one of our staff now at the CERN accelerator is aimed at the study of "peripheral" interactions of high-energy pions on nucleons, utilizing a pion spectrometer with spark-chamber particle detectors. This experiment will be repeated at the C.E.A. for an incident photon beam. Many other experiments are under design and construction for use at C.E.A. These include a spark-chamber measurement of the Compton-scattering of high-energy photons (which is being performed initially using the Cornell 1.25-Bev. synchrotron); measurements of the photoproduction of pions from nucleons using counter-detection techniques, with a significant new technique for the analysis of data by a computer system designed as an integral component of the detection apparatus; the observation of photo-induced reactions involving only neutral particles by use of a cylindrical spark-chamber with plates of high-Z material and appropriate anticoincidence techniques; use of the hodoscope-detector for the measurement of μ-pair production, to set limits on the validity of quantum-electrodynamics in the range of high-momentum transfers; and the development of a 500-liter liquid hydrogen bubble chamber for use at C.E.A.

Finally, the vigorous development is being continued of the PEPR system for the analysis of data on high-energy reactions obtained by visual techniques. The prototype system under study has already succeeded in recognizing tracks and recording their positions and angles to within ±1.5°. It is anticipated that the successful development of such a data analysis facility will extend over a new range the utility of currently available visual techniques of experimentation in high-energy physics.

LOW-ENERGY NUCLEAR PHYSICS

A number of groups in the Laboratory are engaged in research in low-energy nuclear physics. These researches involve the use of an electron linear accelerator, two Van de Graaff accelerators, a cyclotron, and various radioactive sources.

The discovery of the Mossbauer effect (recoil-less gamma-ray scattering) has provided a new tool for radioactivity studies of broad applicability. This technique is being utilized in our Laboratory in a number of fundamental investigations (e.g., a new demonstration of the absence of the "ether drift," with very high precision) and in a number of new applications to the study of the solid state.

As in the past, a great variety of techniques are being utilized for the study of nuclear energy levels and the properties of excited nuclear states. Such studies include precision measurements of nuclear level energies by the O.N.R. Accelerator Group, studies of the spins and parities of nuclear levels by means of angular distribution measurements in a variety of reactions and through angular correlation studies in radioactive decays. In this connection, the completion of a multi-channel spectrometer for use with the Van de Graaff accelerator is making possible such angular distribution measurements over the entire angular range in a single exposure. The economy of time and effort and the increased precision and reliability made possible by this spectrometer have enabled the initiation of a program of study of "stripping" and "pickup" reactions induced by H^3 and He^3 as well as by deuteron projectiles.

Studies of the angular distributions of elastically and inelastically scattered alpha-particles, carried out at the cyclotron, have made important contributions to the elucidation of the modes of "collective interaction" in nuclei. The program of extensive modification, with expansion of the associated facilities, now being carried out on the cyclotron will result in a research tool of much greater capability and versatility.

This Laboratory has also been pre-eminent in the measurement of magnetic moments of excited nuclear levels. Such observations continue to be carried out by our Radioactivity Group and by use of accelerator-produced reactions at the 4-Mev. (Rockefeller) electrostatic accelerator. The range of techniques applied to this problem is now being expanded by the introduction of atomic beam methods designed to utilize extremely small numbers of radioactive atoms produced at the cyclotron.

Finally, the application of nanosecond timing techniques to neutron-time-of-flight observations, developed at the electron linac, has been improved and extended. These techniques, capable of excellent energy resolution in the Mev.-energy range, have been and continue to be applied to the study of nuclear structure as evidenced by the spectra and angular distributions of photoneutrons from a variety of nuclei. The experiments on the lightest nuclei—D, Be, Li,—are being extended to heavy nuclei as well. In addition, the fundamental investigations on the photo-disintegration of the deuteron are being broadened by the development of methods of determining the polarization of the product neutrons. An experiment for this last purpose, involving apparatus planned originally for a small-scale experiment at the M.I.T. machine, has been undertaken recently in collaboration with members of the Rensselaer Polytechnical Institute using the high-intensity linac recently installed there. The beam energy and intensity of that machine will allow performance of this important experiment with good statistics.

THEORETICAL PHYSICS

The strong interaction between our theoretical and experimental groups, especially in the field of low-energy-nuclear physics, has long been an outstanding feature of this Laboratory. Thus, subjects investigated during the past year relate to almost all of those mentioned in the preceding section. Particularly noteworthy, perhaps, is the work on the understanding of the alpha-scattering experiments, carried out in close collaboration with the cyclotron group, and the fundamental work on the nucleon-nucleon interaction utilizing the "boundary-condition" model developed by the theoretical group.

In the field of elementary particle physics, work continues on the fundamentals of field theory and its applications, as well as applications of the dispersion approach, to interactions involving mesons and strange particles. The phenomenological understanding of high energy interactions is a field in which the group has been active for some time. Under the impetus of a growing experimental high-energy program—especially in view of the approaching operation of the Cambridge Electron Accelerator—this type of activity is being increased both by the temporary augmentation of the group and by planned additions to the group on a more junior level.

Participants in the work of the Laboratory during the past year totaled 464 persons, including 50 academic staff members, 110 graduate students and 114 undergraduate students of the Departments of Chemistry and Physics, 38 research associates and D.S.R. staff members at the post doctoral level, six visiting physicists and chemists from other universities, and 146 employees in supporting categories (engineers, technicians, machinists, administrative and computational personnel, etc.). Fifteen Ph.D. degrees, two Master of Science degrees, and 21 Bachelor of Science degrees were completed by students engaged in thesis research in physics and chemistry within the Laboratory.

BERNARD T. FELD

Operations Research Center

The Operations Research Center, established in March, 1953, continues to grow in strength.

The members of the staff of the Center make an important contribution to operations research education at M.I.T. by offering an extensive program of subjects in several departments of the Institute.

The Center affords an opportunity for all students who have an interest in operations research to meet for formal and informal exchange of ideas; it allows them to combine work on actual operations research problems with the pursuit of theoretical knowledge. Special programs for master's and doctor's degrees are coordinated by the Interdepartmental Committee on Operations Research, and visiting fellows regularly make use of the Center's facilities to pursue a program of study and research.

The Center is engaged in sponsored research in the fields of inventory and storage operations, queuing, transportation, decision processes, control theory, mathematical programming, simulation, and computer-directed instruction. Members of the Center participate in the activities of several government agencies and industrial firms.

Work on the dynamics of inventory systems continues, though not at the pace of a year ago. Research on the operation of the M.I.T. libraries has been reactivated, and a number of studies and recommendations have been presented to the Director of Libraries for his consideration and possible action.

Two years ago, the Center began a program of research in automatic instruction to develop a teaching machine with as many of the desirable characteristics of a human tutor as possible. In order to achieve even partially such sophisticated decision-making properties, it was necessary to use a logical element with the power of a general-purpose computer. Consequently, the research focussed on how a teaching machine governed by a computer could be made an efficient and stimulating participant in the educational process. This research culminated in the development of a prototype computer-directed teaching machine with very desirable characteristics. A continuing program of research is now devoted to achieving further progress in the abilities of this machine and to determining the economical feasibility of computer-directed instruction.

This past year has seen a special research effort in the analysis of Markovian systems. Research has been performed on such topics as observation of a Markov process through a noisy information channel, adaptive control systems based on partially observable Markov processes, and search evasion processes wherein a searcher is seeking a mobile opponent. This research in systems analysis is expected to grow even more in the coming year with particular reference to the problems of Bayesian statistical estimation in Markovian systems.

PHILIP M. MORSE

Solar Energy Research

The Godfrey L. Cabot Solar Research Fund supports work done in the Departments of Architecture, Chemistry, Chemical Engineering, Civil Engineering, and Mechanical Engineering.

The M.I.T. Solar House in Lexington, having served its purpose of providing data on the performance of such houses, has been converted to a conventional structure. Ken-ichi Kimura, a Tokyo architect-engineer, has been engaged in studies of how to build flat-plate solar collectors of long life at low cost.

Four Solar Energy Fellowships plus additional personnel funds support work in the Chemistry Department: on solar energy storage by photochemical conversion under Professor Lawrence J. Heidt and on photosynthesis under Professor George H. Büchi.

HOYT C. HOTTEL

Spectroscopy Laboratory

The Laboratory was fortunate during the past year to have certain aspects of the investigations of optical masers by Professors Charles Townes, Ali Javan, and their associates added to its research activities. Many of the maser studies fit in well with existing work and facilities, especially those dealing with excitation of Raman spectra by masers and with the detection of difference frequencies of masers in the far infrared. These researches have proved stimulating and mutually advantageous to the maser group and to the workers in the more conventional forms of spectroscopy.

The 10-inch interferometrically-controlled ruling engine, operated on one of Dean George R. Harrison's projects, continues to produce outstanding diffraction gratings, although difficulties have recently arisen as a result of vibrations produced by the increased building activities at the Institute. Special pains are being taken in the mounting of the 18-inch engine now under construction to reduce such effects. Many requests are now in hand from astronomers, space physicists, chemists, and spectroscopists in general for large echelles and gratings to be ruled on the new engine. Those produced on the present engine are being replicated commercially and distributed to research workers all over the world.

In the field of molecular spectroscopy, far infrared studies continue to be of special interest. The difficulties of spectroscopic work in the wavelength range from 0.05 to 1 mm. are mainly associated with the feebleness of sources and insensitivity of detectors for these wavelengths. Work is in progress to assess the utility of high-temperature plasmas as sources, and the possibilities of optical masers are being examined theoretically. Infrared spectra at wavelengths up to 0.3 mm. have been obtained with a graphite bolometer of Bell Telephone Laboratories' design operating at 1.5°K. The performance was better in signal-to-noise ratio by a factor of about five than our best detector operating at room temperature. Other low-temperature detectors, particularly a gallium-doped germanium bolometer developed at Texas Instruments, are under investigation, and it is hoped to augment the performance of the low-temperature bolometers still further, perhaps by an order of magnitude or more.

Molecular spectra in the far infrared have been obtained with four-membered ring molecules exhibiting vibrations of unusual anharmonicity, as well as with molecules of large rotational constants whose pure rotational spectra are not readily accessible to microwave spectroscopy. Numerous solid-state spectra have also been investigated in this region.

The program of spectroscopic studies of compounds of biophysical interest has made considerable progress during the past year. A combined gravimetric, infrared, and ultra-violet investigation of the structural changes produced by hydration in desoxyribonucleic acids (DNA) has led to interesting conclusions about how the helices of these vital molecules are held together and the effect of water on their structure.

Results of the work of the Spectroscopy Laboratory are published in scientific papers listed under the publications of the Departments of Chemistry and Physics.

Spectroscopy Laboratory

Visiting scientists working in the Laboratory during the past year included Dr. Michael Falk of Laval University, Professor J. Stuart Foster of McGill University, Dr. Thadho Jaseja and Dr. Baij Nath Khanna of Aligarh University (India), Mr. Kajuro Shimizu of Gakushuin University, (Tokyo), and Dr. Clive H. Perry of Queen Mary College (London).

RICHARD C. LORD

Graduate School

The current explosive development in pure science and in its applications in engineering and technology accentuates strongly the importance of graduate education. It is, therefore, worthwhile to review the present role of M.I.T. in graduate education and to forecast its likely role during the next decade, when its position may well become much more dependent on outstanding quality than on quantitative productivity.

Up to the present, M.I.T.'s quantitative position in doctoral production in the physical sciences and engineering has been unique in the country. As given in the last edition of *American Universities and Colleges* M.I.T.'s total of science and engineering doctorates in the decade 1948-1958 was 1,631, as compared with: the University of California (all campuses), 1,489; and the University of Illinois, 1,350. The American Society for Engineering Education figures of doctoral degrees granted in engineering in 1960-1961 show M.I.T. 96, followed by the University of Illinois, 79; and the University of Michigan, 53. In physics, figures from *Physics Today* for the decade 1949-1959 show the University of California (all campuses), 426; followed by M.I.T., 318; and Columbia University, 175.

While numerically less prominent, the graduate programs in such fields as economics, political science, city and regional planning, industrial management, linguistics, and psychology are becoming rapidly recognized on a national level.

Pleasant though our simple, obvious position of numerical preeminence is, remaining for long in this position is not likely, nor is it of major importance in today's context. It is not only reasonable, but essential, that the great state universities respond to the increasing demand for doctorates and that they expand at the graduate level as they are doing at the undergraduate level. The Association of Graduate Schools has from the beginning included a number of the great state universities among its leading members. Such institutions, which draw upon an elastic tax base for whatever support is necessary to meet a strongly felt demand, are necessarily in a position very different from that of private institutions in terms of ability to expand.

What, then, is the pattern for the future distribution of graduate work in the United States? Two somewhat counter currents are observable. Studies such as Berelson's *Graduate Education in the United States* document the impression that generally the same institutions continue to be leaders in graduate education over the decades. Only gradually have additional institutions developed the necessary strength to join the group of leaders. In the same vein, President Logan Wilson of the American Council on Education recently observed in *The Graduate Record* of the Ohio State University that the leading graduate institutions in 1962 would, in general, be the leading institutions in 1972. Certainly the basis of a strong graduate school lies in the accumulated spirit and tradition of scholarly learning and research, developed in a community of creative, productive scholars of top quality supplied with the means for supporting doctoral students and programs.

Another thread of development is expressed in and implemented by the National Defense Education Act Title IV Fellowship Program. A principal purpose of this program is to increase the geographical distribution of resources for graduate study. Its support is applicable only to "new or expanded" graduate programs. Its critics point out that the initiation of a new program or the expansion of an existing one has, in certain cases, been at the expense of a strong existing program operating at less than minimum capacity. Its critics also point out that recognized strength in doctoral work evolves at a distinctly deliberate pace, as a strong faculty is gathered together and its program supported over a term of years under able, inspiring leadership. Quality in graduate work cannot be attained on order at an arbitrary location in a short term. Nevertheless, in actual practice the support of N.D.E.A. Title IV has undoubtedly strengthened, rather than weakened the nation's graduate resources, even though its objective in supporting "new or expanded" programs is, in the eyes of graduate educators, tangential rather than central to the fundamental problem. Unquestionably, one basic need in enhancing the nation's graduate resources is to provide support for the full exploitation of already strong graduate programs.

In this context, M.I.T.'s role appears clear: our basic emphasis must continue to be upon outstanding quality in a slowly growing graduate operation. We may recall M.I.T.'s current policy on size of graduate operation. Graduate students are limited in numbers by ceiling quotas on schools and within schools on departments. As a matter of over-all policy, normal growth expressed in the quotas may be up to 5 per cent per year, with specially approved permissive quotas for new or specially expanded activities such that the total growth shall not exceed 8 per cent per year. The basic limitation on rationally derived quotas is budgetary, a practical expression of limits on faculty, space, and facilities. Actually, during the last several years some of the major departments have grown at a rate somewhat slower than their quotas would have permitted simply because on realistic departmental appraisal, actual resources available were insufficient for meeting high standards for as many graduate students as the quota would permit.

It seems abundantly clear that the primary concern of the M.I.T. Graduate School must be to offer opportunity and encouragement for graduate work of the highest quality under leadership of a preeminent faculty. The size of our Graduate School, provided it is adequate for reasonably efficient operation, is completely secondary to the standard of quality. We should expect, indeed national needs demand, that other institutions, especially the large, vigorous state universities, overtake us in numbers of doctorates produced, recognizing that under today's conditions the measure of total numbers has no real significance or relevance to our mission.

Graduate Student Subsidy

Today, as throughout the history of graduate work in this country, the graduate student comes to his graduate study without resources and expects them to be provided in one way or another. M.I.T.'s principal fields of graduate endeavor are, fortunately, in subject areas of great national importance and so appropriate—and tremendously valuable—

national fellowship programs are rapidly developing. However, these major national programs in no sense take the place of the fellowship monies over which we have control. The critical problem remains that of offering adequately attractive fellowships to new, first-year students of outstanding promise applying to us from other institutions. Outstanding ability in students is as important to an outstanding graduate school as outstanding ability in a faculty, and whether we like it or not the ablest applicants for graduate work will be offered fellowships from several good schools with which our grants must compete. The Sloan Fellowships for first-year engineering graduate students interested in teaching, the fellowships derived from the subvention accompanying each Woodrow Wilson Fellow electing M.I.T., the fellowships from the Ford Foundation grant, the numerous industrial fellowships, and especially the Whitney Fellowships supported by M.I.T.'s graduate assistance endowment funds are all vital to us in attracting outstanding new applicants.

We have now sufficient experience with the Whitney Fellowships to relate the changing magnitude of the cash award to the changing fraction of offers accepted, suggesting how to design our offers in order to achieve a given result. We have found, for example, that the magnitude of the cash award must be increased something over $100 per year to maintain a constant fraction of acceptance. We also find that the fraction of acceptance is linearly relatable to the size of the cash award. We propose to use these data in setting our future fellowship offers in order to obtain a desired result, rather than to change them after the acceptance fraction has dropped below what we wish to see.

Another conclusion made clear within the past year is that the total pattern of graduate student subsidy at M.I.T. (national programs, foundation programs, industrial fellowships, and the funds over which we have some or full control) has become so complex that we must re-determine the best means for administering Institute-controlled graduate student aid to optimize the total result in producing the best graduate student body. One possibility is some degree of decentralization by allocations to schools, but the matter is distinctly complex, and a good answer requires a careful study. This is what may be called the short, or immediate, view of our graduate student subsidy problem.

There is also a longer term view to be considered. Several national programs involve significant numbers of fellowships for M.I.T. students. For example, sixteen Woodrow Wilson Fellowships, aimed at encouraging graduate students with a potential interest in teaching, were given to students who ultimately came to M.I.T. in 1961-1962 and this program also provided subventions from which we supported ten additional graduate students.

But the Federal agencies are quantitatively the largest and statistically the most rapidly growing source of support for graduate students, especially in the fields of M.I.T.'s particular emphasis. Among these, the pioneer National Science Foundation programs have the greatest impact on us. The Foundation's original Graduate Fellowship, initiated for the academic year 1952-53, provided us with 157 fellowships for graduate students in 1961-62. The more recent (1959) N.S.F. Cooperative Graduate Fellowship, associated with and administered in part by the individual institution, provided for 48 M.I.T. graduate students in 1961-62. The National Institutes of Health Fellowships supported more than 20 graduate students in various departments this year, and Atomic Energy Commission Fellowships, initiated in the academic year 1957-58, supported 26 students.

Our assistance under the National Defense Education Act (Title IV) has also been growing as this table shows, with the following pattern of programs and numbers of fellowships approved.

Year of award	*Program*	*Number of fellowships*
1959-60	Political Science	4
1960-61	Political Science	6
	City and Regional Planning	4
1961-62	Political Science	4
	City and Regional Planning	3
	Industrial Management	4
1962-63	Industrial Management	4
	Linguistics	4

Each of these, as awarded, is a three-year fellowship, supposedly seeing a well-prepared graduate student through his doctoral program.

The National Aeronautics and Space Administration (N.A.S.A.) is evolving a training grant program, to be administered in large part by the institution, in which M.I.T. may participate in the near future.

The pattern of support for graduate student subsidy that emerges is this: in the fields of concern to M.I.T. the rate of growth of federal support is very large. We can foresee within a relatively small number of years a broadly based pattern of federal subsidy of graduate students that carries the major portion of the effort in these fields. Under these conditions our own fellowship monies will constitute a very small fraction of the total fellowship support given to our graduate students; however our own resources will remain an element of great importance in giving us flexibility of action to attract selected outstanding applicants. It is probable that spending somewhat more fellowship money than we now have available would be a wise investment. However, in view of the rate of development of federal sources of fellowship support, the case for long-term endowment of institutional fellowships is not very forceful. A much stronger case appears possible for year-to-year grants from general funds on an annual basis in the several-year interval during which likely expansion of federal graduate student support evolves. These are all subjects for study during the coming year; obviously, we must be sensitive and responsive to these developments.

Trends in Educational Programs

The significant specific developments in graduate work are so numerous that they are best described in the separate school and departmental reports. Here I can most appropriately give attention to general trends.

One major trend in our graduate work, in which other major institutions share, is the rapidly increasing emphasis on and interest in multidisciplinary and interdepartmental activities. This intellectually desirable development appears to be achieving viability, indeed vitality, that summarily dismisses concern for departmental provincialism.

A mere mention of subject matter areas, special research, and facilities, is sufficient to suggest the widespread incidence of multidisciplinary activities. These include: the Center for Materials Science and Engineering, with a major new physical facility approaching the construction stage; the Research Laboratory of Electronics; the Laboratory for Nuclear Science; the life sciences, with biology and nutrition interacting with physics, chemistry, and other disciplines; the earth sciences, strongly rooted in the quantitative and physical sciences and embracing meteorology, oceanography, geology, and space science; magnetohydrodynamics; the educational syntheses of dynamics and thermodynamics in engineering; the Center for Communication Sciences, relating the pure and applied physical sciences with linguistics, biology, and psychology; the Center for International Studies, reaching into and cooperating with a variety of disciplines in studying basic social and human problems; the School of Industrial Management, applying numerous social, physical, and mathematical sciences as well as engineering; and the Joint Center for Urban Studies, where research in city and regional planning is influenced deeply by engineering and the social and physical sciences. This list, by no means complete, suggests the vitality and power associated with interdisciplinary interactions occurring at the Institute.

In a somewhat parallel way we are also involved in inter-institutional collaboration and cooperation. Our cross-registration arrangement with Harvard University for graduate students is no less important educationally because it has become routine in its practical arrangements. The Computation Center, a notable focus of interdisciplinary interaction also through its New England regional operation, provides a significant inter-institutional exchange at the graduate student as well as at the faculty level. These are only a few of the inter-institutional interactions that notably extend our range of influence in graduate education and the opportunities open to our own graduate students.

Returning to our own campus, this year marks the formal release of Professor Avery A. Ashdown from his responsibilities as Master of the Graduate House, where for 29 years he has exercised a level and quality of leadership and influence which can be appreciated only by those who have participated in it. Professor Francis Bitter has accepted the responsibility of Graduate House Master, and he and Mrs. Bitter will continue in their own way the tradition of warm faculty-graduate student interaction in which Dr. Ashdown has pioneered. We look forward to an augmented pattern of such relationships in a new Graduate Center.

While we do not yet have funds for the new Graduate Center, planning continues. Concepts of what such a center should achieve and of how it should accordingly be designed evolve slowly; yet we hope to be prepared to make wise decisions when the funds for the much-needed new facilities are finally available.

Graduate School

At its October 10 meeting, the Committee on Graduate School Policy voted to recommend to the Faculty that it recommend to the Corporation the authorization of the Doctor of Philosophy Degree in psychology. Following the process used in recent years, an *ad hoc* committee to review the resources and program underlying this degree has been appointed by Acting Dean John T. Norton; its members were Professor Harold Schlosberg, (Chairman), Head of the Psychology Department at Brown University; Dr. Dana L. Farnsworth, Director of Medical Services at Harvard University: Professor Patrick M. Hurley, Chairman of the Faculty at M.I.T.; Professor Walter A. Rosenblith; and Professor Patrick M. Wall. The committee was enthusiastically favorable to the authorization of this degree as an additional contribution of M.I.T. both to the field of psychology in its own right and in relation to work in our other disciplines.

The Dean of the Graduate School, and M.I.T. as an institution, are greatly indebted to Professor John T. Norton for his generous and able contribution as Acting Dean for the calendar year ending January 15 1962, during which the undersigned was absent on leave to serve as President Pro Tem of Robert College, Istanbul. The extraordinary richness of M.I.T.'s resources in people, talent, and spirit is doubly impressive upon return from a more modest—even if distinguished—institution.

Some of the significant statistics on the Graduate School operation of the past year follow.

Advanced Degrees Conferred, 1961-62

	S.M.	*Engineer*	*Sc.D.*	*Ph.D.*	*Total*
September, 1961	158	12	19	41	230
February, 1962	111	17	18	34	180
June, 1962	359	57	45	67	528
Total	**628**	**86**	**82**	**142**	**938**

Graduate School Registration, 1961-62

	Summer, 1961	*Fall, 1961*	*Spring, 1962*
School of Engineering	756	1617	1516
School of Science	289	817	771
School of Architecture and City Planning	23	82	72
School of Humanities and Social Science	17	138	139
School of Industrial Management	83	260	242
Total	**1168**	**2914**	**2740**

U.S. or Canadian citizens	952	2382	2366
other	216	532	374
Total	**1168**	**2914**	**2740**
Regular Students	1070	2462	2366
Special Students	98	452	374
Total	**1168**	**2914**	**2740**
Civilian students (male)	—	2683	2532
Civilian students (female)	—	81	66
Military students	—	150	142
Total		**2914**	**2740**

Fellowships, Scholarships, and Staff Awards Administered by M.I.T., 1961-62

	Number of Awardees	*Amount*
Fellowships from industrial and special funds	299	709,066.50
Fellowships and scholarships from M.I.T. general funds	72	147,863.00
Staff tuition scholarships	476	309,473.83
Total	847	**$1,166,403.33**

HAROLD L. HAZEN

Vice President, Academic Administration

As the professional aspects of the Institute's educational and research programs have progressed and deepened, there has been a comparable effort to develop and strengthen the parts of our total program which serve the student outside the classroom (and which, incidentally, also serve other members of the Institute community). Reports of the heads of the administrative offices concerned with these aspects of our program follow. It is a responsibility of the Vice President, Academic Administration, to represent the President on administrative matters relating to these activities.

The reports which follow give a more complete account of progress, but I should like to call particular attention to events in these areas of the past year which have special significance. These include:

1. The continuing wise development of the intercollegiate aspects of our very successful athletic program.

2. The progressive improvement in the student residential system, including the extension of the housemaster system.

3. The start of construction of two major additions to the residential system, a dormitory which will accommodate 116 women students as well as a housemaster and his family, and a group of buildings which will accommodate 210 married student families.

4. The policy reaffirmation of the fraternities as "a vital and essential part" of the residential system at M.I.T., together with the expression of tangible ways in which the Institute can be of help to the fraternities in relation to special problems which they face.

There are numerous problems and opportunities which still confront us in these areas. At least three are deserving of special attention in this report and, among others, will be receiving our careful consideration in the months ahead. They are:

1. The need to increase still further the quality and quantity of both undergraduate and graduate student housing;

2. The need to develop a long-range solution to the space problem of the Medical Department which results from the growth of the Institute community as well as the increase in per capita use of the available medical services;

3. The need to continue to seek out new financial resources for undergraduate scholarship support under our direct control, particularly in the light of our growing dependence upon scholarships awarded outside M.I.T.

MALCOLM G. KISPERT

Dean of Student Affairs

Effective at the beginning of this report year, the title of the office of the Dean of Students was changed to the office of the Dean of Student Affairs. The new title is intended to describe more adequately the expanding areas of responsibility which have resulted from the rapid growth of the Institute's over-all educational program during the past few years. As the curricula of all undergraduate programs have been made increasingly more flexible to meet new and changing objectives, the "Dean's Office" inevitably has become more involved in academic matters. As the Institute has progressed toward the goal of a residential university, the housing program has become an extremely important part of our broad educational program. So, too, the manifold extra-curricular activities, the maturing athletic programs, and the increasing responsibility of student government are now contributing in greater measure to the quality of the educational experience of each student.

Responsibility for the formulation and implementation of policies to further the development of these extra-curricular educational programs and to enhance their relationships with the formal academic aspects of student life is an important part of the task of the Dean of Student Affairs. Thus, the Dean's Office is responsible for what might be called our horizontal educational structure while the academic deans are responsible for the vertical educational structures of the respective schools.

Increased concern for student affairs is not being undertaken, however, at the expense of concern for individual students. As in the past, the Dean's Office continues to carry responsibility for helping each student maintain the personal well-being which is clearly requisite for his successful academic performance. Although we shall continue to improve the general student environment, we are well aware that the great multiplicity of circumstances affecting students makes individual consideration both desirable and inevitable in a large number of cases.

Despite the significant and rapid progress M.I.T. has made toward achieving the character of a true university, many deficiencies remain. Students as well as faculty and administrative officers continue to express very real concern. Carl Wunsch '62, editor of *The Tech* for 1961-62 and recipient of a Karl Taylor Compton Prize, expressed this concern in an editorial entitled "An M.I.T. Education" published this past February. The following comments are taken from the editorial:

> We do not know how close the faculty thinks it is coming in arriving at its aims in undergraduate education here, but a great many undergraduates have had disturbing thoughts about their education. The Institute is a much more serious place, and in some ways a grimmer place, than most colleges of reality or fiction. Graduates are in many senses of the word professional people, and their studying is directed towards a goal that many professions require only after several more years of work in law school, etc. It is this professional competence that M.I.T. does so well in instilling in students; the other factors in life M.I.T. falls down in. . . .
>
> The tendencies of the four years here are to encourage a singleness of purpose that lies wholly within a narrow professional field, in many ways far removed from physical reality. . . .
>
> M.I.T. has set itself high goals for the second hundred years of its existence. If it hopes to have its graduates play as large a role in the coming century as it would like, it will probably have to change its atmosphere from one of purely scientific ferment to one of general intellectual upheaval.

These and many other questions relating to non-curricular and curricular matters have led this year to the establishment of two parallel study groups by the Faculty Committee on Educational Policy. The Committee has charged these two groups with the tasks of carrying out broad and intensive studies of academic curricula, teaching methods, student and faculty attitudes, housing, extra-curricular programs, and general environment. One group, under the leadership of Professor Jerrold R. Zacharias, has primary responsibility for curricular matters—with specific concern for the undergraduate "core" subject content and teaching methods. The second group carries primary responsibility for non-curricular matters—again particularly at the undergraduate level. For this second study, the Dean's Office is acting as a coordinating agency for certain segments of the program being carried out by several faculty standing committees and administrative offices and a number of cooperating student groups. Although this combined study is conceived as a major effort extending over two or more years, the progress which has already been made in some areas of interest to the Dean's Office is reflected in certain of the following portions of this report.

STUDENT ACTIVITIES

Some seventy-odd recognized student activities—varying in membership from under ten to over 2,000 and in various stages of fiscal and managerial health—continue to form the major concern of the Activities Development Board. Primarily an advisory group, this student-faculty committee under the chairmanship of Professor Herbert H. Woodson paid particular attention this year to the campus humor magazine, *Voo Doo,* and to the general problems of fiscal responsibility and managerial continuity brought to the Committee's attention by the chairman of the undergraduate Finance Board, George Wyman '62, and his successor, Peter Van Aken '63.

Following several suggestions of the Activities Development Board, the *Voo Doo* managing board throughout the year improved the magazine's position, increased sales, and returned *Voo Doo* to a reasonably healthy financial status.

To assist many of the larger activities maintain necessary continuity, the Activities Development Board is now encouraging the establishment of alumni or faculty advisory groups—a pattern which was common until the early 1950's but which has now disappeared.

The Tech, which only a few years ago appeared to be losing student and faculty respect, has rebounded under a series of exceptionally able student leaders. During the past year the newspaper exhibited a remarkable new maturity and responsibility in reporting and commentary.

In another area of communications, WTBS completed its first year of F-M operation. The uniformly high quality of the station's programming has been noted by several observers.

As co-chairman, Michael Jablow '62 and Bardwell Salmon '62 led an able student committee to success in producing the largest Parents' Weekend ever held at M.I.T.

Under Joseph Everingham's skillful guidance, M.I.T. students continued to enlarge and improve our extra-curricular drama program. In particular, Dramashop was awarded a Karl Taylor Compton prize in recognition of its enrichment of the cultural life of the Institute.

M.I.T.'s extra-curricular musical program for the year culminated in the newly inaugurated Spring Festival of Music which for the first time brought before a body of prominent alumni the musical forces of the Glee Club, Symphony Orchestra, Concert Band, and Choral Society. The programs of old and new music found spontaneous and popular acclaim.

All performances of Beethoven's String Quartet of the Humanities Series were sold out; and the ten informal library concerts were so well attended that students and staff had to sit on the floor.

The Glee Club gave concerts with Smith, Vassar, and Holyoke; the Symphony Orchestra gave concerts at Smith and Amherst; the Concert Band's tour was a notable success; and the Choral Society prepared for its third European tour by extending its already wide range of programs.

E. Dennis Johnson '62 was awarded a Karl Taylor Compton Prize for his quiet effective contributions to the musical life of the Institute. Professor Klaus Liepmann continued to provide the rare combination of professional and teaching skill which has resulted in outstanding acceptance and participation for music at M.I.T.

Space limitations prohibit reporting the progress of each activity. Suffice to say that the Institute's underlying philosophy of student freedom and responsibility continues to result in high quality in the area of activities development and operation.

STUDENT GOVERNMENT

As in the area of student activities, the major problems which concerned the Institute Committee and its Executive Committee were those of continuity, communication, and responsibility.

Student entrepreneural activities came under scrutiny, and formulation of a general code for both regulation and encouragement of such activities was begun.

The student judicial committee system and judicial relations with the Faculty Committee on Discipline and with administrative offices were topics of great interest. Student government intends to carry out a major study of this area during the coming year, in the hope of achieving improvement in mutual cooperation.

The Student Committee on Educational Policy participated effectively in the further development of student-faculty relationships through its interest in the Undergraduate Seminar Program and the Freshman Feedback System, the latter being a program to permit lecturers and students to discuss problems in understanding the material. Richard Stein '62 received a Karl Taylor Compton Prize in recognition of his outstanding leadership of this Committee.

The Student Center Committee and a number of additional interested undergraduates, graduates, and staff members worked long hours with Dean Robert J. Holden and with Professor Eduardo F. Catalano, who has been named architect for the Student Center. Although a few comparatively minor disagreements remain, all who have studied Professor Catalano's designs for the long-awaited and much-needed building enthusiastically endorse his solution to this difficult problem.

PERSONNEL

During this academic year, Richard Balch, Director of Athletics since 1955, resigned to return to Stanford University. Ross H. Smith, formerly associate director of athletics at Cornell University, succeeded Mr. Balch in this challenging position.

Richard McDowell, Assistant to the Dean of Student Affairs since his graduation in 1960, resigned to return to graduate work and Laurence Bishoff '59 has succeeded him in the Dean's Office.

At the close of my first hectic year as Dean of Student Affairs, I should be remiss if I did not express my sincere appreciation to each of my associates for the particularly generous and selfless help they have provided to the "freshman dean." Several of these gentlemen have prepared the following reports on those areas of interest which are of primary concern to them.

KENNETH R. WADLEIGH

STUDENT HOUSING

The report year was marked by several developments of unusual importance in the residential system of the Institute. Burton House became a fully self-contained house with the completion of its dining room and supporting facilities. Designed by Professors William H. Brown and Eduardo Catalano of the Department of Architecture, the new room is admirably suited to use for meetings as well as a dining room. In the process of integrating the new structure into the House, provision was made for a house library, a new lounge, and an office for the House Committee. Herbert C. Lebovitz '52, an alumnus of Burton House, has generously endowed the library, and a carefully planned program of book purchases has begun. The support of the Alumni Fund, which made a major contribution to financing the dining room, has also implemented the reorganization and redecoration of the lobby and ground-floor areas of the House, which are notable improvements in its amenities.

Construction of two major additions to the residential system was begun during the year. The first, a residence for women students which will fill a long-felt and steadily increasing need, has been made possible through the gift of Mrs. Stanley McCormick, an alumna of the Class of 1904. The new house will accommodate 116 girls and includes provisions for a Master and his family as well as guest rooms for occasional visitors. A dining room, library-lounge, floor lounges with kitchenettes, and penthouse study-lounge and sun deck will combine to make the house a place for comfortable living and effective studying. The architects are Anderson, Beckwith, and Haible; the basic design of the house has been the personal concern of Professor Herbert L. Beckwith. Beginning with the Class of 1966, women undergraduates will be required to reside in the new house, and the present dormitory at 120 Bay State Road will be terminated. It is expected that the present enrollment of some 70 undergraduate women will increase substantially in the next few years. With the establishment of a fitting and proper home for them, the long tradition of women as students at the Institute will enter a new dimension.

The second major addition to the residential system, also scheduled for completion by the fall of 1963, is a group of buildings to accommodate 210 married students and their families. The complex at the west end of the campus will consist of a 16-story tower containing 90 efficiency apartments (living-bedroom, bath, and kitchen) and 60 apartments of living room, bedroom, bath, and kitchen, and four three-story buildings comprising apartments with two bedrooms. Suitable storage areas, play areas for children, generous automobile parking, baby-carriage accommodations, and quarters for a well-baby clinic, a store, and a resident manager are provided in the village, which has been designed by Hugh Stubbins and Associates and is financed through the Housing and Home Finance Agency. Since the demolition of Westgate and Westgate West in 1958-59, our married students—in October, 1961, they numbered 1276, 137 undergraduate and 1139 graduate—have faced increasing difficulty in finding suitable housing. This project will bring back to the campus a considerable proportion of the membership of the Technology Dames—the wives of students—whose return will be welcomed indeed.

Less tangible than the foregoing two new ventures, but over the long term comparable in significance, was the issuance in March of "The Institute and Its Fraternities: A Progress Report." This paper, in which the Corporation Committee on Student Activities, the Faculty Committee on Student Environment, and the Offices of the President, the Vice President and Treasurer, and the Dean of Student Affairs concurred, declared the fraternities "a vital and essential part" of the residential pattern of the Institute and stated that they "merit and have our support and endorsement." Taking a realistic view of the legal, financial, and operational problems surrounding earlier plans for bringing a number of fraternities to the Cambridge campus, the report, which was circulated to all parties concerned—active members, advisers, and alumni corporation officers—established the basis for closer co-operation between the Institute and the various chapters, provided for more liberal financial assistance to fraternities desiring to purchase or to remodel chapter houses, and looked to future collaboration in planning for the integration of fraternity houses into urban renewal projects yet to come. Through these means, it is hoped that the Institute fraternity system will be assisted substantially in consolidating and improving its present physical situation.

The report took cognizance as well of the academic purpose for which fraternities and their physical setting exist. Through it, the Institute offered to provide fraternities on request with a resident tutor on the same basis as that on which the tutorial plan operates in the undergraduate houses. By the end of the report year, nine chapters had taken advantage of this offer; tutors will be in residence in their houses at the start of the academic year 1962-63.

In many ways the most important component of the residential system is the personal—the Masters, Faculty Residents, Senior Tutors, and Tutors who, living in residence with graduates and undergraduates, serve truly as vicars for a largely non-resident faculty and bring into student life the stimulation of association with older minds. The dean among this group, Professor Avery A. Ashdown, Master of the Graduate House since its inauguration by President Karl T. Compton in 1933, retired at the end of the report year after a career of unmatched devotion to the advancement and enhancement of graduate life at the Institute. He is succeeded by Professor Francis Bitter; Professor and Mrs. Bitter will take up residence in the Graduate House in the fall.

The full tutorial plan was extended to Baker House at the close of the year with the appointment as Master there of Professor E. Lee Gamble; he and Mrs. Gamble succeed Dr. and Mrs. Alar Toomre in residence. Dr. Toomre as Faculty Resident at Baker during the preceding two years contributed greatly to the well being of the House, particularly in bringing into its orbit many distinguished members of the faculty as speakers and leaders of discussions. Professor and Mrs. Howard R. Bartlett rounded out their fourth year in residence at Burton House, where Professor Bartlett became Master in 1958. The physical improvements of Burton House earlier mentioned were greatly facilitated by his careful attention and by his skill in bringing student opinion to mature and helpful expression during the planning stages. Burton House is noted for its manifold creative extra-curricular activities, ranging from electronics to chorales, in all of which Professor and Mrs. Bartlett have given able guidance.

The Senior House continued its all-inclusive program of house activities during the year, the traditional play this spring being an original composition by a member of the House. After two dynamic years Professor Samuel J. Mason is taking leave for a year from his post as Master there. This post will be filled by Professor Murray Eden, who has been Senior Tutor since 1960 and whose familiarity with the House and its life assures the most desirable kind of continuity in its affairs. Professor F. Albert Cotton, who became Faculty Resident of the East Campus in 1959, relinquished that post at the end of the report year to devote full attention to his teaching and research endeavors. His tour as Resident of the Parallels was marked by continuity of the individualism fostered by student government there and by good spirit and cooperation. He is succeeded by Professor William H. Curry, Jr., of the Department of Naval Science.

The East Campus is the only residential center not as yet brought into the full tutorial plan. Study of the entire complex of the Parallels, the Senior House, and Walker Memorial was initiated this spring, for the purpose of ascertaining how best the whole might be developed as a continuing residential area. Professor Marvin Goody of the Department of Architecture has the problem in hand. If a solution can be found which will increase the accommodations available to students and which will provide for the establishment of a Master, Senior Tutor, and Tutors in the East Campus, a gain of pronounced importance will have been achieved.

The need for additional residential space implied above becomes crystal clear when we look at a few figures. We began the academic year 1962-63 with 1,753 unmarried graduate students; the Graduate House accommodates 452. Of our 3,348 unmarried male undergraduates, 1,510 were in residence in the Houses. Fraternity houses accommodated 908 of the 1,146 fraternity members. The others, living in apartments and "fraternity annexes," are counted among the 725 students living in rooming houses and apartments and for whom there is no room on the campus. These "independents" do not include the 205 commuters who live in their own family homes. The proposed Graduate Center and additional undergraduate accommodations, through the further development of East Campus and/or through the erection of a new undergraduate house for men, are important needs for the future of the Institute.

The objectives and means to attain these objectives of the entire undergraduate residential program, including the housemaster-tutor system, the Institute Houses and the fraternities, formed the major topic of study of the Faculty Committee on Student Environment during this past year. The Committee, under the chairmanship of Professor Holt Ashley, has unanimously and enthusiastically endorsed rapid development along the lines set out in the preceding paragraphs. We look forward to increased faculty participation at a number of levels within the residential system.

FREDERICK G. FASSETT, JR.

ATHLETICS

The success of the athletic program at M.I.T. may be measured by its contributions to the growth of individual students and to the establishment of a generally wholesome way of life within the student community.

For purposes of determining policy and evaluating the operation of the program, the Director of Athletics is assisted by a board appointed by the President and composed of three faculty members, four undergraduates, three alumni, the Dean of Student Affairs, the Medical Director, and a representative of the Institute's administration.

Much effort has been made to insure desirable outcomes consistent with the broad educational objectives of the Institute. Activities have been beamed widely toward the entire community, hoping to meet the athletic and recreational needs of all students. We regularly strive to establish genuine student awareness of a direct relationship between the pursuit of wholesome interests in physical activity and happiness in later life. We emphasize that carry-over interests contribute greatly to general health.

In program planning, we recognize the wide range of athletic interests among the students attracted to M.I.T. and the necessity for developing a curriculum to meet a variance in abilities as well as interest.

The broad scope of the program includes: (1) instruction in physical education for all entering students with course selection by individuals; (2) an intramural program developed around living groups within the community; (3) athletic clubs in specific areas of interest; (4) individual participation on an informal or casual basis; and (5) a strong program of intercollegiate athletics embracing competition at varsity and freshman levels in eighteen sports.

In reporting on this program, I feel it would be unwise to single out any one area as most desirable in terms of results. We purposely place different emphases on specific objectives for the several divisions. For example, the less formal organization of the intramural program, with fewer disciplines and less demand upon students' time, regularly attracts a large segment within the community. There are, however, those undergraduates, perhaps fewer in number, who seek out and benefit most from the more highly competitive intercollegiate activities. For these students, the pursuit of the intercollegiate program presents unique opportunities for the development of desirable qualities of character; among these qualities are the aim to achieve maximum potential, the exercise of leadership, and the will to win coupled with an ability to benefit constructively when one has fallen short of victory in a particular contest. Mediocrity in terms of accepting underachievement is as undesirable in intercollegiate athletics as it is in the classroom or laboratory. We believe that sound coaching on the field contributes to the development of favorable attitudes of performance in the years following graduation.

ATHLETIC STAFF

As a result of the resignation of George D. Wood, Jr., Assistant Director of Public Relations who had been directing sports information for the Athletic Department, Glenn P. Strehle, Assistant to the Director of Athletics, assumed the responsibility for sports publicity. Ronald L. Keenhold resigned as instructor in physical education and coach of freshman swimming; he was replaced by Hendrik Gideonse on a part-time basis. Gerrit W. Zwart succeeded Val Skov as coach of lightweight rowing, the latter having resigned to devote full time to his professional career.

PHYSICAL EDUCATION PROGRAM

The physical education program this past year offered instruction in nineteen activities. Sailing, swimming, tennis, physical development, ice skating, and judo continued to be most popular, attracting 64 per cent of the 3,347 registrants. Although participation in the program is required of all freshmen, the opportunity for course selection consistent with personal interests and an emphasis by the staff on the long range value of the habit of exercise have led to continued participation well beyond the required minimum. The du Pont Athletic Center, Briggs Field, and the Alumni Pool are used by large numbers of students regularly enjoying physical recreation on an informal basis. Much of their initial interest is a result of instruction obtained in the physical education classes.

Although priority in class registration is given to those students fulfilling the requirements, it is interesting to note that the Department was able to accept 382 students this year for non-credit participation. This figure includes 15 graduate students and 9 undergraduate women, the latter for classes in fencing, swimming, and tennis.

INTERCOLLEGIATE ATHLETICS

The intercollegiate athletic program enjoyed a most successful year, both in qualities of competition and in student participation. Outstanding records were compiled in soccor, basketball, skiing, and rowing. The soccer team climaxed the season with a come-from-behind victory over Army before a large gathering on Field Day. Robert Mehrabian '64 was the leading scorer in the New England League. The basketball team had a record of seventeen wins and four losses, completing the season with a fifteen-game winning streak, the third longest in the nation. David H. Koch '62, son of Fred C. Koch '22, broke almost all the M.I.T. scoring records and was named to the New England All-Star Team.

The heavyweight crew won four of its five races during the regular season and returned both the Karl Taylor Compton Cup and the Admiral Edward L. Cochrane Cup to the Institute. The Compton Cup is awarded annually to the winner of the Harvard, Princeton, and M.I.T. heavyweight varsity race. The victory this year was the first for M.I.T. since the Cup was placed in competition in 1933. The Cochrane Cup signified victory over the varsities of Wisconsin, Dartmouth, Brown, and Boston University.

The lightweight crew demonstrated superior class in winning the Geiger Cup in the annual competition among Cornell, Columbia, and M.I.T. Later in the Eastern Sprint Regatta they finished in a triple tie for the varsity championship with Navy and Cornell. On the basis of their splendid season, they were entered in the Thames Cup competition of the Henley Royal Regatta on July 4 to 8. After a first-round win over University College, Dublin, M.I.T. was defeated by a crew representing the National Provincial Bank of England, who went on to win the cup. The Bankers set a new course record in the Thames competition in defeating M.I.T.

The ski team, winners of the New England Intercollegiate Ski Championship in mid-season, entered the winter carnivals of the Eastern Intercollegiate Ski Association. H. Bent Aasnaes '63 surprised the major competitors by winning the Eastern Intercollegiate Ski Jumping Championship.

To add to the foregoing accomplishments, the swimmers won nine of thirteen meets; the wrestlers finished third in the New England championships; the fencers defeated Harvard in the course of a fine season; the rifle team won twenty-one matches while losing only five, winning first place in the New England College Rifle League Finals; and the tennis squad was victorious in ten of sixteen competitions.

Although we do not judge the success of intercollegiate athletics solely on the number of contests won or lost, it is gratifying to note that Tech men can and do compete favorably.

THE INTRAMURAL PROGRAM

The intramural program has had a most successful year under the leadership of Robert A. Lytle, Jr. '62 and the Intramural Council. Although no statistics are available regarding the number of individual students who participated in the fifteen sports, we can report a record number of teams entered in all competitions. Further, the new rule excluding varsity athletes from intramurals during the same season as their varsity sport has resulted in increased opportunities for many students who might otherwise be displaced by varsity athletes.

The Intramural Council voted to exclude Graduate House from the competition for the All-Sports Trophy this year, and the change seems to have produced favorable results. The Graduate House teams enjoy the competition but have little interest in the trophy, whereas the undergraduate living units take much pride in the recognition attached to the trophy.

THE ATHLETIC ASSOCIATION

In recent years the athletic program has expanded greatly with regard to facilities, staff, and the scope of the entire program. Throughout this expansion, the M.I.T. Athletic Association has continued to fulfill an important role, not only as an aid in the administration of the program but also as an educational experience for the students. This year the Executive Committee of the Athletic Association met weekly with the Director of Athletics. The important contributions to general athletic affairs and to the competent undergraduate management of the intercollegiate teams and the letterman's club are clear examples of unexcelled leadership and direction of this Executive Committee.

Outstanding service has been rendered by Thomas G. Burns '62, President; Philip S. Schmidt '62, Varsity Vice President; Robert A. Lytle, Jr. '62, Intramural Vice President; Chester H. Riley '62, T-Club President; and Elliott H. Bird '63, Recorder. The Letterman's Club received one of the Karl Taylor Compton Prizes this past May for its contribution to student life at the Institute.

ATHLETIC CLUBS

The role of the athletic clubs in the M.I.T. program becomes increasingly important as the program expands to include the organization of interest groups outside the intercollegiate teams. In fencing, rugby, water polo, weight lifting, judo, and pistol and rifle, the less-formal club organization seems ideally suited to provide the necessary framework for instruction and regular practice sessions. Competitions are scheduled as available; eligibility rules are not a consideration; graduate students and frequently staff personnel take part.

The most notable fact in the club activities of the past year is the marked rise in the interest in judo. M.I.T.'s Rockwell Cage was the site this past winter of the New England A.A.U. Judo Championships, which were won by the M.I.T. Judo Club. In addition to the usual Y.M.C.A. A.A.U. club entries, there were clubs from Harvard, Dartmouth, and other New England colleges. There is a strong indication that regular intercollegiate competition may soon be available in judo.

ATHLETIC AWARDS

The Clifford Award, donated by the class of 1948 to recognize the Athlete-of-the-Year, was won by Charles W. Gamble '62 of Littleton, Colorado. A diminutive leader, playmaker on the basketball team, and outstanding college golfer in the East, "Chuck" was a popular choice for the award.

The Admiral Edward L. Cochrane Award to the senior who best demonstrated "qualities of leadership, humility and scholarship" went to Dirk Berghager '62, captain of the soccer team.

The Eastern College Athletic Conference has designated the Merit Medal to honor the senior who best combines achievement in athletics and scholarship, and the initial winner at M.I.T. is Philip J. Robinson '62, who has been outstanding in varsity soccer, basketball and lacrosse and who has an excellent academic record.

FACULTY, STAFF, AND ALUMNI RECREATION

During 1961-62 a total of 4,884 members of the faculty, staff, employees, and alumni obtained athletic cards for personal and family use of the athletic facilities. The most popular activities for these groups were squash, tennis, swimming, and individual exercise. Family interest was foremost in ice skating and swimming. An additional 247 families registered in the Nautical Association for participation in the sailing program. Swimming and skating classes for faculty children numbered 32 and 48 registrants, respectively.

SUMMER DAY CAMP

The summer day camp continues to attract capacity attendance from families of Institute faculty and staff. Boys and girls, ages 6 through 13, are active in a daily program of swimming and sailing with additional instruction in arts and crafts, archery, rifle, group games, and painting, and in golf and tennis for the older groups.

The day camp not only utilizes the excellent athletic facilities during a relatively slack period but also provides a desirable service within the Institute community.

ROSS H. SMITH

COUNSELING

The Institute's policy continues to be that counseling in general is most effectively accomplished by members of the faculty. The Freshman Advisory Council is composed of about eighty members of the faculty, while there are well over one hundred Faculty Counselors organized by departments for upperclass and graduate students. The House Masters, Senior Tutors, and Tutors now provide counseling within the Institute Houses in a way that was unknown ten years ago. Several fraternities now plan to have resident tutors, selected jointly by the individual fraternity and the Dean's Office.

Counseling is certainly not restricted to those students in academic difficulty. In the broadest sense, most counseling occurs when students discuss their professional problems and aims with faculty members. Faculty members are clearly better qualified for this academic counseling than counselors without professional competence in the fields of science or engineering. Many students whose problems are more of a personal than a professional nature take counsel with us in the Dean's Office or with Dr. Benson R. Snyder, Psychiatrist-in-Chief of the Medical Department, and his associates.

While we have made progress in developing an effective counseling system, there are still many shortcomings. For example, many students do not come to know well a single member of the faculty. Too frequently, letters of recommendation for many seniors can be phrased only in vague and general terms based solely on grades. We continue to find that the best and the poorest students are most apt to be known by several faculty members. The problem here is not how to divide a fixed amount of faculty contact in a different ratio but rather how to further our efforts to know each student well and in ways that are not confined solely to his grades.

The faculty's concern for students who are not realizing their potential and are consequently in academic difficulty is expressed, in part, through the Committee on Academic Performance. The attention of the Committee has increasingly focused on the causes of students' difficulties and on more effective ways of helping these students. Dr. Snyder and Professor John T. Rule, former Dean of Students, have continued at the request of the Committee a research project initiated over a year ago which promises to throw light on the relationships between a student's academic performance and his characteristic way of handling stress within the Institute environment.

During the past year the Committee on Academic Performance made several significant changes in its policies in regard to both freshmen and upperclassmen. Instead of disqualifying some freshmen at midyear as in the past, the Committee now plans to place such students on probation so that they may either continue or withdraw voluntarily. (This change is based on the conviction that the Institute accepts responsibility for each freshman for the academic year, and that the responsibility and the freshman cannot both be discharged simultaneously after only four months.) An upperclassman has been disqualified in the past if his average for any term dropped suddenly below a level of D minus. In the future, the Committee plans in almost all cases to place such a student on probation. The general result of these changes will be that disqualification of a student will occur ordinarily only after the student has been unsuccessful in improving the quality of his work following his being placed on probation.

It is also the Committee's intention to use its influence to urge students on probation to take greater advantage of the Institute's counseling resources in the hope that the underlying causes of poor performance may be uncovered in a larger number of cases.

Such changes in policy might surprise an alumnus who graduated ten or more years ago and whose notion of the purpose of the Committee on Academic Performance was colored by the assumption that it served primarily as the faculty's academic executioner. But the general conclusion of those members of the faculty and administration who are most involved in the counseling of students is that academic difficulty is seldom the result of intellectual inadequacy. Instead, its causes lie in the general area of character and personality where emotional and psychological factors are far more significant than I.Q. scores.

WILLIAM SPEER

FRESHMAN ADVISORY COUNCIL AND FRESHMAN WEEK END

As in the past, the eighty members of the Freshman Advisory Council were appointed this year on a proportional basis from all of the academic departments. Professor Nathan H. Cook served as chairman of the Council and of its ten-man executive committee. The Council assumed responsibility for general academic and personal counseling of the entire freshman class and for those sophomores who did not choose to enter a particular course at the beginning of their second year. At registration day in September there were 112 students in this category, and in February there were 64. These numbers compare with 80 and 37 in the same periods of the preceding year, the initial year of the option. Professor William Siebert of the Committee had general supervision of this "undesignated sophomore" program.

The Council as a whole met four times during the year: prior to Freshman Week End, at mid-term grade time, and at the end of both fall and spring terms. The Executive Committee met ten times during the year to deal with a number of questions relating to the operation of the first year. A most fruitful development of the past year was the increased contact between the leadership of the required freshman subjects and the Council, and between the individual instructors and advisers. Equally important was the establishment of effective linkages between living group counselors and advisers.

In addition to the prime counseling contribution of each individual adviser, the Council sponsored general programs for all freshman, principally the orientation program in September and the Course selection program in the early spring. A Newsletter containing items of general interest to freshmen was circulated several times during the year.

The Freshman Week End program, presented in the four-day period preceding September registration, provided a welcome for the entering freshmen and sought to help them gain some measure of confidence in their new surroundings. The major portion of the time available was assigned to the Freshman Advisory Council for essential academic business and for the presentation of a series of lectures entitled Introduction to Technology. This series, formulated by Professors Siebert and Henry M. Paynter, effectively introduced the new students in a highly personal, entertaining manner to a few areas of research and teaching of current interest at the Institute. Another segment of time was given over to an introduction to student activities and living groups. The reception for students and parents given by President and Mrs. Stratton was a very genuine occasion of welcome.

The Freshman Week End program is a joint venture of the Office of the Dean of Student Affairs, the Freshman Advisory Council, and the Student Freshman Co-ordinating Committee. Michael Jablow '62 was awarded a Karl Taylor Compton Prize in recognition of his outstanding contribution to this year's program.

We now recognize that the four-day program can serve only as one segment in the general orientation of freshmen. Now being discussed are proposals which may provide a meaningful extension of the program throughout the first term.

It has become increasingly clear during the ten years of operation of the Faculty Advisory Council that the personal qualities of each adviser in his relationships with his freshman students contribute most to the success or failure of this advisory system. We have not yet been able to devise means to adequately recognize the contribution of many of these individual faculty members who have given so generously of themselves to further the interests of their emerging colleagues. To achieve this recognition is one of the tasks ahead.

ROBERT J. HOLDEN

RELIGIOUS ACTIVITIES

The several student religious organizations and the religious counselors experienced a substantial year of increasing interreligious cooperation and conversation. It is indeed gratifying to note the leadership which the combined groups are now taking to further religious understanding and respect. All of the counselors report increased personal contacts with students.

During the year the Rev. William J. Sullivan, C.S.P., joined the counseling staff as an assistant to the Rev. J. Edward Nugent, C.S.P., and the Rev. John A. Russell, Jr., representing the Methodist denomination, was appointed to the Institute on a full-time basis.

Of interest both to students and to faculty were several special programs presented during the year. The Protestant Ministry presented Professor Reinhold Neibuhr on one occasion and also sponsored a seminar with Dean Gordon S. Brown and Professors Huston Smith and Albert Bush-Brown. The Hillel Foundation sponsored Dr. Mordecai M. Kaplan, and the Graduate House Council presented Professor Paul Tillich. The various seminars and discussion groups sponsored by the several traditions gave further evidence of the considerable interest of students in religious matters.

ROBERT J. HOLDEN

Student Aid Center

It is an interesting coincidence that the total financial assistance received by the undergraduate student body during 1961-62 was almost equivalent to the amount set as the objective for student aid in the current Second Century Fund drive—$3,000,000. To summarize briefly, $1,450,200 was awarded in scholarships, $533,068 was awarded in loans, and $938,800 was earned by undergraduates in campus jobs; a total of $2,922,068 was thus made available through these three forms of aid.

With the numbers in our undergraduate population relatively the same as last year and the tuition set at the same level, one would expect only slight changes in the amounts of financial assistance extended during the past academic year. However, as the comparative statistics in the table will show, one-half (49.5 per cent) of all undergraduates received direct aid (scholarships and loans) in 1961-62—a gain of 6.5 per cent in dollars and 15 per cent in numbers assisted. It should be kept in mind that each year our student body changes approximately by 25 per cent, which may, in part, account for these increases.

Undergraduate Scholarships and Loans, 1961-62

	1961-62			1960-61		
	Number	*Awards*	*Total*	*Number*	*Awards*	*Total*
UNDERGRADUATE SCHOLARSHIPS						
From M.I.T. endowment funds:						
Freshman scholarships	247	$244,978.80		242	$220,556.00	
Other undergraduate scholarships	285	$286,533.00		223	$170,150.00	
			$531,511.80			$390,706.00
From outside sources:						
Freshman scholarships	229	$258,802.10		183	$259,650.00	
Other undergraduate scholarships	612	$659,886.85		524	$636,335.00	
			$918,688.95			$895,985.00
	1373		$1,450,220.75	1172		$1,286,691.00
UNDERGRADUATE LOANS						
	781	$515,958.00		725	$542,402.50	
	15	15,110.00		13	13,410.00	
	3	2,000.00		26	18,500.00	
Technology Loan Fund			$533,068.00			$574,312.50
Mead Fund						
Other loan funds	1722*		$1,983,288.75	1493*		$1,861,003.50

* This total is modified to allow for individuals receiving both scholarship and loan.

SCHOLARSHIPS

For the third successive year it is most gratifying to report a substantial increase in the undergraduate scholarship endowment through gifts and bequests totalling more than $1,750,000; the capital increment was better than 20 per cent, representing the largest gain in scholarship endowment in many years. Substantial amounts were bequeathed to the Institute by Hattie G. Atkins, Mrs. Iolia Lohbiller, F. P. von Olker, and Mrs. Rose N. Richheimer. To the previously established James and Donald H. Sheridan Fund, slightly more than $500,000 was added in the final settlement of the estate.

New scholarships have been funded by capital gifts from Nils Anderson, Kenneth E. Bell '17, Rudolf E. Gruber '16 in establishing the Rita Welch Gruber Memorial Scholarship, Charles B. Malone, Jr. '15, and Theodore A. Mangelsdorf '26. Other scholarships have been established through current annual gifts by Sidney G. Albert '29, D. James Athan '54, William E. Hartman '37, the Huguenot Society of America, and the Link Foundation.

From a review of the table it will be noted that a sizable number of undergraduates received financial assistance from sources "outside" of the Institute's scholarship endowment income; these "outside gifts" represent better than 60 per cent of the total scholarship dollars awarded. This office gratefully records the excellent opportunity given to 841 undergraduates to attain their educational objectives at M.I.T. by better than 260 benefactors. It is not possible to list every donor, though more than half of this support came from foundations, companies, corporations, and private funds and trusts. A large number of private organizations widely distributed through the United States have assisted young people from their geographical areas to meet the costs of education. M.I.T. alumni clubs, fraternal organizations, professional societies, the Commonwealth of Massachusetts, the states of Rhode Island and New Jersey, and a number of individuals (some anonymous) make up a large and diversified list of contributors of financial support for needy students. The National Merit Scholarship Corporation sponsored the largest group of scholars, while the M.I.T. Alumni Fund, the Alfred P. Sloan Foundation, the General Motors Corporation, and several other industrial companies materially assisted in keeping M.I.T. scholarship opportunities on a national scale. In many instances, corporations, foundations, and companies, in addition to the support to individuals made unrestricted grants to the Institute to "help meet the cost of education." During the year this form of financial support amounted to $181,475, the largest amount received in a single college year up to the present time.

It might be well to sound a note of caution on the Institute's scholarship support from "outside sources." Some organizations have made gifts on the basis of a specified number of years; other groups have adopted a rotation system to spread their gifts to a number of colleges rather than concentrating their generosity on a limited group. It should be kept in mind that major changes in policy and attitude toward this type of support may occur in these "outstanding sources." It is reasonable to assume that the Institute may be approaching a maximum in this area and that the future may bring a levelling-off process with a decrease both in number of donors and total dollars contributed. Comparative data of the past ten years will illustrate the marked increase of "outside assistance":

	1951-52	*1955-56*	*1961-62*
Tuition	$800	$900	$1500
Number of scholarships	553	654	1373
Total scholarship dollars	$188,311	$354,622	$1,450,220
Number of donors	7	50	262
Total "outside dollars"	$35,162	$134,630	$918,689
Number of scholarships provided	62	160	841

LOAN FUNDS

Prior to the solicitation for the Second Century Fund, the Institute held, in addition to the Technology Loan Fund, some fifteen other named funds for student loans. These funds vary widely in their capital amounts and some are restricted to students in specific professional fields. All of these funds, except for the limitations noted, are operated in the same manner (with the same interest rates, repayment plans, etc.) as the Technology Loan Fund; thus in a general way they might be considered as part of it. During the past year the Institute's capacity for student loans was augmented by the establishment of three memorial funds: the John A. Herlihy ('27) Memorial Fund for students in aeronautics and astronautics, established by the United Aircraft Foundation; the Richard H. Tingey ('27) Memorial Fund, established by the Herman W. Falk Foundation; and the Michael J. Pollock ('59) Memorial Fund, established by his parents and friends. Through a bequest, the Thomas F. and Lida Niles Connors Loan Fund became available for civil engineering students. In commemoration of the twenty-fifth year of his graduation from M.I.T., Felix S. Klock '36 established a loan fund for undergraduate students in his name and in that of some of his friends. The Ford Foundation extended the scope of its "forgivable loans" to pre-doctoral students in engineering who plan to make their careers in university and college teaching.

During the year 1,247 requests for loan assistance were considered; 1,102 were presented to the Technology Loan Fund; and 961 applications were approved for a total of $661,082.50. Included in this total are 180 graduate students who were granted $145,874.50, an increase both in numbers and amounts over 1960-61. A total of $41,355.00 was loaned from other loan funds of the Institute to 59 individuals, including graduates and undergraduates. To 19 graduate students, $36,850.00 was granted from the Ford Foundation Fellowship Loan Fund. Requests for assistance under the Installment Credit Plan decreased by almost one-half compared to the previous year. Nevertheless, the summation of all the different forms of credit extension granted to both graduate and undergraduate students represents a substantial sum granted to 18 per cent of our total student body:

Source	*Number*	*Amount*
Technology Loan Fund	961	$661,082.50
Other M.I.T. loan funds	78	78,210.00
Installment Credit Plan	69	29,350.00
Total	**1108**	**$768,642.50**

SCHOLARSHIPS FOR FACULTY CHILDREN

The next academic year will witness the Institute's complete dissociation from the Tuition Exchange Plan; during the year 1961-62 six "imports" were registered and five graduated in June, 1962, leaving one member of 1963 eligible for this form of assistance.

A total of 130 faculty children received scholarship benefits amounting to $101,756 under the Faculty Children Scholarship Plan. There were 18 faculty children at the Institute, and 112 were enrolled in 62 different institutions of higher learning. This plan, which will contribute up to $850 for 1962-63 toward the tuition of each faculty child in college, remains most popular and is sincerely appreciated by faculty members.

OTHER BENEFITS

Undergraduate and graduate students receiving benefits from the federal government under the provisions of Public Laws 550 and 634 totaled 79 in the fall term, 71 in the spring term, and 13 in the 1962 Summer Session.

For 1962-63 George W. Davies has been appointed Assistant to the Director of Student Aid; he replaces Ernest G. Hurst '60, who resigned to give full time to graduate work.

THOMAS P. PITRE

Admissions Office

The following statistics concerning admissions are for the year ending with registration in September, 1962, since that is the logical termination of the Admissions Office year.

FIRST-YEAR CLASS:	*1961*	*1962*
Total applications	6282	5559
Completed final applications	3597	3276
Admissions offered	1528	1590
Actual registrations	893	885
Registrations as per cent of admissions	58.5%	55.7%
Number of secondary schools represented	697	675
Per cent from nine northeastern states	45%	44%
COLLEGE TRANSFERS:		
Total applications	537	448
Applications completed	239	231
Admissions offered	123	126
Actual registrations	94	86
Registrations as per cent of admissions	76.4%	68%
GRADUATE STUDENTS:		
Total applications	3835	4382
Admissions offered	2196	2307
Actual registrations	1355	1410
Registrations as per cent of admissions	62%	61%

Advanced Placement

	Number of students seeking credit		*Number of subjects credited*	
PROCEDURE:	*1961*	*1962*	*1961*	*1962*
College Board Test Program	237	271	395	476
Advanced Standing Examination	37	13	41	32
College transcript	30	32	71	47
Total	**280**[1]	**292**[1]	**507**	**555**

[1] In some cases credit was sought and earned through two procedures; duplication is eliminated in the totals.

SUBJECTS CREDITED:	*Number of students given credit of one semester or more* 1961	1962
Chemistry	51	51
Mathematics	103	129
Physics	3	8
Freshman Elective	22	24

Contacts

NUMBER OF SECONDARY SCHOOLS VISITED:	1961	1962
By Educational Counselors (college nights)	153	147
By faculty and administrative staff members[1]	579	542
By the Admissions Office staff	181	194
Total	913	883
NUMBER OF PERSONAL INTERVIEWS:		
At M.I.T.	1407	1181
In New York	152	131
By Educational Counselors	2725	2537
Number of persons taking tours of M.I.T.	4966	4024

APPLICATION TRENDS

The number of applications for admission to the Graduate School continues to increase, having hit a new high this year. Transfer applicants remain at a relatively stable level. The number of completed applications for admission to the freshman class dropped off significantly for the second successive year. At present, the averages of all of the qualitative factors of those who apply— scholastic indices, geographic distribution, school distribution, and personal qualifications— are holding up well enough so there is no cause for immediate concern. Most of the decrease in numbers can be attributed to more careful guidance, to a general reduction in the average number of multiple applications, and to the somewhat discouraging effects of large numbers of rejections in the past.

Continuance of the present trend for several more years, at anything like the 1960-62 rate, would be serious. It behooves us, there-

[1] Faculty and administration personnel making school visits during 1961-62 were Professors Douglas P. Adams, Dwight M. B. Baumann, Eugene Bell, John Blair, Primus B. Bon, Albert Bush-Brown, Robert L. Coble, William H. Dennen, Robert Evans, Jr., Robley D. Evans, Bernard S. Gould, Justin E. Kerwin, William F. Massy, Sanford A. Miller, Walter McKay, James R. Munkres, George W. Pearsall, William H. Pinson, Jr., George S. Reichenbach, Herbert H. Richardson, Campbell L. Searle, Thomas B. Sheridan, Arthur C. Smith, B. Alden Thresher, William M. Whitney, and Robert C. Wood; and J. Samuel Jones, John F. Maxwell, Richard L. McDowell, Thomas P. Pitre, and Constantine B. Simonides.

fore, to amplify our efforts to convey to secondary schools and to qualified youth the accurate story about M.I.T. undergraduate education. We have been one of the acknowledged leaders in college-secondary school contacts. As other colleges improve their techniques, we must also continue to advance in this respect. It seems eminently clear that the general public impression of M.I.T. (with its combination of highly favorable and partly critical stereotypes) will not, in itself, produce enough good incoming freshmen to sustain the high standards we have established. Two years ago the Director of Admissions hailed the time when we would have "fewer and better applicants." We are experiencing such a situation now; our major task is to insure that applicants continue to be better.

COURSE SELECTION AND ADVANCED PLACEMENT

We retain, I think successfully, the practice of admitting all students at the freshman level to M.I.T. as a whole, with no reference to intended field of study. This practice ignores—or at least fails to resist—the continuing upward trend in the percentage who intend to go into science. Both the current popularity of pure, as contrasted to applied, science and the selection process itself support this trend. Minor alterations in the selection process could retard the trend slightly; but only major changes in policy will halt it and restore a preference for engineering. There is little evidence that such major changes are imminent.

Advanced Placement and other processes leading to the granting of advanced credit to freshmen continue to expand in numbers and scope. However, the rate of increase has fallen off appreciably; the indications are that the curve is definitely flattening. This suggests that the program for Advanced Placement will continue to affect significantly the schedules of many freshmen, but that basic alteration of the freshman curriculum, as a result of widespread acceleration programs in secondary schools, is still a long way off.

OTHER DEVELOPMENTS

With completion of the Women's Dormitory, it appears that we will once again be able to apply precisely the same standards of selection to female as to male applicants. Thereafter, our total selection process will still, in effect, be discriminating in only two minor respects—both primarily financial. The number of foreign students admitted to various undergraduate levels is curtailed by the policy of not offering scholarship aid to foreign students during their first year of residence here. And the number of well-qualified students unable to come to M.I.T. because the magnitude of their financial need exceeds the amount of aid that can be offered is a significant, though fortunately not large, percentage.

About 40 per cent of those freshmen whom we admit decide to go elsewhere. This figure is not uncommon among competitive-admissions colleges, but some of the preferred colleges have appreciably lower rates of attrition between acceptance and matriculation. Possibly the increased tuition this year is responsible for the slightly higher loss this year than last. Nevertheless, the figures are not reassuring; we must somehow get across to the public a more favorable image of undergraduate education at M.I.T. if we are to raise the percentage of those accepted who actually come here.

THE IMAGE OF UNDERGRADUATE EDUCATION

The Admissions Office is constantly confronted with images of M.I.T. which must be corrected if we are to compete really favorably with other top universities and liberal arts colleges. Some of these undesirable images are quite unfair, in terms of present-day M.I.T.; this requires correction of a false impression. Others are unfavorable but nevertheless founded on truth; these may call for correction of the situation at M.I.T. And still others are just plain false notions, such as the stereotype that the *best* undergraduate education bears the trademark "liberal arts."

We are convinced that the progress made in recent years toward developing a "predominantly residential college," toward strengthening the humanities program, toward liberalizing the curricula and the selection of a professional course, and toward amplifying the points of personal contact between faculty and students has helped greatly in improving our image. More than 30 years ago the Dean of Undergraduate Students observed that "the misapprehension, still widespread in many quarters, that the Institute puts aside every consideration except scholastic ability ought to be, and is being discouraged. Much is also being done to dissipate the false but nevertheless prevalent feeling that the Institute is to be attempted only by 'geniuses'." These observations apply equally appropriately today. We have progressed far, but have yet to discover the magic formula for both "liberalizing" the Institute and at the same time preserving its character "as a place for men to work, and not for boys to play," as Francis Amasa Walker put it.

ACKNOWLEDGMENTS

Over the years the Admissions Office has followed the policy of working as closely as possible with other groups in the Institute—particularly the Graduate School Office, Dean's Office, Registrar's Office, Student Aid Center, Medical Department, Alumni Office, and (we can add without apology) the Athletic Department. We hope we have been of some service to these groups. We gladly acknowledge indebtedness to them for the contributions they have made to the general Admissions Office program.

The assistance of members of the faculty, notably in the school visiting program, is invaluable. We express our gratitude to those 31 men who, collectively, visited 542 secondary schools on behalf of the Institute, and also to the department heads and colleagues who helped carry on while these visitors were in the field.

Similarly, we express appreciation to those 30 members of the administration and faculty, including members of the Admissions Committee, who read many hundreds of application folders and rendered judgments both on individual applicants and on the general qualities we seek in applicants.

As an additional attempt to obtain information on what the faculty desires or expects in students, we asked leaders of the undergraduate Seminars to report to us on the presence or absence of qualities they considered desirable in the individual members of their small seminar groups. These data, helpfully supplied by virtually all of the seminar leaders, have been summarized and will be used both as a guide in future admissions procedures and as a basis for further studies of non-academic factors relevant in the selection of freshmen.

The Educational Council, a group of 800 devoted alumni, constitute an essential arm of the Admissions office which reaches into every state and several foreign countries to assist in guidance at the secondary school level and in pre-selection interviews. No report of the Admissions Office would be complete without a special testimonial to services performed by this patient, hard-working group. They constitute the single most important medium for interpreting the undergraduate M.I.T. program to the potential student.

ROLAND B. GREELEY

Registrar

All statistics on registration and staff in the following tables are given as of the fifth week of the Fall Term, except: 1943-44 as of August 2, 1943; 1944-45 as of November 27, 1944; and 1945-46 as of July 3, 1945. For statistics not listed in the following pages, consult the report of the Registrar for 1958-59.

Table 1. Student Registration since the Founding of the Institute*

Year	*Number of Students*	*Year*	*Number of Students*	*Year*	*Number of Students*
1865–66	72	1898–99	1,171	1931–32	3,188
1866–67	137	1899–00	1,178	1932–33	2,831
1867–68	167	1900–01	1,277	1933–34	2,606
1868–69	172	1901–02	1,415	1934–35	2,507
1869–70	206	1902–03	1,608	1935–36	2,540
1870–71	224	1903–04	1,528	1936–37	2,793
1871–72	261	1904–05	1,561	1937–38	2,966
1872–73	348	1905–06	1,466	1938–39	3,093
1873–74	276	1906–07	1,397	1939–40	3,100
1874–75	248	1907–08	1,415	1940–41	3,138
1875–76	255	1908–09	1,461	1941–42	3,055
1876–77	215	1909–10	1,479	1942–43	3,048
1877–78	194	1910–11	1,506	1943–44	1,579
1878–79	188	1911–12	1,559	1944–45	1,198
1879–80	203	1912–13	1,611	1945–46	1,538
1880–81	253	1913–14	1,685	1946–47	5,172
1881–82	302	1914–15	1,816	1947–48	5,662
1882–83	368	1915–16	1,900	1948–49	5,433
1883–84	443	1916–17	1,957	1949–50	5,458
1884–85	579	1917–18	1,698	1950–51	5,171
1885–86	609	1918–19	1,819	1951–52	4,874
1886–87	637	1919–20	3,078	1952–53	5,074
1887–88	720	1920–21	3,436	1953–54	5,183
1888–89	827	1921–22	3,505	1954–55	5,348
1889–90	909	1922–23	3,180	1955–56	5,648
1890–91	937	1923–24	2,949	1956–57	6,000
1891–92	1,011	1924–25	2,938	1957–58	6,179
1892–93	1,060	1925–26	2,813	1958–59	6,259
1893–94	1,157	1926–27	2,671	1959–60	6,270
1894–95	1,183	1927–28	2,712	1960–61	6,289
1895–96	1,187	1928–29	2,868	1961–62	6,454
1896–97	1,198	1929–30	3,066		
1897–98	1,198	1930–31	3,209		

* From 1943 to 1946 Army and Navy students are omitted (see Table 3-B in reports for 1943 to 1946).

Table 1-A. Student Registration in the Summer Session since 1948

Year	**In Regular Subjects*	*†In Other Subjects*	*Year*	**In Regular Subjects*	*†In Other Subjects*
1948	2,146	. .	1955	1,619	1,653
1949	1,875	171	1956	1,553	2,497
1950	1,852	259	1957	1,548	1,757
1951	1,861	813	1958	1,650	1,752
1952	1,689	832	1959	1,635	1,510
1953	1,672	1,289	1960	1,600	1,696
1954	1,675	1,398	1961	1,668	1,412

* Students attending regular subjects from M.I.T. curricula.
† Students attending professional and technical subjects which are not part of M.I.T. curricula and in general carry no academic credit.

Table 2. The Corps of Instructors

	1957	*1958*	*1959*	*1960*	*1961*
Faculty members of the staff:					
Professors	201	209	230	246	265
Associate Professors	169	171	179	188	209
Assistant Professors	206	211	211	199	213
Ex-Officio	15	16	16	17	17
Professors Emeriti (Lecturers)	15	17	16	19	26
Research Associates	1	1	1	1	1
Total faculty	**607**	**625**	**653**	**670**	**731**
Other members of the staff:					
Instructors	145	136	145	179	166
Technical Instructors	12	12	12	14	13
†Administrative Assistants	5	. .	. .	. .	. .
Teaching Assistants	261	286	282	326	306
Lecturers	40	51	55	52	61
Research Associates	118	140	163	184	183
Research Assistants	621	647	653	665	696
Technical Assistants	47	52	47	58	62
Total of other staff	**1,249**	**1,324**	**1,357**	**1,478**	**1,487**
Total staff	**1,856**	**1,949**	**2,010**	**2,148**	**2,218**
Other members of the faculty:					
Faculty and administrative officers, Emeriti (not Lecturers)	60	58	58	49	50
Total of other faculty	**60**	**58**	**58**	**49**	**50**

† Not included beginning in 1958–59.

Table 3. Classification of Students since 1958

Course	1959–60 1	1959–60 2	1959–60 3	1959–60 4	1959–60 G	1959–60 Total	1960–61 1§	1960–61 2	1960–61 3	1960–61 4	1960–61 G	1960–61 Total	1961–62 1	1961–62 2	1961–62 3	1961–62 4	1961–62 G	1961–62 Total	Course Number
School of Architecture and Planning:																			
Architecture (IV-A)	13	29	30	22	35	129	..	25	30	29	37	121	..	28	25	26	39	118	IV-A
Fifth year	..	..	..	35	..	35	..	..	..	30	..	30	..	..	..	29	..	29	
City and Regional Planning (IV-B)	..	..	..	..	43	43	..	..	..	..	40	40	..	..	..	..	43	43	IV-B
Total	**13**	**29**	**30**	**57**	**78**	**207**	..	**25**	**30**	**59**	**77**	**191**	..	**28**	**25**	**55**	**82**	**190**	
School of Engineering:																			
Aeronautics and Astronautics (XVI)	61	60	27	57	183	388	..	44	47	28	190	309	..	55	33	47	187	322	XVI
Aeronautics and Astronautics (XVI-B) (Cooperative)	..	..	5	14	..	19	..	..	7	10	..	17	..	..	13	8	..	21	XVI-B
Building Engineering and Construction (XVII)	..	..	..	..	21	21	..	..	..	..	21	21	..	..	..	..	21	21	XVII
Chemical Engineering (X)	82	68	81	90	146	467	..	54	62	79	145	340	..	46	47	67	124	284	X
Chemical Engineering Practice (X-A) (Graduate)	..	..	..	..	16	16	..	..	..	..	23	23	..	..	..	..	20	20	X-A
Chemical Engineering Practice (X-B) (Undergraduate)	..	..	..	2	..	2	..	..	..	..	..	..	..	..	..	..	..	..	X-B
Civil Engineering (I)	19	30	32	34	100	215	..	22	33	35	111	201	..	12	21	35	123	191	I
Army Engineer	..	..	..	..	5	5	..	..	..	..	7	7	..	..	..	..	7	7	
Electrical Engineering (VI)	211	204	107	128	396	1,046	..	185	125	99	431	840	..	..	..	..	..	..	VI
Electrical Engineering (VI-I)	..	..	..	..	..	..	..	..	..	..	..	..	..	171	156	155	479	961	VI-I
Electrical Science and Engineering (VI-2)	..	..	..	..	..	..	..	..	..	..	..	..	..	51	30	27	2	110	VI-2
Electrical Engineering (VI-A) (Cooperative)	..	..	42	47	39	128	..	..	55	45	20	120	..	..	48	39	27	114	VI-A
Electrical Science and Engineering (VI-B)	..	39	24	18	11	92	..	33	26	19	10	88	..	..	..	..	..	..	VI-B
Mechanical Engineering (II)	37	78	88	69	222	494	..	54	61	79	214	408	..	49	55	75	213	392	II
Textile Technology	..	..	..	..	7	7	..	..	..	..	12	12	..	..	..	..	9	9	II-T
Mechanical Engineering (II-B) (Cooperative)	..	..	8	5	..	13	..	..	8	11	..	19	..	..	5	8	..	13	II-B
‡Metallurgy (III-A)	15	15	29	40	147	246	..	8	7	30	158	240	..	10	10	5	156	217	III
‡Materials Science (III-B)	..	..	..	..	..	..	..	11	10	..			..	10	16	10			
Ceramics	..	..	..	..	17	17	..	..	..	..	16	16	..	..	..	..	17	17	
Naval Architecture and Marine Engineering (XIII)	6	10	8	10	25	59	..	6	7	10	19	42	..	5	7	3	22	37	XIII
Naval Construction and Engineering (XIII-A)	..	..	..	..	80	80#	..	..	..	..	69	69#	..	..	..	..	60	60#	XIII-A
Nuclear Engineering (XXII)	..	..	..	..	107	107	..	..	..	..	122	122	..	..	..	..	125	125	XXII
Sanitary Engineering (XI)	..	..	..	..	14	14	..	..	..	..	19	19	..	..	..	..	15	15	XI
Shipping and Shipbuilding Management (XIII-B)	..	..	..	..	3	3	..	..	..	..	2	2	..	..	..	..	..	..	XIII-B
Total	**431**	**504**	**451**	**514**	**1,539**	**3,439**	..	**417**	**448**	**445**	**1,589**	**2,899**	..	**409**	**441**	**479**	**1,607**	**2,936**	

School of Humanities and Social Science:																			
Economics, Politics, and Engineering (XIV-A)	2	3	7	11	112	155	..	9	1	10	120	156	..	5	10	3	127	177	XIV
Economics, Politics, and Science (XIV-B)	..	8	5	7			..	3	9	4			..	3	20	9			
Humanities and Engineering (XXI-A)	2	..	7	7	..	16	..	2	3	12	..	17	..	3	5	4	..	12	XXI-A
Humanities and Science (XXI-B)	13	15	22	13	..	63	..	16	36	20	..	72	..	13	21	34	..	68	XXI-B
Modern Languages (XXIII)	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10	10	XXIII
Science Teaching (IX-C) or Science and Mathematics Teaching (XXI-C)	..	..	..	..	2	2		Discontinued											IX-C or XXI-C
Total	**17**	**26**	**41**	**38**	**114**	**236**	..	**30**	**49**	**46**	**120**	**245**	..	**24**	**56**	**50**	**137**	**267**	
School of Industrial Management:																			
Industrial Management (XV)	**21**	**52**	**62**	**91**	**179**	**405**	..	**39**	**55**	**70**	**218**	**382**	..	**23**	**50**	**72**	**254**	**399**	XV
School of Science:																			
Biochemical Engineering (XX-B)	..	..	1	1	..	2	..	..	1	2	..	3	..	..	..	..	..	..	XX-B
Chemistry (V)	56	23	29	17	202	327	..	42	16	29	203	290	..	39	41	14	206	300	V
Geology and Geophysics (XII)	5	8	11	10	62	96	..	8	10	12	58	88	..	6	14	12	60	92	XII
Geology and Geophysics (XII-A)	..	..	..	..	2	2	..	..	..	..	2	2	..	..	..	..	..	..	XII-A
¶Life Sciences (VII)	9	29	18	18	59	133	..	22	28	18	60	128	..	27	31	31	75	164	VII
Mathematics (XVIII)	98	71	55	59	128	411	..	83	68	59	135	345	..	105	87	66	136	394	XVIII
Meteorology (XIX)	..	..	..	..	48	48	..	..	..	..	54	54	..	..	..	..	46	46	XIX
*Nutrition, Food Science and Technology (XX)	3	4	4	3	48	62	..	3	3	4	35	45	..	..	..	..	32	32	XX
Physics (VIII)	283	171	129	88	231	902	..	178	112	124	246	660	..	130	147	107	257	641	VIII
Total	**454**	**306**	**247**	**196**	**780**	**1,983**	..	**336**	**238**	**248**	**793**	**1,615**	..	**307**	**320**	**230**	**812**	**1,669**	
Undesignated	..	..	..	..	..	..	..	58	..	..	..	58	..	85	..	..	..	85	Undesignated
First year	..	..	..	..	..	..	899	..	..	..	..	899	908	..	..	..	..	908	First year
Grand total	**936**	**917**	**831**	**896†**	**2,690**	**6,270**	**899**	**905**	**820**	**868†**	**2,797**	**6,289**	**908**	**876**	**892**	**886**	**2,892**	**6,454**	Grand total
					#First graduate year — 24 Second graduate year — 26 Third graduate year — 30						#First graduate year — 18 Second graduate year — 26 Third graduate year — 25						#First graduate year — 16 Second graduate year — 21 Third graduate year — 23		

* Prior to 1961–62, Food Technology.
† These totals include the fifth year in Architecture (IV-A).
‡ Beginning in 1960–61 Metallurgy was changed to Metallurgy, III-A, and Materials Science, III-B.
§ Beginning in 1960–61 no Course designation was required for first-year students.
¶ Prior to 1961–62, Quantitative Biology.

Table 3-A. Women Students Classified by Schools, Courses, and Years, 1961–62

Course		*Year* 2	3	4	G	*Total*
School of Architecture and Planning:						
Architecture (IV-A)		1	..	..	2	
Fifth year		..	..	1	..	3
City and Regional Planning (IV-B)		..	..	..	6	6
Total		**1**	**..**	**1**	**8**	**10**
School of Engineering:						
Chemical Engineering (X)		2	..	..	1	3
Civil Engineering (I)		..	..	..	1	1
Electrical Engineering (VI)		1	..	..	4	5
Mechanical Engineering (II)		1	1	..	1	3
Mechanical Engineering (Cooperative) (II-B)		..	1	..	..	1
Metallurgy (III-A)		..	..	..	2	
Materials Science (III-B)		..	1	..	..	3
Naval Architecture and Marine Engineering (XIII)		..	..	1	..	1
Sanitary Engineering (XI)		..	..	..	1	1
Total		**4**	**3**	**1**	**10**	**18**
School of Humanities and Social Science:						
Economics, Politics, and Engineering or Science (XIV-A, XIV-B)		..	3	..	12	15
Humanities and Engineering or Science (XXI-A, XXI-B)		1	..	3	..	4
Modern Languages (XXIII)		..	..	..	3	3
Total		**1**	**3**	**3**	**15**	**22**
School of Industrial Management:						
Industrial Management (XV)		..	..	..	**1**	**1**
School of Science:						
Chemistry (V)		2	3	..	12	17
Geology and Geophysics (XII)		..	..	..	3	3
Life Sciences (VII)		2	2	1	14	19
Mathematics (XVIII)		9	6	4	10	29
Meteorology (XIX)		..	..	..	1	1
Nutrition, Food Science and Technology (XX)		..	..	..	3	3
Physics (VIII)		4	3	4	7	18
Total		**17**	**14**	**9**	**50**	**90**
Undesignated		4	..	..	..	4
First-year students	23					23
Grand total	**23**	**27**	**20**	**14**	**84**	**168**

Table 3-B. Special Students Classified by Schools, Courses, and Years, 1961[1]–62

Course		*Year* 2	3	4	G	*Total*
School of Architecture and Planning:						
Architecture (IV-A)		2	1	2	8	13
City and Regional Planning (IV-B)		..	..	..	5	5
Total		**2**	**1**	**2**	**13**	**18**
School of Engineering:						
Aeronautics and Astronautics (XVI)		..	..	1	60	61
Building Engineering and Construction (XVII)		..	..	..	2	2
Chemical Engineering (X)		..	..	1	5	6
Civil Engineering (I)		..	..	..	4	4
Electrical Engineering (VI)		..	6	..	136	142
Mechanical Engineering (II)		1	1	2	33	37
Textile Technology		..	..	..	3	3
Metallurgy (III-A)		..	3	..	15	19
Materials Science (III-B)		1	..	..	..	
Ceramics		..	..	..	1	1
Naval Architecture and Marine Engineering (XIII)		..	1	..	4	5
Nuclear Engineering (XXII)		..	..	..	8	8
Total		**2**	**11**	**4**	**271**	**288**
School of Humanities and Social Science:						
Economics, Politics, and Engineering or Science (XIV-A, XIV-B)		..	4	1	13	18
Humanities and Engineering (XXI-A)		..	..	3	..	3
Modern Languages (XXIII)		..	..	..	3	3
Total		..	**4**	**4**	**16**	**24**
School of Industrial Management:						
Industrial Management (XV)		**2**	**2**	**2**	**17**	**23**
School of Science:						
Chemistry (V)		..	..	..	9	9
Geology and Geophysics (XII)		..	..	1	2	3
Life Sciences (VII)		1	1	..	20	22
Mathematics (XVIII)		2	4	3	34	43
Meteorology (XIX)		..	..	..	14	14
Nutrition, Food Science and Technology (XX)		..	..	..	3	3
Physics (VIII)		..	2	3	44	49
Total		**3**	**7**	**7**	**126**	**143**
Undesignated		1	..	..	..	1
First-year students	4					4
Grand total	**4**	**10**	**25**	**19**	**443**	**501**

[1]Included also in Table 3.

Table 4. Continued, Former, and New Students

	1957–58	1958–59	1959–60	1960–61	1961–62
Continued Students:					
Undergraduate and Graduate Students registered at the end of the last academic year (including Special Students)	3,996	4,020	4,047	4,178	4,263
Noncontinued Students:					
Former Undergraduate and Graduate Students who previously attended the Institute but were not registered at the end of the last academic year (including Special Students)	302	286	312	285	313
Undergraduate Students who enrolled for the first time since secondary school (excluding Special Students)	883	917	917	883	892
Undergraduate Students who enrolled for the first time at the Institute and who transferred from another collegiate institution (excluding Special Students)	162	142	131	76	80
Graduate Students who enrolled for the first time at the Institute (excluding Special Students)	588	681	657	659	685
Special Undergraduate and Graduate Students with no previous Institute registration	248	213	206	208	221
Total	**6,179**	**6,259**	**6,270**	**6,289**	**6,454**

Table 5. Regular Students from Other Colleges and Graduates of M.I.T. Classified by Schools and Courses, 1961–62

	Entered with no previous degree	*Entered with Bachelor's degree from other colleges* U	G	*Entered Graduate School with Bachelor's degree from M.I.T.*
School of Architecture and Planning:				
Architecture (IV-A)	9	15	29	2
Fifth year	6	14	..	..
City and Regional Planning (IV-B)	..	..	37	1
Total	**15**	**29**	**66**	**3**
School of Engineering:				
Aeronautics and Astronautics (XVI)	9	3	95	32
Building Engineering and Construction (XVII)	..	..	8	11
Chemical Engineering (X)	14	1	90	49
Civil Engineering (I)	21	..	101	25
Electrical Engineering (VI)				
Electrical Engineering (1)	51	3	236	107
Electrical Engineering and Science (2)	3	..	..	2
Electrical Engineering (Cooperative) (VI-A)	7	..	..	27
Mechanical Engineering (II)	30	2	121	58
Textile Technology	..	..	6	..
Metallurgy (III-A)	..	1	96	45
Materials Science (III-B)	2	..		
Ceramics	..	..	14	2
Naval Architecture and Marine Engineering (XIII)	3	..	11	7
Naval Construction and Engineering (XIII-A)	1	..	59	1
Nuclear Engineering (XXII)	..	..	93	24
Sanitary Engineering (XI)	..	..	13	2
Total	**141**	**10**	**943**	**393**
School of Humanities and Social Science:				
Economics, Politics and Engineering or Science (XIV-A, XIV-B)	1	..	102	12
Humanities and Engineering or Science (XXI-A, B)	2	..	..	..
Modern Languages (XXIII)	..	..	7	..
Total	**3**	..	**109**	**12**
School of Industrial Management:				
Industrial Management (XV)	**10**	**3**	**187**	**50**
School of Science:				
Biology (VII)	3	..	45	10
Chemistry (V)	3	..	191	6
Geology and Geophysics (XII, XII-A)	1	..	39	19
Mathematics (XVIII)	9	1	88	14
Meteorology (XIX)	1	..	30	2
Nutrition, Food Science and Technology (XX)	..	..	22	7
Physics (VIII)	21	2	143	70
Total	**38**	**3**	**558**	**128**
Undesignated	7	1	..	..
Grand total	**214**	**46**	**1,863**	**586**

Table 6. List of American Colleges and Universities with Number of Graduates Entering the Institute as Regular Students, 1961–62

Alabama Polytechnic Inst.	1
Alabama, University of	1
Amherst College	5
Antioch College	1
Arizona State University	2
Auburn University	1
Bard College	1
Boston College	3
Boston University	4
Bowdoin College	1
Brandeis University	2
Brigham Young University	1
Brooklyn College	4
Brown University	3
Bryn Mawr College	1
California Inst. of Tech.	3
California University at Berkeley	15
California, University of, at Davis	1
California University at Los Angeles	2
California University at Riverside	1
California, University of, at Santa Barbara	1
Carnegie Institute of Tech.	3
Case Institute of Tech.	4
Chicago, University of	3
Cincinnati, University of	1
Citadel, The	1
City College, The N. Y.	8
Clark University	1
Clemson Agricultural Coll.	1
Coe College	1
Colorado School of Mines	1
Colorado, University of	3
Columbia University	9
Connecticut, University of	2
Cooper Union, The	2
Cornell University	17
Chrysler Inst. of Eng.	1
Dartmouth College	2
Dayton, University of	2
Delaware, University of	1
Detroit, University of	2
Drexel Institute of Tech.	4
Duke University	3
Eastern Nazarene College	1
Emory University	1
Florida State University	1
Florida, University of	3
Fordham University	2
General Motors Institute	8
Georgetown University	3
Georgia Institute of Tech.	8
Grinnell College	2
Harvard University	16
Harvey Mudd College	2
Haverford College	4
Hofstra College	1
Holy Cross, College of	1
Illinois Institute of Tech.	2
Illinois, University of	9
Iowa State University	2
Iowa, State University of	7
Johns Hopkins University	1
Kansas State University	2
Kansas, University of	1
Lebanon Valley College	1
Lehigh University	5
LeMoyne College (New York)	1
Lincoln University	1
Long Island University	1
Louisiana Poly. Institute	1
Louisiana State University	2
Luther College	1
Maine, University of	1
Manhattan College	2
Mankato State College	1
Marquette University	3
Maryland, University of	1
Massachusetts Institute of Technology	229
Massachusetts, Univ. of	4
Medical College of Virginia	1
Miami University (Ohio)	1
Miami, University of	1
Michigan College of Mining and Technology	3
Michigan State University	5
Michigan, University of	9
Milwaukee School of Eng.	1
Minnesota, University of	7
Mississippi State Univ.	3
Missouri Sch. of Mines and Metals	2
Missouri, University of	2
Montana School of Mines	1
Morehouse College	1
Mount Holyoke College	1
Newark College of Eng.	2
New Hampshire, Univ. of	2
New Mexico College of Agric. and Mechanic Arts	1
New Mexico, University of	2
New York State Maritime Academy	1
North Carolina State Coll.	2
North Carolina, Univ. of	2
North Dakota University	1
Northeastern University	10
Northwestern University	3
Notre Dame, Univ. of	6
Oberlin College	3
Occidental College	1
Ohio State University	3
Ohio University	1
Ohio Wesleyan University	2
Oklahoma, University of	2
Oregon State College	1
Oregon, University of	2
Pennsylvania State Univ.	5
Pennsylvania, University of	7
Pittsburgh, University of	3
Poly. Institute of Brooklyn	6
Pomona College	3
Portland State College	1
Portland, University of	1
Princeton University	11
Providence College	2
Purdue University	9
Queen's College (N.Y.)	3
Radcliffe College	2
Reed College	1
Rensselaer Poly. Inst.	15
Rhode Island, Univ. of	2
Rice Institute	5
Rochester Inst. of Tech.	1
Saint Louis University	1
Simmons College	1
Smith College	2
South Carolina, Univ. of	1
Southern California, Univ. of	3
Stanford University	7
Stevens Inst. of Tech.	3
Swarthmore College	4
Syracuse University	5
Tennessee, University of	2
Texas Christian University	2
Texas Technological Coll.	3
Texas, University of	11
Trinity College (Conn.)	1
Tufts University	8
Tulane University	3
Union College (New York)	1
U.S. Air Force Academy	4
U.S. Coast Guard Academy	2
U.S. Military Academy	9
U.S. Naval Academy	23
U.S. Naval Postgraduate School	4
Utah, University of	5
Vanderbilt University	2
Vermont, University of	1
Villanova University	4
Virginia Military Inst.	2
Virginia Polytechnic Inst.	7
Virginia, University of	4
Wabash College	1
Washington, State Coll. of	1
Washington University (Mo.)	2
Washington, University of	4
Wayne University	2
Wesleyan University	3
West Virginia, Univ. of	1
Williams College	6
Wisconsin, University of	4
Worcester Poly. Institute	5
Yale University	21
Yeshiva University	3

In all, graduates of 170 American colleges and universities and 114 foreign colleges (not listed above) entered the Institute.

Table 7. Geographical Distribution of Students, 1961–62

United States:	
Alabama	17
Alaska	8
Arizona	21
Arkansas	12
California	235
Colorado	44
Connecticut	175
Delaware	17
District of Columbia	39
Florida	144
Georgia	41
Hawaii	14
Idaho	12
Illinois	261
Indiana	71
Iowa	31
Kansas	46
Kentucky	32
Louisiana	30
Maine	32
Maryland	108
Massachusetts	1,602
Michigan	147
Minnesota	56
Mississippi	8
Missouri	60
Montana	17
Nebraska	26
Nevada	0
New Hampshire	46
New Jersey	323
New Mexico	17
New York	889
North Carolina	32
North Dakota	10
Ohio	203
Oklahoma	45
Oregon	26
Pennsylvania	314
Rhode Island	37
South Carolina	16
South Dakota	6
Tennessee	55
Texas	109
Utah	18
Vermont	16
Virginia	89
Washington	69
West Virginia	17
Wisconsin	73
Wyoming	7
U.S. Territories and Dependencies:	
Puerto Rico	6
Virgin Islands	1
Total, United States	5,730
Foreign countries:	
Argentina	13
Australia	2
Austria	3
Belgium	7
Bolivia	2
Brazil	15
British West Indies	3
Burma	4
Canada	111
Ceylon	1
Chile	8
Colombia	13
Costa Rica	2
Cuba	5
Cyprus	1
Denmark	2
Ecuador	1
Eire	4
England	21
Ethiopia	2
Formosa	21
France	30
French West Indies	1
Ghana	5
Greece	22
Guatemala	2
Haiti	1
Honduras	1
Hong Kong	27
India	66
Indonesia	3
Iran	13
Iraq	9
Israel	23
Italy	16
Japan	41
Kenya	1
Korea	28
Lebanon	11
Liberia	1
Luxembourg	1
Malaya	3
Mexico	15
Morocco	1
Netherlands	3
Netherlands West Indies	1
New Zealand	1
Nigeria	10
Norway	15
Okinawa	1
Pakistan	6
Panama	1
Peru	6
Philippines	13
Poland	2
Portugal	2
Salvador	2
Scotland	2
Sierra Leone	1
Singapore	3
Spain	5
Sweden	4
Switzerland	9
Thailand	7
Tunisia	1
Turkey	6
South Africa, Republic of	9
United Arab Republic	19
Uruguay	4
Venezuela	16
Vietnam	4
West Germany	9
Total, foreign	724
Grand total	6,454

Table 8. Number of Degrees Awarded in September, 1961, January, 1962,

	S.B. Sept.	S.B. Jan.	S.B. June	B.Arch. Sept.	B.Arch. Jan.	B.Arch. June	S.M. Sept.	S.M. Jan.	S.M. June	M.Arch. and M.C.P. Sept.	M.Arch. and M.C.P. Jan.	M.Arch. and M.C.P. June
School of Architecture and Planning:												
Architecture	..	..	..	7	2	11	..	..	..	20	2	1
City and Regional Planning	..	..	..	..	..	..	..	..	..	..	1	7
Total	..	..	..	**7**	**2**	**11**	..	..	..	**20**	**3**	**8**
School of Engineering:												
Aeronautics and Astronautics	4	4	37	..	..	..	8	2	39	..	..	..
Building Engineering and Con.	..	..	..	..	..	..	5	..	4	..	..	..
Ceramics	..	..	..	..	..	..	3	..	..	..	..	..
Chemical Engineering	2	5	57	..	..	..	3	11	23	..	..	..
Chemical Engineering Practice	..	..	1	..	..	..	1	8	3	..	..	..
Civil Engineering	4	1	28	..	..	..	10	4	25	..	..	..
Electrical Engineering	20	9	173	..	..	..	45	17	72	..	..	..
Materials Engineering	..	..	..	..	..	..	..	..	..	..	..	..
Mechanical Engineering	6	4	63	..	..	..	16	14	36	..	..	..
Metallurgy	1	2	12	..	..	..	7	12	13	..	..	..
Naval Arch. and Marine Eng.	..	1	2	..	..	..	2	1	24	..	..	..
Nuclear Engineering	..	..	..	..	..	..	6	14	14	..	..	..
Sanitary Engineering	..	..	..	..	..	..	..	..	5	..	..	..
Shipping and Shipbuilding Man.	..	..	..	..	..	..	..	..	..	..	..	..
Textile Technology	..	..	..	..	..	..	1	..	..	..	..	..
Total	**37**	**26**	**373**	..	..	..	**107**	**83**	**258**	..	..	..
School of Humanities and Social Science:												
Economics and Engineering	..	..	..	..	..	..	..	..	..	..	..	..
Economics and Science	..	..	..	..	..	..	..	..	..	..	..	..
Economics, Politics, and Eng.	3	..	2	..	..	..	..	..	..	..	..	..
Economics, Politics, and Science	..	..	4	..	..	..	..	..	..	..	..	..
Humanities and Engineering	..	..	3	..	..	..	..	..	..	..	..	..
Humanities and Science	2	2	27	..	..	..	..	..	..	..	..	..
Industrial Economics	..	..	..	..	..	..	..	..	..	..	..	..
Political Science	..	..	..	..	..	..	..	..	..	..	..	..
Total	**5**	**2**	**36**	..	..	..	..	..	..	..	..	..
School of Industrial Management:												
Industrial Management	**10**	**5**	**62**	..	..	..	**11**	**15**	**74**	..	..	..
School of Science:												
Biochemical Engineering	..	..	..	..	..	..	1	..	..	..	..	..
Biochemistry	..	..	..	..	..	..	..	..	..	..	..	..
Biology	..	..	..	..	..	..	1	..	..	..	..	..
Biophysics	..	..	..	..	..	..	..	..	..	..	..	..
Chemistry	1	..	13	..	..	..	3	1	2	..	..	..
Earth Sciences	1	..	10	..	..	..	..	..	..	..	..	..
Food Technology	..	..	3	..	..	..	..	..	..	..	..	..
Geology and Geophysics	..	..	..	..	..	..	..	1	4	..	..	..
Life Sciences	..	1	23	..	..	..	..	..	..	..	..	..
Mathematics	2	5	60	..	..	..	1	2	1	..	..	..
Meteorology	..	..	..	..	..	..	5	..	1	..	..	..
Nutrition, Food Science and Technology	..	..	..	..	..	..	..	..	2	..	..	..
Oceanography	..	..	..	..	..	..	..	..	1	..	..	..
Physics	7	4	87	..	..	..	2	3	4	..	..	..
Quantitative Biology	1	..	..	..	..	..	..	..	..	..	..	..
Total	**12**	**10**	**196**	..	..	..	**13**	**7**	**15**	..	..	..
Without Course specification	..	..	..	..	..	..	7	3	4	..	..	..
Grand total	**64**	**43**	**667**	7	2	**11**	**138**	**108**	**351**	**20**	**3**	**8**

and June, 1962

Engineer Sept.	Engineer Jan.	Engineer June	Ph.D. Sept.	Ph.D. Jan.	Ph.D. June	Sc.D. Sept.	Sc.D. Jan.	Sc.D. June	Total Sept.	Total Jan.	Total June	
												School of Architecture and Planning:
..	..	..	..	..	..	..	..	..	27	4	12	Architecture
..	..	..	..	..	1	..	..	..	..	1	8	City and Regional Planning
..	..	..	..	..	**1**	..	..	..	**27**	**5**	**20**	Total
												School of Engineering:
..	2	7	..	2	1	4	1	3	16	11	87	Aeronautics and Astronautics
..	1	..	..	..	..	..	..	..	5	1	4	Building Engineering and Con.
..	..	..	1	..	..	..	1	2	4	1	2	Ceramics
2	..	1	..	..	..	3	5	10	10	21	91	Chemical Engineering
..	..	..	..	..	..	..	..	..	1	8	4	Chemical Engineering Practice
1	2	2	1	..	..	1	2	4	17	9	59	Civil Engineering
2	9	14	3	2	4	4	4	6	74	41	269	Electrical Engineering
1	..	1	..	..	..	..	..	1	1	..	2	Materials Engineering
4	3	6	..	2	3	3	1	12	29	24	120	Mechanical Engineering
2	..	2	..	..	1	4	2	6	14	16	34	Metallurgy
..	..	23	..	..	..	..	..	..	2	2	49	Naval Arch. and Marine Eng.
..	..	..	2	2	4	..	2	1	8	18	19	Nuclear Engineering
..	..	1	..	..	1	..	..	..	..	..	7	Sanitary Engineering
..	..	..	..	..	..	..	..	..	..	..	..	Shipping and Shipbuilding Man.
..	..	..	..	..	..	..	..	..	1	..	..	Textile Technology
12	**17**	**57**	**7**	**8**	**14**	**19**	**18**	**45**	**182**	**152**	**747**	Total
												School of Humanities and Social Science:
..	..	..	..	..	..	..	..	..	..	..	..	Economics and Engineering
..	..	..	..	..	..	..	..	..	..	..	..	Economics and Science
..	..	..	..	..	..	..	..	..	3	..	2	Economics, Politics, and Eng.
..	..	..	..	..	..	..	..	..	..	..	4	Economics, Politics, and Science
..	..	..	..	..	..	..	..	..	..	..	3	Humanities and Engineering
..	..	..	..	..	..	..	..	..	2	2	27	Humanities and Science
..	..	..	5	1	5	..	..	..	5	1	5	Industrial Economics
..	..	..	1	..	2	..	..	..	1	..	2	Political Science
..	..	..	**6**	**1**	**7**	..	..	..	**11**	**3**	**43**	Total
												School of Industrial Management:
..	..	..	..	..	**1**	..	..	..	**21**	**20**	**137**	Industrial Management
												School of Science:
..	..	..	..	..	..	..	..	..	1	..	..	Biochemical Engineering
..	..	..	..	..	..	..	..	..	..	..	..	Biochemistry
..	..	..	1	1	7	..	..	..	2	1	7	Biology
..	..	..	..	..	..	..	..	..	..	..	..	Biophysics
..	..	..	10	12	14	..	..	..	14	13	29	Chemistry
..	..	..	..	..	..	..	..	..	1	..	10	Earth Sciences
..	..	..	2	..	..	..	..	..	2	..	3	Food Technology
..	..	..	4	1	1	..	..	..	4	2	5	Geology and Geophysics
..	..	..	..	..	..	..	..	..	..	1	23	Life Sciences
..	..	..	5	3	9	..	..	..	8	10	70	Mathematics
..	..	..	..	1	..	..	..	..	5	1	1	Meteorology
..	..	..	..	1	..	..	..	..	..	1	2	Nutrition, Food Science and Technology
..	..	..	..	..	..	..	..	..	..	..	1	Oceanography
..	..	..	6	6	13	..	..	..	15	13	104	Physics
..	..	..	..	..	..	..	..	..	1	..	..	Quantitative Biology
..	..	..	**28**	**25**	**44**	..	..	..	**53**	**42**	**255**	Total
..	..	..	..	..	..	..	..	..	7	3	4	Without Course specification
12	**17**	**57**	**41**	**34**	**67**	**19**	**18**	**45**	**301**	**225**	**1,206**	Grand total

Vice President, Academic Administration

All statistics on degrees are arranged by school as of the current year. During the years 1868 to 1949 the general divisions were Architecture, Engineering, and Science. In 1950 the School of Humanities and Social Science was established, and in 1951 the School of Industrial Management was added.

Table 9. Number of Degrees of Bachelor of Science Awarded

	Total by decades							
	1868–70	*1871–80*	*1881–90*	*1891–1900*	*1901–10*	*1911–20*	*1921–30*	*1931–40*
School of Architecture and Planning:								
Architecture†	..	12	24	162	188	233	223	23
Architectural Engineering	..	..	..	..	..	..	108	64
Total		**12**	**24**	**162**	**188**	**233**	**331**	**87**
School of Engineering:								
Aeronautical Engineering	..	..	..	..	..	..	68	287
Aeronautics and Astronautics	..	..	..	..	..	..	..	..
Building Engineering and Construction	..	..	..	..	..	..	32	99
Chemical Engineering	..	..	..	91	123	372	571	434
Chemical Engineering Practice	..	..	..	..	..	..	99	90
Civil Engineering	12	84	86	256	407	504	653	284
Electrical Engineering (including VI-A)[1]	..	..	72	335	349	468	1,000	719
Electrochemical Engineering	..	..	..	..	28	84	133	56
General Engineering	..	..	..	..	..	6	226	222
Mechanical Engineering (including II-A)	5	40	147	329	502	623	797	602
Metallurgy[2]	..	..	..	..	..	..	..	52
Military Engineering	..	..	..	..	..	..	1	4
Mining Engineering and Metallurgy	8	44	64	74	250	129	174	137
Naval Architecture and Marine Engineering	..	..	..	43	133	‡69	100	173
Sanitary Engineering	..	..	..	29	54	123	34	20
Total	**25**	**168**	**369**	**1,157**	**1,846**	**2,378**	**3,888**	**3,179**
School of Humanities and Social Science:								
Economics, Politics, and Engineering or Science	..	..	..	..	..	..	..	..
Humanities and Engineering or Science[3]	..	..	..	..	..	..	..	..
Total	..	..	..	..	..	..	..	..
School of Industrial Management:[4]								
Business and Engineering Administration	..	..	..	..	..	142	872	641
Industrial Management	..	..	..	..	..	..	..	..
Total	..	..	..	..	..	**142**	**872**	**641**
School of Science:								
Biology or Natural History (including VII-A)[5]	..	3	11	25	27	49	57	129
Chemistry	2	27	80	154	151	111	141	166
Earth Science[6]	..	..	..	..	..	..	..	..
Food Technology and Biochemical Engineering	..	..	..	..	..	..	..	..
General Science or General Course	2	11	17	49	20	26	17	73
Geology and Geophysics	..	..	..	8	6	3	36	22
Life Sciences	..	..	..	..	..	..	..	..
Mathematics	..	..	..	..	..	..	19	48
Meteorology[7]	..	..	..	..	..	..	..	..
Physics	..	5	6	24	19	21	49	170
Total	**4**	**46**	**114**	**260**	**223**	**210**	**319**	**608**
Grand total	**29**	**226**	**507**	**1,579**	**2,257**	**2,963**	**5,410**	**4,515**

* Includes only January and June degrees.
† See also Table 11. Figures for 1923 to 1939 include Architectural Engineering, which at that time was considered Engineering.
‡ Two received the degree in Naval Architecture, Course XIII-B, in 1916 and three in 1917.
[1] Prior to 1909 this Course was designated as Option 3 (Electrochemistry) of Physics.
[2] Prior to 1938 these degrees were included in Mining Engineering and Metallurgy.
[3] Prior to 1958, these degrees were included in General Engineering and General Science or General Course.
[4] Considered Engineering until 1950.
[5] Includes Quantitative Biology; changed to Life Sciences beginning in January, 1962.
[6] Considered Geology and Geophysics until February, 1961.
[7] Considered Engineering until 1956.

1941–50	1951–60	1961–	Grand total	*Calendar year since 1958 (included in decade total)* 1958	1959	1960	1961	1962*	
									School of Architecture and Planning:
..	..	..	**865**	..	..	..	..	..	Architecture†
..	..	..	**172**	..	..	..	..	..	Architectural Engineering
..	..	..	**1,037**	..	..	..	..	..	Total
									School of Engineering:
526	340	..	**1,221**	43	40	..	..	..	Aeronautical Engineering
..	55	85	**140**	..	..	55	44	41	Aeronautics and Astronautics
114	131	..	**376**	1	..	..	..	..	Building Engineering and Construction
740	726	135	**3,192**	85	59	80	73	62	Chemical Engineering
95	108	1	**393**	8	8	6	..	1	Chemical Engineering Practice
272	457	66	**3,081**	47	41	30	37	29	Civil Engineering
1,218	1,518	343	**6,022**	187	178	194	161	182	Electrical Engineering (including VI-A)[1]
..	..	..	**301**	..	..	..	..	..	Electrochemical Engineering
230	133	..	**817**	4	..	..	..	..	General Engineering
1,164	1,049	147	**5,405**	114	103	72	80	67	Mechanical Engineering (including II-A)
194	311	42	**599**	32	38	33	28	14	Metallurgy[2]
..	..	..	**5**	..	..	..	..	..	Military Engineering
..	..	..	**880**	..	..	..	..	..	Mining Engineering and Metallurgy
234	139	15	**906**	14	9	9	12	3	Naval Architecture and Marine Engineering
4	..	..	**264**	..	..	..	..	..	Sanitary Engineering
4,791	**4,967**	**834**	**23,602**	**535**	**476**	**479**	**435**	**399**	Total
									School of Humanities and Social Science:
61	152	21	**234**	16	17	17	15	6	Economics, Politics, and Engineering or Science
..	49	57	**106**	10	18	21	25	32	Humanities and Engineering or Science[3]
61	**201**	**78**	**340**	**26**	**35**	**38**	**40**	**38**	Total
									School of Industrial Management: [4]
909	732	..	**3,296**	86	..	..	..	..	Business and Engineering Administration
..	172	131	**303**	..	91	81	64	67	Industrial Management
909	**904**	**131**	**3,599**	**86**	**91**	**81**	**64**	**67**	Total
									School of Science:
74	116	16	**507**	8	10	16	16	..	Biology or Natural History (including VII-A)
232	207	42	**1,313**	26	22	16	29	13	Chemistry
..	..	23	**23**	..	..	..	13	10	Earth Science[5]
35	62	8	**105**	7	5	2	5	3	Food Technology and Biochemical Engineering
58	62	..	**335**	6	2	..	..	..	General Science or General Course
32	141	..	**248**	16	16	10	..	..	Geology and Geophysics
..	..	24	**24**	..	..	..	..	24	Life Sciences
72	220	127	**486**	18	34	54	62	65	Mathematics
56	38	..	**94**	2	2	..	..	..	Meteorology[6]
306	617	208	**1,425**	73	92	74	117	91	Physics
865	**1,463**	**448**	**4,560**	**156**	**183**	**172**	**242**	**206**	Total
6,626	**7,535**	**1,491**	**33,138**	**803**	**785**	**770**	**781**	**710**	Grand total

Table 10. Number of Degrees of Master of Science Awarded

	Total by decades							
	1886–90	*1891–1900*	*1901–10*	*1911–20*	*1921–30*	*1931–40*	*1941–50*	*1951–60*
School of Architecture and Planning: †								
Architecture	..	8	45	31	..	..	..	..
Architectural Engineering	..	..	..	..	9	10	..	..
Total	..	**8**	**45**	**31**	**9**	**10**	..	..
School of Engineering:								
Aeronautical Engineering	..	..	..	17	59	76	307	312
Aeronautics and Astronautics	..	..	..	..	..	..	..	63
Building Engineering and Construction	..	..	..	..	..	..	21	66
Ceramics	..	..	..	..	..	3	3	13
Chemical Engineering	..	3	2	18	69	152	275	467
Chemical Engineering Practice	..	..	..	..	245	284	241	256
Civil Engineering	..	1	4	27	53	179	194	350
Electrical Engineering (including VI-A)	..	..	7	43	462	474	546	1,164
Electrochemical Engineering	..	..	..	4	16	8	..	..
Fuel and Gas Engineering	..	..	..	..	15	11	..	..
Mechanical Engineering	..	1	8	22	100	176	388	559
Metallurgy	..	..	..	..	8	36	92	230
Mining Engineering	..	..	..	9	8	16	..	..
Naval Architecture and Marine Engineering	..	..	2	1	5	20	60	169
Naval Construction	..	..	..	5	..	..	..	..
Naval Construction and Engineering	..	..	39	43	101	89	206	..
Nuclear Engineering ¶	..	..	..	..	..	..	..	67
Petroleum Engineering	..	..	..	..	..	5	..	..
Railroad Operation	..	..	..	..	..	14	..	..
Sanitary Engineering	..	..	2	8	3	10	53	99
Total	..	**5**	**64**	**197**	**1,144**	**1,553**	**2,386**	**3,815**
School of Humanities and Social Science:								
Economics and Engineering or Science	..	..	..	..	..	**12**	**16**	**19**
School of Industrial Management: ‡								
Industrial Management	..	..	..	..	**4**	**60**	**122**	**581**
School of Science:								
Biology and Public Health (including VII-A)	..	1	1	10	1	19	25	34
Chemistry	2	3	8	22	32	51	53	46
Food Science and Technology	..	..	..	..	..	..	..	..
Food Technology and Biochemical Engineering	..	..	..	..	..	..	12	51
General Science	..	1	..	..	..	..	..	..
Geology and Geophysics	..	..	1	5	21	15	17	48
Mathematics	..	..	..	2	9	25	45	96
Meteorology §	..	..	..	..	..	35	99	118
Nutrition	..	..	..	..	..	..	..	..
Oceanography	..	..	..	..	..	..	..	..
Physics	..	3	2	2	16	40	50	121
Total	**2**	**8**	**12**	**41**	**79**	**185**	**301**	**514**
Without Course classification	..	..	..	5	308	263	123	357
Grand total	**2**	**21**	**121**	**274**	**1,544**	**2,083**	**2,948**	**5,286**

* Includes only January and June degrees.

† See also Table 11. Figures for 1923 to 1939 include Architectural Engineering, which at that time was considered Engineering.

‡ Considered Engineering until 1950.

§ Considered Engineering until 1956.

¶ Included in Chemical Engineering before 1959.

		Calendar year since 1958 (included in decade total)					
1961–	*Grand total*	*1958*	*1959*	*1960*	*1961*	*1962**	
							School of Architecture and Planning: †
..	**84**	..	..	..	..	..	Architecture
..	**19**	..	..	..	..	..	Architectural Engineering
..	**103**	..	..	..	..	..	Total
							School of Engineering:
..	**771**	30	50	..	..	..	Aeronautical Engineering
124	**187**	..	..	63	83	41	Aeronautics and Astronautics
19	**106**	6	8	6	15	4	Building Engineering and Construction
4	**23**	1	4	2	4	..	Ceramics
74	**1,060**	72	45	40	40	34	Chemical Engineering
36	**1,062**	21	31	23	25	11	Chemical Engineering Practice
69	**877**	43	53	35	40	29	Civil Engineering
212	**2,908**	132	149	125	123	89	Electrical Engineering (including VI-A)
..	**28**	..	..	..	..	..	Electrochemical Engineering
..	**26**	..	..	..	..	..	Fuel and Gas Engineering
114	**1,368**	64	70	65	64	50	Mechanical Engineering
54	**420**	20	19	31	29	25	Metallurgy
..	**33**	..	..	..	..	..	Mining Engineering
59	**316**	27	32	41	34	25	Naval Architecture and Marine Engineering
..	**5**	..	..	..	..	..	Naval Construction
..	**478**	..	..	..	..	..	Naval Construction and Engineering
51	**118**	..	33	34	23	28	Nuclear Engineering ¶
..	**5**	..	..	..	..	..	Petroleum Engineering
..	**14**	..	..	..	..	..	Railroad Operation
15	**190**	11	10	7	10	5	Sanitary Engineering
831	**9,995**	**427**	**504**	**472**	**490**	**341**	Total
							School of Humanities and Social Science:
..	**47**	**4**	**1**	**3**	..	..	Economics and Engineering or Science
							School of Industrial Management: ‡
188	**955**	**89**	**91**	**94**	**99**	**89**	Industrial Management
							School of Science:
2	**93**	1	5	..	2	..	Biology and Public Health (including VII-A)
10	**227**	3	7	5	7	3	Chemistry
1	**1**	..	..	..	..	1	Food Science and Technology
4	**67**	4	10	11	4	..	Food Technology and Biochemical Engineering
..	**1**	..	..	..	..	..	General Science
14	**121**	7	5	11	9	5	Geology and Geophysics
12	**189**	10	13	14	9	3	Mathematics
15	**267**	9	8	10	14	1	Meteorology §
1	**1**	..	..	..	..	1	Nutrition
2	**2**	..	..	..	1	1	Oceanography
22	**256**	10	12	13	15	7	Physics
83	**1,225**	**44**	**60**	**64**	**61**	**22**	Total
27	**1,083**	37	34	19	20	7	Without Course classification
1,129	**13,408**	**601**	**690**	**652**	**670**	**459**	Grand total

Table 11. Number of Degrees Awarded in Architecture and City Planning

	Total by decades						Calendar year since 1958 (included in decade total)				
	1921–30	*1931–40*	*1941–50*	*1951–60*	*1961–*	*Grand total*	*1958*	*1959*	*1960*	*1961*	*1962**
Bachelor in Architecture	. .	146	126	257	41	**570**	19	22	26	28	13
Bachelor in City Planning†	. .	14	13	4	. .	**31**	. .	. .	. .	. .	. .
Master in Architecture	63	81	78	191	29	**442**	25	19	20	26	3
Master in City Planning	. .	18	82	114	24	**238**	16	16	17	16	8
Grand total	**63**	**259**	**299**	**566**	**94**	**1,281**	**60**	**57**	**63**	**70**	**24**

* Includes only January and June degrees.

† From 1935 to 1944, Bachelor of Architecture in City Planning.

Table 12. Number of Degrees of Engineer Awarded

	1949–57	*1958*	*1959*	*1960*	*1961*	*1962**	*Total*
Aeronautical Engineer	27	3	3	2†	5	9	49
Building Engineer	4	..	..	1	..	1	6
Chemical Engineer	5	4	3	5	7	1	25
Civil Engineer	9	2	2	8	3	4	28
Electrical Engineer	69	20	24	19	25	23	180
Marine Mechanical Engineer	3	1	1	2	1	..	8
Materials Engineer	..	..	..	..	1	1	2
Mechanical Engineer	71	10	10	11	22	9	133
Metallurgical Engineer	14	3	5	2	4	2	30
Meteorologist‡	2	..	..	..	..	..	2
Naval Architect	6	2	2	1	..	2	13
Naval Engineer	259	22	23	30	26	21	381
Nuclear Engineer	..	..	..	..	1	..	1
Sanitary Engineer	7	1	1	..	..	1	10
Grand total	**476**	**68**	**74**	**81**	**95**	**74**	**868**

* Includes only January and June degrees.
† Engineer in Aeronautics and Astronautics beginning in 1960.
‡ Degree discontinued after July, 1955.

Table 13. Number of Degrees of Doctor of Philosophy Awarded

	Total by decades							
	1907–10	*1911–20*	*1921–30*	*1931–40*	*1941–50*	*1951–60*	*1961–*	*Grand total*
School of Architecture and Planning:								
City and Regional Planning	..	..	..	..	..	..	1	**1**
School of Engineering:								
Aeronautical Engineering or Aeronautics and Astronautics	..	..	..	..	..	6	5	**11**
Ceramics	..	..	..	..	..	1	1	**2**
Chemical Engineering	..	..	..	..	..	..	1	**1**
Civil Engineering	..	..	..	..	..	1	1	**2**
Electrical Engineering	..	..	..	..	1	9	12	**22**
Mechanical Engineering	..	..	..	..	..	4	10	**14**
Metallurgy	..	..	..	..	..	5	2	**7**
Naval Architecture and Marine Engineering	..	..	..	..	..	..	1	**1**
Nuclear Engineering	..	..	..	..	..	5	13	**18**
Sanitary Engineering	..	..	..	..	..	2	3	**5**
Total	..	..	..	..	**1**	**33**	**49**	**83**
School of Humanities and Social Science:								
Group Psychology	..	..	..	..	8	1	..	**9**
Industrial Economics*	..	..	..	..	19	99	20	**138**
Political Science	..	..	..	..	..	..	4	**4**
Total	..	..	..	..	**27**	**100**	**24**	**151**
School of Industrial Management:								
Industrial Management	..	..	..	..	..	..	**1**	**1**
School of Science:								
Biology	..	1	10	17	21	38	12	**99**
Chemistry	7	19	59	146	180	342	61	**814**
Geology	1	7	10	22	20	71	12	**143**
Mathematics	..	..	6	25	35	70	30	**166**
Meteorology	..	..	..	..	..	14	2	**16**
Nutrition, Food Science and Technology	..	..	..	..	4	28	5	**37**
Physics	..	2	6	48	159	283	42	**540**
Total	**8**	**29**	**91**	**258**	**419**	**846**	**164**	**1,815**
Grand total	**8**	**29**	**91**	**258**	**447**	**979**	**239**	**2,051**

* Includes one in 1954 and two in 1956 in Psychology.
† Includes only January and June degrees.

Calendar year since 1958 (included in decade total)					
1958	*1959*	*1960*	*1961*	*1962†*	
					School of Architecture and Planning:
..	..	..	..	1	City and Regional Planning
					School of Engineering:
..	3	3	2	3	Aeronautical Engineering or Aeronautics and Astronautics
..	..	1	1	..	Ceramics
..	..	..	1	..	Chemical Engineering
..	1	..	1	..	Civil Engineering
..	1	7	6	6	Electrical Engineering
..	..	4	5	5	Mechanical Engineering
1	1	3	1	1	Metallurgy
..	..	..	1	..	Naval Architecture and Marine Engineering
..	2	3	7	6	Nuclear Engineering
1	1	..	2	1	Sanitary Engineering
2	**9**	**21**	**27**	**22**	Total
					School of Humanities and Social Science:
..	..	..	..	..	Group Psychology
9	18	16	14	6	Industrial Economics*
..	..	..	2	2	Political Science
9	**18**	**16**	**16**	**8**	Total
					School of Industrial Management:
..	..	..	..	1	Industrial Management
					School of Science:
2	3	4	4	8	Biology
36	41	44	35	26	Chemistry
6	8	11	10	2	Geology
6	12	2	18	12	Mathematics
2	1	3	1	1	Meteorology
1	1	9	4	1	Nutrition, Food Science and Technology
25	29	22	23	19	Physics
78	**95**	**95**	**95**	**69**	Total
89	**122**	**132**	**138**	**101**	Grand total

Table 14. Number of Degrees of Doctor of Science Awarded

	Total by decades						
	1911–20	1921–30	1931–40	1941–50	1951–60	1961–	Grand total
School of Engineering:							
Aeronautical Engineering	2	4	5	18	31	11	**71**
Ceramics	..	..	7	16	25	6	**54**
Chemical Engineering	..	23	78	114	117	33	**365**
Civil Engineering	..	2	12	23	46	14	**97**
Electrical Engineering	3	12	30	34	141	27	**247**
Electrochemical Engineering	..	1	1	..	..	..	**2**
Materials Engineering	..	..	..	..	..	1	**1**
Mechanical Engineering	..	4	13	35	125	20	**197**
Metallurgy	..	14	25	70	169	26	**304**
Mineral Engineering	1	..	4	..	..	..	**5**
Naval Architecture and Marine Engineering	..	1	..	..	2	1	**4**
Nuclear Engineering	..	..	..	..	9	3	**12**
Petroleum Engineering	..	..	1	..	..	..	**1**
Sanitary Engineering	..	..	2	3	18	..	**23**
Total	**6**	**61**	**178**	**313**	**683**	**142**	**1,383**
School of Science:							
Chemistry	..	2	5	4	3	..	**14**
Food Technology and Biochemical Engineering	..	..	..	3	10	..	**13**
Geology	1	2	4	5	2	..	**14**
Mathematics	..	2	3	..	1	..	**6**
Meteorology	..	..	6	25	17	..	**48**
Physics	..	5	18	14	7	..	**44**
Total	**1**	**11**	**36**	**51**	**40**	..	**139**
Grand total	**7**	**72**	**214**	**364**	**723**	**142**	**1,522**

* Doctor of Science in Aeronautics and Astronautics beginning in 1960.

† Includes only January and June degrees.

Calendar year since 1958 (included in decade total)					
1958	*1959*	*1960*	*1961*	*1962†*	
					School of Engineering:
1	2	3*	7	4	Aeronautical Engineering
2	2	3	3	3	Ceramics
11	17	13	18	15	Chemical Engineering
4	9	3	8	6	Civil Engineering
16	15	17	17	10	Electrical Engineering
..	..	..	..	..	Electrochemical Engineering
..	..	..	..	1	Materials Engineering
12	19	10	7	13	Mechanical Engineering
23	11	10	18	8	Metallurgy
..	..	..	..	..	Mineral Engineering
..	..	1	1	..	Naval Architecture and Marine Engineering
..	7	2	..	3	Nuclear Engineering
..	..	..	..	..	Petroleum Engineering
..	2	..	..	..	Sanitary Engineering
69	**84**	**62**	**79**	**63**	Total
					School of Science:
..	..	1	..	..	Chemistry
..	1	1	..	..	Food Technology and Biochemical Engineering
..	..	..	..	..	Geology
..	..	..	..	..	Mathematics
..	..	1	..	..	Meteorology
1	..	..	..	..	Physics
1	**1**	**3**	..	..	Total
70	**85**	**65**	**79**	**63**	Grand total

Table 15. Summary of Degrees Awarded (1868–1962)

Bachelor of Science	33,138
Bachelor in Architecture	570
Bachelor in City Planning	31
Master of Science	13,408
Master in Architecture	442
Master in City Planning	238
Master in Public Health (discontinued after 1944)*	104
Advanced Engineering	868
Doctor of Philosophy	2,051
Doctor of Science	1,522
Doctor of Public Health (discontinued after 1944)*	9
Doctor of Engineering (discontinued after 1918)*	4
Grand total	**52,385**

ROBERT E. HEWES

* See the 1959 Report of the Registrar for details.

Educational Council

Membership in the Educational Council increased from 759 to 797 during the year. There were 83 appointments made during this period—65 new appointments and 18 former Council members who resumed activity in new areas. Six new Regional Chairmen were appointed. However, shortly after accepting appointment, two of the chairmen had to resign due to business transfers to other states, and consequently only four Council areas had changes in chairmanship. It is interesting to note, also, that 182 Council members accepted reappointment for new terms during the year.

Of the 796 members at the close of the fiscal year, 757 are located in 191 areas within the United States. The total number of areas in which the Council has representatives increased by seven during the year, and the number of areas in which there is an active school assignment program increased by ten to a total of 160. Council members are working with 1,433 schools—an increase of 130 for the year. In addition, 386 schools are assigned for the purpose of admissions referrals only. Undoubtedly the number of Council members and assigned schools will continue to increase gradually. Because of population shifts and the construction of new schools, we must continually review the Council program in organized areas, and be prepared to make frequent changes. Occasionally it is necessary to completely reorganize areas, and very likely we shall add new Council members in some of the smaller cities not now covered.

At the present time there are thirty-nine Honorary Secretaries in foreign countries. During the year, discussions were held to determine other foreign cities in which we should have representatives and to select alumni for appointment in those cities. This preparatory work is nearly completed, and early in the new fiscal year we expect to ask alumni in fourteen foreign cities to serve as Honorary Secretaries.

M.I.T. was invited to participate in 201 college nights at various schools throughout the country during the past year. A few were attended by our staff members, but it is impossible to make such arrangements for all these programs. Council members have been extremely cooperative in representing the Institute; last year we asked Council members to attend 170 college nights, and arrangements were made for representation at 148 programs. In addition to this kind of contact and the regular visits of Council members to their assigned schools, members of the Educational Council accompanied M.I.T. school visitors on 238 of the 736 school visits made by faculty and staff members during the fall of 1961 and the spring of 1962. Council members can be of considerable assistance to our school visitors and can also benefit by sitting in on discussions between high school students and members of the M.I.T. faculty or staff. Although Council members have actively participated in the school visiting program, we hope to involve them even more in the future, especially in the planning stages.

There has been some discussion in the past regarding the possibility of appointing some of our alumnae to the Educational Council in order to assist the girls who apply to the Institute. We feel that a more effective discussion of the Institute from a woman's point of view may be achieved by having an alumna talk with prospective women students. In one city an alumna has already been appointed for this sole purpose. We have given consideration to expanding this program, and it now appears that we shall continue the experiment by asking a limited number of alumnae in other cities to serve on this same basis.

A total of 4,581 applicants for September, 1962, admission were referred to Council members for personal conferences. Members of the Council submitted interview reports on 2,537 of these students, and approximately three-fourths of the freshmen entering M.I.T. in September will have talked with a Council member. In addition, a large number of applicants for 1963 and later have already been referred to Council members, and many of them have had one or more contacts with a member of the Educational Council.

Staff members conducted interviews in New York City for the fourth consecutive year. A total of 210 applicants from New York City were asked to make appointments, and during a one-week period in December three staff members interviewed 131 students. We found this arrangement works well: it fits our new Admissions time-table better than the previous method of sending four staff members to New York in pairs for two one-week periods, and is more economical. We intend to repeat this procedure during the coming year.

The Educational Council is well known to school and college personnel and generally is thought of as one of the best alumni programs of its type. This year we continued to receive many favorable comments from high school principals and guidance officers concerning the work the Council members are doing.

JAMES H. EACKER

Foreign Student Office

During the last academic year, M.I.T. has made considerable use of a preliminary application form for foreign student applicants. Information obtained by this form has been used for a preliminary screening of applicants, so that in spite of a steady increase in the requests for places we have been able to reduce the number of final applications filed:

	September, 1959	*September, 1960*	*September, 1961*	*September, 1962*
Inquiries received	2,578	4,113	4,716	5,274
Applications sent	1,550	1,645	2,214	1,713

The number of foreign students enrolled at M.I.T. has continued with little change during the past four years:

	1958-59	*1959-60*	*1960-61*	*1961-62*
Undergraduate	268	274	220	228
Graduate	506	516	560	565
Total	**762**	**790**	**780**	**793**

Howard University, with 16.6 per cent, has the highest proportion of foreign students at any American university. M.I.T. is second, with 12.3 per cent, and Harvard (7.7 per cent) is third.

M.I.T.'s international commitments are also reflected in the large number of faculty, research staff, postdoctoral students, and guests who are here from foreign nations yearly. According to the Institute of International Education, of 5,530 foreign "faculty and scholars" at U.S. universities in 1961-62, M.I.T. claimed 314; only the University of California (425) and Harvard (411) exceeded this number.

One of the most important services to our foreign students is to help them in some way to know Americans. The traditional form for this is in invitations to partake of "home hospitality," and for many years this has been an important and valuable project of the Matrons. This year the Foreign Student Hospitality Committee, under the leadership of Mrs. P. L. Thibault Brian and including Matrons representing each department, has arranged for the entertainment of foreign students in many faculty homes.

A new plan for hospitality to foreign students is the development of a closer relationship between students and Americans on a family basis—"Host Family Programs" or "Family in America Programs." Last year two M.I.T. religious counselors, the Reverend Oscar Ice and the Reverend Richard Roelofs, organized such a program; the hosts were volunteers from Protestant churches in Greater Boston.

Encouraged by this successful example, the Foreign Student Office is organizing its own program, largely using M.I.T. alumni families. Mrs. Norman J. Padelford, Chairman, and Mrs. Glenn Eichenseer, Vice Chairman, have pledges of help from over one hundred alumni, each of whom has volunteered to act as host for a new foreign student.

Several student groups have contributed to the program for foreign students. Members of the United Christian Fellowship have acted as welcoming guides to new students and as chauffeurs for room-hunting; the International Program Committee was active in a number of ways, the most important being the organization of the program for International Week; the Graduate Student Council's Welcoming Committee sponsored a dinner at the M.I.T. Faculty Club for all new foreign graduate students; and the Dames' Service Committee was helpful to foreign student wives in many ways and now plans expanded activity next year.

Housing is the most difficult problem for most foreign students. The pressures on available housing near M.I.T. are so great that many foreign students are forced into substandard living quarters. This problem has been somewhat alleviated by the excellent work of the Matrons' Foreign Student Housing Committee, which helped in placing about fifty families at the beginning of the fall term. In addition, the Matrons have given a total of $1,600 from proceeds of the Furniture Exchange for an emergency fund for foreign students.

The M.I.T. Women's Association Foreign Student Committee, besides helping women foreign students already at M.I.T., has given two travel grants to newly admitted foreign students.

Professor B. Alden Thresher, Fulbright adviser, has announced that eleven M.I.T. seniors and graduate students have received grants for foreign study in 1962-63, and five Fulbright grants to members of the staff for overseas teaching and research have been announced.

Vice President, Academic Administration

In addition to the undersigned and to Eugene R. Chamberlain, Associate Adviser to Foreign Students, Peter D. Leavitt has served as part-time Associate Adviser to Foreign Students during the past year.

PAUL M. CHALMERS

Medical Department

The past year was a very busy one for the Medical Department. There was a striking increase in the patient load, and the Department was taxed to cope with this demand for service. It has become quite apparent that additional space, equipment, and—most importantly—personnel will be needed, not only to provide for the increased utilization of the medical services by the present population, but also to take care of the demands that will be created by the expansion of the Institute community.

The Medical Department presently occupies 21,594 square feet of space, including areas in Buildings 3 and 20. We estimate that 56,000 square feet will be needed to offer satisfactory in-patient, outpatient, and occupational medical service to the M.I.T. community in ten years.

PERSONNEL

The Department has been strengthened this year by the appointment of Dr. Melvin H. Rodman, a specialist in internal medicine, to a full-time position. He has been associated with the Department for several years on a part-time basis. In addition to his duties in the medical clinic and the infirmary, Dr. Rodman has undertaken the supervision of our employee health program.

Dr. Lyman G. Richards, who has served as otolaryngologist for many years with great skill and kindness, retired at the end of the year, and his position was taken by Dr. John C. Trakas. Dr. Richards' resignation was accepted with regret, but we are pleased to report that he will continue work in his specialty by serving as Secretary of the American Academy of Otolaryngology.

A major loss to our surgical clinic was the retirement of Miss Alice M. Browne after thirty-five years of devoted service. In recognition of this, and attesting to the high regard in which she is held, she was made an honorary member of the Alumni Association in June, 1962.

AMBULATORY CLINIC

There was an increase in the number of visits in every clinic except for otolaryngology, where the activity was unchanged. The most striking increase in service was in the medical clinics, where the number of visits increased by about 25 per cent, rising from 8,413 last year to 10,612 this year. The total number of visits to the ambulatory clinics was 34,771, an increase of 4,393 from the year before. We have no explanation for the increase in activity, as there were no major epidemics during the year.

The only change in the operation of the clinics was the institution of an appointment system for the surgical clinic similar to the system that has been so successful in the medical clinic for the past three years. This was done with trepidation, but after some chaos the system began to work smoothly and we plan to continue to operate the surgical clinic by appointment.

ATHLETIC INJURIES

Dr. Thomas Boyd has continued to serve as surgeon for the athletic program. The number of sports injuries treated by the Medical Department was 172, an increase of about 17 per cent from last year. There were thirteen fractures, with six of these occurring in touch football. The most severe injury during the year involved fractures of both the tibia and fibula resulting from a fall while skating.

DENTAL

The dental clinic offers dental hygiene and diagnostic service but does not provide dental therapy. There were 5,128 visits to the clinic during the year, an increase of about 15 per cent over the previous year.

EMPLOYEE HEALTH

As a result of the 1,627 pre-employment physical examinations performed during the year, 42 applicants were found to have serious health problems. The majority of these had cardiovascular diseases, but a wide spectrum of disease was discovered including three cases of cancer, three cases of uncontrolled diabetes, and one case of active tuberculosis.

A program for the periodic health examination of employees engaged in occupations where loss of control might be hazardous, not only to themselves but to others, was begun during the year. Ninety-one employees in this category were examined; four were found to have health problems of sufficient severity to make a change in occupation advisable.

Another new health program begun during the year, was the invitation to all employees aged 60 and 63 to have a complete physical examination, including routine laboratory tests, without charge. This is a completely voluntary program; the results will be treated as confidential and released only upon written request of the patient. Twenty employees had such examinations, and several potentially serious conditions which needed medical treatment were found.

The retirement physical examination program was continued. This involves the yearly examination of employees between ages 65 and 70 who wish to continue work at M.I.T. Seventy-seven employees were examined and, fortunately, it was not necessary to recommend retirement for medical reasons for any in this group.

EXAMINATION OF NEW STUDENTS

We have continued the practice instituted a year ago of requiring all entering students to be examined by a physician of their choice before admission. On arrival or within a few weeks thereafter, each student is seen by a member of the Medical Department for a brief interview. At this time, the previously completed medical history and physical examination is reviewed so that any pathology past or present may be discussed. We are also continuing the practice of screening all new students with the "Heaf" tuberculin test and 70 mm. photofluorogram. In the coming year we hope to retest the senior class which was the first freshman class to have tuberculin tests on admission.

FACULTY HEALTH SURVEY

The Faculty Health Survey continues to be a major service of the Medical Department. Last year 438 members of the faculty and administrative staff were examined. The importance of the program for health protection is illustrated by the fact that during the year a case of early cancer, two cases of diabetes, and several instances of hypertension were found among people who were free of symptoms and thought they were in good health.

INFIRMARY

There was an increase in the use of the infirmary during the past year, with 690 admissions as compared with 600 the year before. Because of the small number of beds, it is the policy of the Department to limit infirmary admissions to students whenever more than one half the beds are occupied. Therefore, it is not surprising that 92 percent of patients admitted to the infirmary were students, though they comprised only 60 percent of the ambulatory clinic patients. The most common diseases among the infirmary patients were upper respiratory infection (viral), influenza, gastroenteritis (viral), infectious mononucleosis, streptococcal pharyngitis, and pneumonia (viral).

The number of operative procedures performed in the infirmary was 18 per cent less than the previous year. This decline was due almost entirely to a reduction in the number of serious lacerations requiring suture in the operating room. In addition to providing bed care, the infirmary offers emergency medical care when the ambulatory clinic is closed. The number of visits to the infirmary for such care was 1,962, in comparison to the 1,868 visits the previous year.

LABORATORY SERVICES

The number of clinical laboratory tests performed during the year was 16,362, an increase of 40 per cent over the year before. Since no new tests were introduced during the year this large increase in laboratory work reflects the increased utilization of the Medical Department and the fact that an increasing number of patients come to us directly, or referred by their family physicians, with diagnostic problems requiring extensive laboratory studies.

There were 6,334 x-ray examinations and 780 electrocardiograms during the year, an increase of 30 per cent, and 18 per cent, respectively, over the year before.

LINCOLN LABORATORY

The clinic for the care of minor injuries and illness maintained at the Lincoln Laboratory has continued to have the part-time services of Dr. Gordon Winchell and Dr. Charles Keevil. The clinic has a full-time nurse and secretary. The number of visits to this clinic last year was 9,931, which was about the same as the year before. As in the past, pre-employment examinations, consultations, and laboratory studies for Lincoln Laboratory personnel were performed by the Medical Department in Cambridge. Major medical or surgical emergencies are taken to the Emerson Hospital in Concord. A cardiac defibrillator was purchased by Lincoln Laboratory and is kept at the Emerson Hospital, where the emergency staff has been trained in its use.

OCCUPATIONAL MEDICAL SERVICE

An important administrative change was made in the Occupational Medical Service with the appointment of Samuel Levin as Executive Officer. Mr. Levin will continue to direct the radiation safety program, but in addition will assist Dr. Harriet L. Hardy in the administration of all the activities of the Service. As is the case in all preventive medical activities, there is little to report when everything is going well, even though a great deal of work is involved in monitoring potentially hazardous activities. As usual, the Occupational Medical Service has handled a wide spectrum of inquiries concerning harmful exposures and has devoted a great deal of time to assisting the faculty, staff, and students in planning experimental work in such a way as to minimize potential hazards.

The industrial hygiene engineers have devoted a large portion of their time to problems associated with the design of new buildings and necessary ventilation changes in Building 16. The radiation safety group is providing advice in radiation protection design as well as radiation monitoring for the intensive renovation of the cyclotron.

PRENATAL CLINIC

During the past year the prenatal and obstetrical clinic for M.I.T. student wives has continued to function at the out-patient department of the Boston Lying-In Hospital. This is the second year it has been conducted in conjunction with a similar program at Harvard. During the year, there were thirty-six deliveries and one miscarriage. Twelve young mothers enrolled for prenatal care only, since they were moving from the Boston area at the time of the expected delivery. Fifty-nine student wives registered for the complete program, which includes both prenatal care and delivery. Many of these, of course, will be delivered during the coming year. The cost for the past two years has been $235, but the new arrangement with the Boston Lying-In Hospital calls for a moderate increase of $25 to a total of $260 for all care. This program gives every indication of continuing popularity.

PSYCHIATRIC SERVICE

The total number of patients who consulted the psychiatric service last year was 536, an increase of 89 over the previous year. During the academic year 1961-62, 8 per cent of the undergraduates and 3.1 per cent of the graduate students were seen, with the median number of interviews per student being 2.1 and 2.4, respectively. More than half of the students were self-referred. Arrangements were made for sixty-two of the patients to receive ambulatory psychiatric care outside the Institute, either with a clinic or with a private psychiatrist. The majority of these patients were able to continue with their full programs a M.I.T. Seven sudents were hospitalized for major psychiatric illness during the year.

SANITATION

The Institute food handling services and the swimming pools are inspected periodically by our consulting sanitary engineer, Fred E. Smith. Routine bacterial monitoring of cream and milk, food service equipment, and the swimming pool is performed by George W. Broussard, bacteriologist in the Department of Civil Engineering. The fact that our sanitary record continues to be excellent is a tribute to the vigilance of the supervision of the dining service and the swimming pool and the cooperation of the many employees involved.

The problem of sanitation in the fraternity houses is worrisome. Last year there was a major outbreak of bacterial food poisoning (Salmonella) in one fraternity house, with sixteen of the members becoming sufficiently ill to require admission to the infirmary. The Medical Department has repeatedly offered to undertake sanitary inspections of fraternities without charge, but last year only one fraternity requested an inspection. It is understandable that the fraternities are jealous of their independence, but we wish that we could convince them that attention to sanitation is an essential function in group living.

STUDENT MEDICAL INSURANCE

A new insurance policy with more liberal benefits went into effect last year. In addition to offering reimbursement up to $1,500 for each illness, this policy includes a special accident clause which, with certain limitations, covers all medical expenses resulting from an accident up to a maximum of $1,000 and 80 per cent reimbursement up to an additional $7,000. This insurance policy functioned so well last year that we have decided to continue the same policy for 1962-1963. Students taking our student medical insurance receive ambulatory care in the Medical Department, including both diagnostic and therapeutic services, without charge, in addition to hospital coverage mentioned above. Because of the increase in costs of medical services, the fee for the student insurance will be increased from \$55.00 to \$65.00 for a full year, beginning September 1, 1962.

Last year there were 1,280 married students at M.I.T., most of whom were graduate students. Many of these students have very limited means, and major illnesses in their families may jeopardize their academic careers. Next year, in order to meet the need for reasonable family medical insurance, we will offer an insurance program for students which will include their dependents. The cost of this insurance for student and wife will be \$154 for the full year, and if there are children the cost will be \$179. The wives, but not the children, will be entitled to ambulatory care in the Medical Department.

Our student medical insurance program is voluntary, and last year only 62 per cent of the students subscribed. The percentage participation has remained about the same for several years. Unfortunately, each year we encounter serious illness, or accident, in students without insurance coverage and with inadequate financial reserve to handle such major expense.

ALBERT O. SEELER

Placement Bureau

STUDENT PLACEMENT

For the past several years, as has been noted in previous reports, the role, and function of the Placement Bureau has been undergoing change from a job-oriented to a career-oriented activity. The statistics of the past year bear this out, with an ever-increasing percentage of our undergraduates (this year, 58 per cent) continuing on to Graduate School.

A total of 457 companies, government agencies, and graduate schools actively recruited on campus during the year. Their 776 representatives interviewed 1,338 students, who took a total of 6,840 interviews. The following is a breakdown, by degree level, of the number of students who took interviews and the total number of interviews taken:

	Number of students	Number of interviews
Underclassmen	209	578
Bachelor's candidates	499	3,634
Master's candidates	388	1,928
Engineer candidates	21	116
Doctoral candidates	196	500
Miscellaneous	25	84

We have now accounted for 95.5 per cent of the June, 1962, graduating class. The following shows by degree level the disposition of students after graduation:

Employment of 1962 Graduates by Fields

	Doctor's		*Engineer*		*Master's*		*Bachelor's*		*Total*	
	No.	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
Academic research										
M.I.T.	13	12	1	2	8	3	15	2	37	3
Other	11	10	2	3	3	1	4	0.7	20	2
Teaching										
M.I.T.	12	11	—	—	—	—	—	—	12	1
Other	19	17	—	—	1	0.4	2	0.3	22	2
Further study										
M.I.T.	1	1	10	18	75	23	166	26	252	22
Other	—	—	2	3	18	5.6	205	32	225	20
Industry	37	33	6	11	127	39	158	25	328	29
Government	7	6	—	—	14	4	7	1	28	3
Foreign	7	6	6	11	30	9	21	3	64	6
Armed services	2	2	28	49	30	9	22	3	82	7
Miscellaneous	1	1	—	—	8	3	7	1	16	1
Unknown	1	1	2	3	8	3	39	6	50	4
Total	**111**		**57**		**322**		**646**		**1136**	

It is of interest to note with each passing year the increased use of the graduate study information available in the Placement Bureau and the corresponding decrease in the number of our seniors participating in job interviews. At the same time there is a marked increase in the number of graduate students, particularly at the Doctorate level, who are making active use of our facilities.

As in recent years, the salary offers to our graduates continued to rise. The upward trend of these starting salaries appears to be unaffected by the economic condition of the country, and it way well continue for some time.

ALUMNI PLACEMENT

Alumni Placement Office statistics for 1961-62 dramatically underline the shortage of men trained in science and engineering. The number of positions listed with us soared to 8,996, an increase of 60 per cent over last year and 15 per cent above our previous high which was recorded in 1960. Seven hundred and eighty-three companies, 52 colleges, 28 secondary schools, and 37 government agencies were in touch with this office to list specific openings.

For the first time in five years, fewer than 800 men registered, a clear indication that employment was easy to find; and for the very first time, the number of organizations looking for men exceeded the number of men looking for new employment. Not only did we list more than 12 jobs per man, we recorded 1.22 *companies* per man.

While these figures give a clear and accurate picture of insatiable demand, they tend to conceal the fact that a goodly number of healthy, intelligent, and responsible citizens are having more difficulty than ever before in locating work. It is not unusual to become obsolete at 35; it is tragically easy to help build a company only to have it sold and the management jobs consolidated just about the time one's salary reaches the point where it is 'hard to meet.'

Within the year, at this rate, it will be necessary for companies in many fields to stop some of their frantic and expensive search for the additional ideal man and begin to reorganize to use all of their men to capacity. This is something which has been badly needed for the past dozen years.

THOMAS W. HARRINGTON, JR.

Vice President, Research Administration

The Directors of eight activities at the Institute report to the President through the Vice President, Research Administration. These include the Cambridge Electron Accelerator of Harvard and M.I.T., the Division of Sponsored Research, the Industrial Liaison Office, the Joint Center for Urban Studies of Harvard and M.I.T., the M.I.T. Press, the National Magnet Laboratory, and the Summer Session. Reports on each of these activities follow. They all have very close ties to the academic departments, particularly at the professional level. Each Director is therefore concerned with the integration of his activities with the overall educational and research objectives of the Institute. In particular, we are concerned with the integration of a very large sponsored research program into our total program in such a way as to strengthen rather than detract from the teaching function.

Practically all research at M.I.T., as well as at many other major universities, is now sponsored by outside organizations, principally government, foundations, and industry. The sheer size of the total research program today prohibits a major financial contribution on the part of the university, since its normal sources of funds from tuition, endowment, and gifts are already overtaxed for educational objectives. The one exception is found in gifts specifically designated for basic research, but these are increasingly difficult to obtain.

At M.I.T. the pressures for increasing sponsored research programs are even greater than at other universities, since the areas of major interest to many sponsors coincide with three of our areas of major interest: engineering, the physical sciences, and the life sciences.

The new fields on which we are placing increasing emphasis, such as nutrition and psychology, for example, are also significant factors tending to increase the size of our total program.

On the whole, the major change in the magnitude of support for university research which has taken place in this country in the past two decades has been highly beneficial both to the universities and to the sponsors. At M.I.T. it has enabled us to undertake problems far beyond the scope of our own resources, and it has helped keep our faculty and students at the forefront of modern science and engineering. In return, we believe that we have been able to make far greater contributions to education and the advancement of knowledge than would have been possible without this support.

The funding of such a large percentage of the total academic budget from sources beyond the control of the university raises a number of complex problems, many of which are still unresolved. The problem of size is one. We are sometimes criticized—and we recognize the possible validity of such criticism—for depending upon outside sources for such a large portion of our funds; but we see no alternative. The size is largely determined by the desires of our faculty, and these must be respected if we are to maintain a responsible organization with great individual initiative. This does not mean that the administration exerts no control; but to maintain a first-rate faculty we must support individual members to the fullest extent of our available resources. Research in general is becoming increasingly expensive, and therefore funds for large-scale programs must be found if we are to continue as a first-rank technological institution. The logical sources for such support, since it is not available within the university, are from those that have the funds and are most interested in the research results.

Unfortunately, in several instances in the past, the magnitude of our dependence on outside organizations for research support has been grossly misrepresented, principally by the inclusion in these discussions of major projects which we have been asked to undertake for the government in the national interest. These projects are not properly a part of our academic budget.

Another criticism of our large sponsored research program concerns the danger of encroachment on university freedom by the sponsoring organizations, particularly in the case of government contract research. While some exceptions may be cited, our experience has been that as long as the projects are accepted voluntarily by individual faculty members after discussion with technical representatives of the sponsor, there is little danger of any significant loss of freedom in carrying out the research. Indeed, many contracts are written with very wide latitude and with practically the same freedom given to university-supported programs. The decentralization of federal support through many agencies of government has no doubt been a factor in maintaining freedom of action on the part of universities. In any case, the advantages of having funds for expensive equipment and materials and for research personnel far outweigh any minor restrictions we have had to contend with thus far.

A problem of great significance is that we are frequently asked to share the costs of a sponsored research program either by eliminating or decreasing the indirect costs or by providing faculty supervision without charge. In particular, some foundations object to the inclusion of indirect costs in the budget, and some government research grants have provided inadequate reimbursement. This is not always the fault of the agency; for example, the National Institutes of Health has had a rider attached to its appropriation bill by the Congress limiting indirect costs to 15 per cent of direct costs, a standard of reimbursement that provides only somewhat more than half of that required to meet full costs.

It is understandable that some sponsors, with limited funds available, try to buy more research by asking the universities to contribute part of the costs. We have yielded to such pressures, particularly for some foundations and for the National Institutes of Health. However, it is clear that we must exert every effort to close this gap, since it represents a drain on university resources that is becoming increasingly difficult to bear. In the past, small sums could be absorbed by the university; but the magnitude of our present program prohibits us from adopting anything but a policy of full-cost reimbursement. There are indications that our sponsors are gradually recognizing that this policy is necessary to maintain the strength of the universities and to allow them to continue to fulfill a large part of the basic research needs of the country.

Finally, there is a feeling in some quarters that teaching, particularly undergraduate teaching, is being neglected in favor of research. It is true that graduate students benefit directly more than undergraduates from the sponsored research program. However, as Dr. Stratton's report points out, undergraduates are being drawn into these programs in increasing numbers. Moreover, the same faculty is involved in all teaching and research, and hence many of the benefits of these programs spread to all parts of the Institute. It is the obligation of the academic administration to see that a neglect of teaching does not occur in any specific area, and we believe that this job is being done effectively.

CARL F. FLOE

Cambridge Electron Accelerator

The past year saw completion of the construction of the Cambridge Electron Accelerator, a research facility for high-energy physics sponsored jointly by M.I.T. and Harvard University and supported by funds from the U.S. Atomic Energy Commission. Design and construction were started in April, 1956. Initial operation at an energy of 2.2 Bev. (a new energy record for electron accelerators) was achieved on March 7, 1962.

The Accelerator is located on the grounds of Harvard University, at 42 Oxford Street. Contractual responsibility and fiscal supervision are provided by Harvard. A joint Executive Committee of members of the faculties and administrative officials from both schools determines policies for operation of the laboratory as a research facility for scientists of M.I.T., Harvard, and other institutions.

The stage of "essential completion" as defined in the construction contract was satisfied by the initial operation, and the contract was terminated on March 31, 1962. Further development and operation as a research laboratory will be carried on under an "operations" contract with the U.S. Atomic Energy Commission. The total cost of the installation was $11.6 million, and the requested budget for operations and research instrumentation for the fiscal year starting July 1, 1962, is $5.0 million.

Tune-up and trial operations during March and April disclosed limitations to full-power operation in some of the components, which consequently required modifications. Operation at 3.2 Bev. energy was achieved on March 21, limited by overheating in one component of the magnet power supply; in August this repair was completed and the accelerator was brought into condition for operation at the design energy of 6 Bev. During trial operations beam intensity was found to be limited to about one-third of the design intensity due to "beam loading" of the radio-frequency system used for acceleration. Developments are in process to control the beam loading and increase intensity.

Meanwhile, the C.E.A. staff and scientists from the universities have been engaged in assembling and testing research apparatus to utilize the high-energy electrons and x-rays from the accelerator. Initially a total of twelve research programs have been submitted by the scientists and have been approved for support by the Scientific Executive Subcommittee. It is anticipated that several of these research experiments will begin during the coming year.

M. STANLEY LIVINGSTON

Division of Sponsored Research

The upward trend in sponsored research which began during the fiscal year 1956-57 has continued during the year ending June 30, 1962, with the on-campus sponsored research program increasing in volume at an even faster rate than it did during the previous year. Comparative figures for fiscal years 1961 and 1962 are noted below:

DOLLAR VOLUME:

	1960-61	*1961-62*
Federal government	$18,093,548	$21,506,384
Industrial, foundations, and Other non-federal government	2,205,546	2,548,999
Grants-in-aid	—	690,917
	$20,299,094	**$24,746,300**

PERSONNEL EMPLOYED:

	June 30,1961	*June 30, 1962*
D.S.R. staff	307	345
Academic staff devoting time to research projects	1,063	1,224
Support personnel	603	686
	1,973	**2,255**

During the past year, research projects supported by grants-in-aid, which number some 85, were taken over by the Division for business administration. Although a comparable amount of research in all probability has been supported under grants-in-aid in the past, it is now for the first time brought together in one figure so that its magnitude can be truly appreciated. These grants come primarily from industrial concerns, with a few from foundations, and are widely distributed throughout the various departments of the Institute.

The dollar volume figures for research do not include funds received in the form of facility grants and contracts from the federal government. The Institute has been reimbursed by the federal government in the amount of $2,756,500 for facilities and equipment. Most of this–$2,445,575– has been received under a contract with the United States Air Force for the National Magnet Laboratory, a large facility which is fast approaching completion. The balance, $310,925, covers expenses incurred in connection with a number of building modifications and equipment purchases where M.I.T. is sharing the cost with the National Science Foundation, the National Institutes of Health, and the Atomic Energy Commission. Most of the grants and contracts of this type, however, were received near the close of the fiscal year 1962, and expenditures from them will be reflected in the coming year's activities. Grants and contracts for educational facilities are expected to grow in magnitude in the coming years.

The large increase in the dollar volume of sponsored research was distributed through nearly every department and interdepartmental laboratory in the Institute. In the School of Science, the Department of Biology continued to lead the way, although the earth sciences were close behind. In the engineering departments, the activities of the Supersonic Wind Tunnel decreased markedly so that the Department of Aeronautics and Astronautics shows a large decrease in on-campus research. The remaining engineering departments have all maintained their 1961 levels or increased them during 1962.

The volume of research in the National Magnet Laboratory has increased by nearly 50 per cent as the new facility nears completion, and in the coming year it will continue to expand.

Both the Laboratory for Nuclear Science and the Research Laboratory of Electronics have increased noticeably during the year, while the Joint Center for Urban Studies has more than doubled its activities, due in large measure to the program which it has undertaken in connection with the planning of new urban areas in Venezuela.

As the statistics indicate, a major portion of the sponsored research is supported by government agencies, and much of the increase during the past year comes from funds supplied by the National Institutes of Health, the National Science Foundation, and the National Aeronautics and Space Administration. In addition, all agencies of the Department of Defense continued to sponsor basic research throughout the Institute.

The personnel figures noted indicate a continuing increase in the number of academic staff members devoting time to research projects and an ever-increasing participation of research assistants (part-time graduate students) in sponsored research. This active participation of faculty and graduate students indicates clearly the close integration of sponsored research with the academic program of the Institute.

F. LEROY FOSTER

Industrial Liaison Office

In its fourteenth year of operation, the Industrial Liaison Program attained higher levels of activity than in any previous year. This growth in the organized interchange between the Institute and a selected group of research-based corporations attests forcefully to the deep interest on the part of the industrial community in M.I.T.'s expanding programs of education and basic research in science and technology. The number of participating companies and the income associated with the Program increased significantly during the year. At the same time the basic purpose remained that of providing a channel for effective communication between member companies and M.I.T. through organized activity that is adapted individually to each company's structure and interests.

The statistics of operation indicate the new levels of activity reached during 1961-62. Compared with the previous year, the average attendance by company representatives at Industrial Liaison symposia increased by 35 per cent; 39 per cent more individual contacts were made on the campus with members of the M.I.T. faculty and staff; the total volume of publications distributed grew by 33 per cent; 25 per cent more faculty visits were made to company research laboratories; and special requests for Institute publications increased by 20 per cent. To some extent this expanded activity was due to a 16 per cent growth in Liaison Program membership and to generally more favorable economic conditions than existed in 1960. Other major influences underlying this growth were the rapid expansion of the total research effort in industry and a heightened awareness of the importance of keeping in close touch with fundamental research so as to shorten the time interval between discovery and application.

Industrial Liaison income for the year totaled $2,043,000, an increase of 49 per cent over the prior year. At year's end, there were 118 participating firms distributed by industry as following:

Aerospace	17%	Manufacturing	13%
Automotive	3%	Metals	8%
Chemical	15%	Paper	2%
Electronics	19%	Petroleum	11%
Food	3%	Others	7%
Insurance	2%		

Twenty-four companies entered the Program during the year, which is a record number of new members for any one year and is a direct result of the concerted Second Century Fund drive. Eight firms withdrew, primarily for budgetary reasons.

The series of Industrial Liaison symposia attained a new, expanded level of operation during the year. Company interest in these conferences grew significantly, as indicated by the average attendance figure of 94 persons, an increase of 35 per cent over the prior three years. Especially noteworthy was the fact that 35 companies on the average were represented at the meetings as compared to 25 companies during each of the previous three years. Thirteen symposia were held during the year on the following topics: Planning and Managing Organization Change; The Earth's Atmosphere; Single Crystals; Friction, Wear, and Lubrication; Dynamics of Solids and Shells Under Intense Impulsive Loads; Speech and Handwriting; Physical Methods for Organic Structure Determination; Advances in Operations Research; Heat Transfer; High Temperature Materials; Magnetohydrodynamic Energy Conversion; Materials Science and Engineering; and Modern Oceanography. As in the past, progress reports on M.I.T. research activity by faculty members provided the substantive basis for these conferences, and the wholehearted support of the symposium series by the faculty who participated continued to be the keystone for its success. At the same time, the opportunity to present preliminary results of research programs in an informal setting where discussion is emphasized continued to be useful to the M.I.T. staff. A total of 97 Institute staff members took an active part in presenting material at these conferences along with twelve representatives of other organizations. In addition, 126 other M.I.T. staff members attended, indicating that this series of symposia is serving the Institute community internally as a means for communicating information among departments and laboratories.

The conference on Planning and Managing Organization Change was held in Chicago, the High-Temperature Materials symposium in Los Angeles, and one day of the Modern Oceanography meeting in Woods Hole; the balance of the series took place on the campus. The practice which was begun three years ago of planning several meetings away from the campus each year continued to be very well received and has generated considerable goodwill for the Institute among the participants who are especially benefited. The fifteen companies whose major laboratories are on the West Coast have given a particularly enthusiastic reception to the meetings that have been held in Los Angeles over the past three years. The Industrial Liaison Office plans to offer future conferences away from the campus when possible and when the topic is of major interest to a particular group of companies in one area of the country.

The two two-day symposia—Materials Science and Engineering, and Modern Oceanography—justify special mention because of the extremely favorable response and interest which they generated. Establishment by M.I.T. of the Center for Materials Science and Engineering created substantial interest in industry, and the conference provided an exceptionally fine opportunity to describe the programs and plans for the Center to a record number of 145 industrial research managers representing some 54 corporations. The symposium on Modern Oceanography was held jointly with the Woods Hole Oceanographic Institution; the keen interest in this field far surpassed expectations, and a total of 105 individuals attended from 52 firms.

The volume of M.I.T. reports and other publications systematically distributed to member companies was expanded considerably this year. The number of separate publications sent was 408, up 5 per cent from the previous year. However, the demand for multiple copies of publications rose markedly and resulted in a 33 per cent increase in the total number of documents mailed. This expanded volume reflects several factors—a keener awareness of M.I.T. research, the extension of Liaison Program services to additional divisional laboratories of member companies, and the increase in total Program membership. Preprinted copies of papers to be published in technical journals continued to be especially well received; the number of preprints distributed was 165, a 68 per cent increase over the prior year. Preprints now constitute just over 40 per cent of the titles mailed, and it is the aim of the Industrial Liaison Office to expand even further the distribution of preprinted material because of the value which industry places on the timeliness of this form of communication.

A far greater number of special requests for Institute publications were received and processed. In many cases the individual attention given to these requests saved a company considerable time and expense in locating a particular report not readily accessible through other channels.

As in past years, the Directory of Current Research, compiled annually by the Industrial Liaison Office, served a number of useful purposes, both for the member companies and internally at the Institute, by providing a brief but comprehensive listing of the Institute's active research programs. An increase in the number of projects listed from 944 in 1961 to 989 this year was striking evidence of M.I.T.'s expanding programs in a number of fields.

Visits to the campus by key company representatives to talk individually with members of the faculty increased substantially this year, due to more liberal company travel policies following the 1960 business recession, to the growth in Program membership, and to expanding company interests which encompass broader segments of M.I.T.'s research programs. This 39 per cent rise in visitors was distributed among a greater number of faculty and staff, so that the direct impact on particular individuals was almost unchanged. A total of 432 Institute staff members participated in this phase of the Liaison Program as compared to 336 in the preceding year. In general, visitors to the campus had more diverse interests than in 1960, and this was a major factor in the tendency to meet with more faculty members during each visit.

Faculty members made a total of 54 visits during the year to the research laboratories or headquarters of member firms at the request of the Industrial Liaison Office, an increase of 25 per cent. A number of participants have stressed the desirability of this phase of industrial liaison, and a further growth in such visits is anticipated.

The lasting benefits of a particular year's operations cannot be presented simply as statistical results. The operating figures do mark the trend of industry's regard for its professional relationships with the Institute, and the indications as measured by Industrial Liaison activity this past year are strongly positive. However, it is the contributions to the long-term progress of research both within the Institute and in the participating companies—more difficult to measure—that are more significant, and these contributions are felt to be substantial. Through the activity generated under the Program, many faculty members were able to widen their industrial acquaintances, and this led in a number of instances (particularly with younger staff members) to opportunities for private consulting arrangements. Discussions with the managers of industrial research gave faculty members a clearer insight into the long-range interests of particular companies, and in some instances these contacts helped develop research project support. Other shorter-term benefits accruing to the faculty during the year included gifts of company-produced materials, thesis topic suggestions, and technical assistance to graduate students.

Throughout the year, Gary L. Benton, James E. Donahue, Richard B. Finn, Jr., John F. Maxwell, and Thomas Yonker served as Industrial Liaison Officers. James C. McClymont, Jr., left the Office in May, 1962, to accept a position in industry, and Daniel J. Holland was appointed to the staff as Industrial Liaison Officer. The record levels of liaison activity reached during the year are a direct result of the skill and energy with which the Industrial Liaison Officers fulfilled their responsibilities without compromising the personal attention given to each of the member companies. Their accomplishments have been possible only through the active support and full cooperation of the entire faculty and staff of the Institute.

WINSTON R. HINDLE, JR.

Joint Center for Urban Studies

The Joint Center for Urban Studies, established in 1959, is a cooperative research venture of M.I.T. and Harvard University. Its goal, the furtherance of basic research on the city and the region, requires the knowledge of scholars and advanced students from many different fields. During the past year the Joint Center drew its Associate and Research Fellows from M.I.T. and Harvard in areas that included civil engineering, law, architecture, city planning, industrial management, history, economics, social relations, political science, and government.

While the subjects of Joint Center research problems range considerably, they are concentrated in four major areas: comparative analysis, structure, and growth of cities; urban transportation and technology; urban design; and urban and regional problems in developing countries. Within these areas the Joint Center's interest focuses on rising income, population growth, and changes in production, distribution, and standards of living. Such factors underlie the urban and regional problems of our time—whether they are urban renewal or transit schemes, migration and friction of racial and ethnic minorities, political conflicts between suburbs and the downtown central city, or new approaches to urban aesthetics. They influence the choice of appropriate research tools, models, and other ways to improve projection and analysis.

The Joint Center operates under four basic policies of allocating funds. The first is that research must be conducted in a variety of disciplines; the second is that no more than 20 per cent of the annual funds of the Joint Center should be devoted to research on any one project; the third is that some resources be deliberately allocated for exploratory efforts over a wide range of topics; and the fourth criterion is that special grants rather than the general funds of the Center should be used to finance large projects.

Under these policies studies have been undertaken ranging in scope from work on the visual form of the metropolis by Professors Kevin Lynch and Donald Appleyard to evaluation of municipal manpower problems in relation to the changing technological and social characteristics of cities by Professors Robert C. Wood and Vladimer Almendinger. One group of studies nearing completion in 1962 is an analysis of local politics in 21 cities. These case studies in city politics under the direction of Professor Edward C. Banfield have brought together fundamental background data on the structure of government, party organization, voting behavior, influence structure, and the content of various key issues such as urban renewal efforts, racial tensions, and metropolitan organization and planning in each city. The reports from this series, nineteen of which have so far been issued, provide basic material for political scientists and others doing research on urban subjects and facts useful to civic leaders concerned with the political setting in which they must translate policy into action.

Other studies in progress or completed in the past year in the general realm of the comparative analysis, growth, and structure of cities concerned government policy and urban renewal, legal controls on urban land use, national analysis of the urban renewal market, and the future of the downtown department store.

Studies in technology and transportation included the interdependence of transportation and land use planning, transportation and urban form, characteristics of urban passenger transportation systems, an economic and technological analysis of rail rapid transit systems, and an analysis of urban organization and growth in a communications perspective.

Studies on urban design included an analysis of how the elements of community and privacy can be attained in the urban family house and an application of the principles of art criticism to formulate criteria for urban design.

Along quite different lines, other studies have explored aspects of the ethnic and social character of cities: the Negroes, Italians, Jews, Puerto Ricans, and Irish in New York City; the social mobility of manual laborers during the 19th century in a Massachusetts mill town; and the operation of the Massachusetts antidiscrimination law as it affects opportunities for employment and housing.

A major undertaking of the Joint Center is the regional study for the government of Venezuela to devise a strategy for opening up and developing a large, potentially rich region in the southeastern part of the country and to plan several new towns and a new city, Santo Tomé de Guayana, which is expected to have an eventual population of half a million or more. Some of the problems are: to establish an appropriate scale of government investment in transportation, schools, and other public services for the region in the light of market prospects for present Guayana industries; to decide on the kinds of new industries which might be particularly suitable for the region; to plan the immediate housing and public facilities for the thousands of squatters moving into the region looking for work; and to create the kind of urban design in Santo Tome which will help attract the types of people and economic activities that are needed and that will also serve to affirm visually the potential importance of the region.

To meet these varied challenges of the Guayana project required the assembling of a staff with both practical and scholarly capabilities in a wide range of special fields. The Joint Center's staff collaborates with a counterpart team of Venezuelans who will carry on the project. During this year a number of faculty members from many different fields at M.I.T. and Harvard have been called upon to advise on the study. The findings are intended to provide both a firmer basis for decisions by Venezuelan officials and to serve as a model for other developing nations on the integration of urban and economic planning and development.

A further objective of the Joint Center is to provide a common ground where scholars and practitioners can meet. At lunches regularly scheduled throughout the academic year, urban renewal and planning officials, men in the transportation and real estate business, and local and national political figures come together for discussions with members of the Joint Center staff. Among the lunch guests this year, for example, were such men as Lyle Fitch, President of the Institute of Public Administration; Daniel Moynihan, Assistant to the Secretary of Labor; Lewis Weinstein, former chairman of the Massachusetts Housing Board; Walter W. Patchell, Vice President of the Pennsylvania Railroad; and John Madge, Director of Political and Economic Planning in London. Conferences, panels, and seminars served the same purpose. For example, a conference on master planning in May, brought students at M.I.T. and Harvard together with professionals from twenty New England cities to share in the discussion of panelists who came from several universities, a community council, a private consulting firm, and the Boston City Council. Other activities of this kind have included informal staff sessions with professors visiting the Joint Center from other universities here and abroad, monthly seminars for advanced students, and a public forum at Sanders Theatre in December entitled "The New Mayors: Where to Find the Power to Govern," with the mayors of Boston, New Haven, St. Louis, Nashville, and Cambridge as speakers.

It is our conviction that applied research and action programs will improve in the future only as the Joint Center helps to strengthen the different disciplines which contribute to urban and regional studies. What is most needed at this stage of urban and regional studies is an increasing sensitivity to and understanding of the complex issues that characterize every aspect of the contemporary metropolitan world. To help in nourishing this understanding imposes the responsibility to continue to attract able minds of both older and younger generations to work at the Joint Center.

MARTIN MEYERSON

LLOYD RODWIN

The Libraries

A million and a half people came into M.I.T.'s Libraries this year. We received an average of 500 books, reports, journals, slides, and phonograph records daily to classify, catalog, and organize. Never have the Libraries been the focus of so much attention. Faculty and students, in organized groups and individually, have been scrutinizing our operations and interrogating our future. This augurs well.

In this report I shall try to set forth some important facts about the Institute's official library system, its components, and its activities; then a word about the unofficial libraries which are springing up all around us.

The table on the next pages presents a number of statistics about the current operations of the official libraries; each of the five schools has its own, and a few have smaller branches.

ENGINEERING LIBRARY

The Engineering Library occupies an ideal location in the fifth through the seventh floors under the dome of Building 10, near the center of the original campus. It contains the collections for civil, electrical, and mechanical engineering and naval architecture departments which have a total of 6,057 faculty, staff and students. However, it would be misleading to think that all of these or only these constitute the potential users of this Library—a study a few years ago showed that electrical engineering students use the Science Library in larger numbers than the students of any other department—yet there may be some value in counting the population theoretically served by each Library for comparative purposes. The table gives the totals.

Our latest figures show an average of 548 readers a day using the Engineering Library. There are times when every chair is full. This situation will be aggravated by the construction of the Center for Materials Science and Engineering next door. The Library now has a full-time equivalent staff, (including students) of nine.

In discussing any library the most vital consideration is not how much room there is or how good the staff is but the quality of the collections. These factors do not necessarily show a positive correlation. The Long Range Planning Committee for Libraries, appointed by the President in the fall, is studying all our collections and I cannot foresee their conclusions. But it is clear that the shift toward more science in engineering education must be more strongly reflected in the

Library Operations and Activities, 1961-62

	Floor space (sq. ft.)	Number of volumes, June 30, 1962	Empty shelving (lin. ft.)	Annual growth: Number of volumes	Annual growth: Shelving (lin. ft.)	Years to capacity
Dewey Library	9,300	123,091	615	3,800	543	1+
Engineering Library	18,320	121,344	6,431	3,200	457	14
Aeronautics and Astronautics	2,950	37,400	450	400	57	8
General and Humanities Library	41,160	379,080	9,765	13,000	1,857	5
Music Library	(3,360)	5,261	0	800	114	0
Reserve Book Room	(3,720)	13,000	690	0	0	–
Rotch Library	5,100	44,746	215	1,600	228	1
Science Library	15,180	70,074	441	4,400	621	2/3
Archives	1,380	13,123	608	973	139	4
Departments and Administration	11,400	–	–	–	–	–
Total	**104,790**	**807,119**	**19,215**	**28,173**	**4,016**	

Library. Journals and books in mathematics and physics are being bought in increasing numbers. This process will be accelerated as the demands in materials science make themselves felt; so this Library is subject to even more inflationary pressures than our others. Not only must it cover a growing engineering literature; it must at the same time become a science library. This reasoning has lead some to believe that the Institute should combine its engineering and science holdings in a single centrally located building, another question which the Long Range Planning Committee is studying.

Improved quality means more books. More readers keep coming, too. If the Dome continues as a library, we may be forced to consider lightweight construction to put additional reading rooms on the sixth and eighth floors, eliminating the decorative plaster ceiling now concealed by the lighting fixture. The heavy load of book shelves would stay on the periphery (including an eighth floor of 5,000 square feet, which is now unusable) where they have solid support. None of these upper floors is properly lighted, heated, or ventilated, but this could be done at a cost which would be moderate compared to new space. The number of seats and books that can be added will depend on structural

Potential users	Number of chairs	Weekday attendance (as of 1959)	Staff (full-time equiv., including students)	Expenditures: Salaries	Expenditures: Books, periodicals, and materials	Circulation, 1961-62: One- and two-week	Circulation, 1961-62: Overnight	Circulation, 1961-62: Total
2,649	107	719	9½	$ 39,434	$ 25,318	33,051	12,028	45,079
6,057	248	548	11½	46,970	22,848	29,782	10,491	40,273
751	49	216	(2½)	(10,760)	3,929	10,390	1,905	12,295
4,488	257	814*	6	23,260	23,422	59,519	33	59,522
153	86	474*	(2)	(7,280)	6,238	3,833	94	3,927
–	112	553	(2½)	(8,500)	–	2,285	8,137	10,422
647	74	285	4½	16,800	5,518	10,632	5,682	16,314
13,370	214	1,108*	15	58,982	42,760	34,086	19,564	53,650
–	7	5*	1½	10,490	750	–	–	–
–	–	–	53	263,905	84,141	–	–	–
28,115	**1,154**	**4,722**	**101**	**$459,843**	**$214,924**	**183,578**	**57,934**	**241,512**

*as of 1958.

as well as financial considerations.

Minor improvements in the Library continue, and more will be necessary. Automatic sprinklers have been installed in the stacks; the circulation desk needs rearranging for quieter operation and more efficiency. The seating should be increased by 80 on the sixth and seventh floors by providing furniture and lighting; the space is there, unused. The elevators are slow, old, subject to frequent breakdown, and do not operate holidays and weekends. They should be made automatic and run continually. All in all, the Engineering Library is badly in need of the sort of facelifting which the Aeronautics and Astronautics Library has had during the past year.

AERONAUTICS AND ASTRONAUTICS LIBRARY

This Library is located on the third floor of Building 33, which houses its Department, and was remodeled and expanded last year. It is now the most satisfactory of all our facilities from the reader's point of view.

The Aeronautics and Astronautics Library is different from any other in our system in that a major portion of its holdings are technical reports. Just as the journal replaced the book, now reports are replacing journals as the source of the most recent information. This is true in some other fields, but only here have we really succeeded in keeping abreast of the output. New reports were received during the year faster than ever (2,821), and circulation figures show that they were borrowed more than books and journals together. They are kept in filing cabinets, rather than on shelves, and the cabinets are now nearly full. A program of microfilming older reports may have to be undertaken, or they will have to be moved to the Engineering Library, where there is space.

Longer hours this year helped accommodate more readers. To open Saturday mornings and holidays required a janitor to unlock the building as well as a student assistant in the Library. But the demand was such that this was necessary.

ROTCH LIBRARY

The Rotch Library of Architecture and Planning, on the second floor of Building 7, is close to the departments it serves, but there the similarity to the Aeronautics and Astronautics Library ends. A fine, spacious library when it was built twenty-three years ago, Rotch is now so full that a book has to be taken out and stored in the Engineering Library every time one is added. This is the fate of libraries. Throwing away old material to make space for new would be a good solution if the old went out of date fast enough; but it doesn't. The fact is that changing and broadening interests make us buy old material every year, as well as new. We are constantly buying back numbers of journals to complete our sets, and only about half the books we buy are published in the current year.

The Rotch Library space problem is especially difficult because this Library occupies a whole wing of Building 7, and there is little contiguous space in which to expand without new construction.

SCIENCE LIBRARY

The Science Library occupies the ground floor of the south wing of the Hayden Building, except for 1,200 square feet at the west end which is given over to the Map Room. It serves the Departments of Biology; Chemical Engineering; Chemistry; Geology and Geophysics; Mathematics; Metallurgy; Meteorology; Nuclear Engineering; Nutrition, Food Science and Technology; and Physics.

Much of the attention this Library has received this year from faculty committees, editorials and letters in *The Tech*, and the graduate students in an operations research subject (8.75) stems from its extraordinarily heavy use. Thanks to the basement stacks, the problem of shelving is not as critical as in Rotch, but the basement is not as convenient and each year more important things will have to go there. With an average attendance approaching 1,200 on weekdays, there are many times when there is not a vacant seat. Both floors of the Hayden Building were designed so that mezzanines could be added for books and readers when the Library became crowded. This has been done on the second floor and should be as soon as possible at the west end of the first, which is now occupied by the Map Room. The area, about one-tenth of that of the Science Library is now almost completely filled with map cases and a large table. The Map Room used to be an attraction for visitors, but its large revolving globe was damaged while being moved three years ago, and no progress has been made in repairing or replacing it.

Pressure for space in the Science Library will be slackened somewhat when the geology, meteorology, and oceanography collections are moved into the new Green Center for the Earth Sciences. About 9,000 volumes–two years' growth– will go. This relief, plus the conversion of the Map Room space to ground floor and mezzanine with shelving and seating, would allow the Science Library to keep its head above water for longer than indicated in the table—perhaps six or eight years.

The high use-factor of the Science Library has resulted in a constantly objectionable noise level. *The Tech* editorially suggested a partition at the entrance to the Library, separating it from the stairs and providing a lobby in which all the charging and discharging of books for the whole building could be done. It will be ready in the fall.

Reports prepared by the students in Principles and Applications of Operations Research (8.75) give statistics on many aspects of the Science Library operation. One is the extraordinarily high percentage of books returned late: 42 per cent of fourteen-day books and 49 per cent of seven-day books are not returned until overdue. Yet the mean length of time these books were used was 203 minutes, with the largest number reported used about two hours and 89 per cent reported used less than four hours. The students recommended that the Library consider shortening the loan period of heavily used books to seven days.

Many other figures of interest were turned up; for instance, that books in three fields, chemistry, mathematics and physics, account for 70 per cent of all borrowing, though they constitute only 30 per cent of the total collection. This would seem to indicate the desirability of more duplication. The situation should be helped, however, by the gradual acquisition of this type of material in the Engineering Library.

The book checkers were severely criticized for failure to do their job. Oddly enough, this is one of the most difficult positions in the Library to fill. It requires a person mature enough to inspire respect, tactful, firm, conscientious, and proof against boredom. We are now trying the suggestion that book checking be rotated with other jobs every few hours.

Equally distressing was the students' finding that hours pass between a book's return to the Library and the time it is put back on the shelf. Spot-checking showed that the probability of finding a desired book on the shelf was 83 per cent for reserves, 70 per cent for seven-day books, and 50 per cent for fourteen-day books. Books charged out represented an unknown fraction in the last two categories. The situation has been improved and will be watched.

Staff changes made the operation of the Science Library more difficult this year. The promotion of Richard L. Snyder to Associate Director of Libraries and of Joseph M. Dagnese to replace him as Science Librarian brought the usual period of adjustment. Then several resignations at the end of the year have brought another temporary drop in efficiency.

For a month before examinations this spring, the Library was kept open until midnight because students living in East Campus were disturbed by the noise of pile driving for the Earth Sciences Building. The suggestion has been repeatedly made that the Science Library should be open at least until midnight, perhaps longer. This is probably inevitable as crowding during the day becomes worse. Longer hours in several of the other libraries this year came about from similar pressures.

DEWEY LIBRARY

Dewey Library serves the School of Industrial Management and the Department of Economics, except for the Political Science Section and some undergraduate economics subjects. At no time since it was built has this Library been able to hold all the material belonging to it. Some has always been stored either in the Engineering Library or in the basement stacks in the Hayden Building. We have not been farsighted enough in our planning.

"Our greatest and constant concern," writes Miss Barbara Klingenhagen, the Librarian, "is how and where are we going to find shelf space for the increasing amount of material coming in and how can we reduce the overcrowding and the noise in the Library." The School of Industrial Management is still expanding rapidly, and the Library must do the same. Plans have been laid by the Faculty Advisory Committee for a new library, possibly in a separate building. This is at least several years away, and interim expansion is needed now; the Long Range Planning Committee will undoubtedly make suggestions.

The demand for new books, journals, and pamphlets is such that 30 per cent more were added this year than last. As to new journals, 130 new titles were subscribed to but only 88 had started arriving at the end of the year. The trend is to more foreign materials than ever before. There is more interest in Russia, the East European countries, China, and Africa. Special appropriations for economics have helped pay for more books, but the influx has caused a delay in processing which was further aggravated by six-months inability to find a cataloger. It is hoped to have more staff next year to clear up the backlog, or possibly the new machine mentioned below.

At Dewey, a monthly record was kept of all books reported missing. These totaled 134, sixteen of which were subsequently found. Of the balance, eighteen have been replaced and the rest will be if they still cannot be found after further search and are still in print. Twenty-two other books and journals have disappeared via another route which causes repeated trouble in all the Libraries. When an item does not return on time, the signature card may be found to contain a false name and number, false at least in the sense that the borrower cannot be located at M.I.T. The circulation desks are so busy at many times of day that they fail to ask to see identification.

In this Library there has been a particularly happy collaboration between the students who work evenings and week ends and the professional staff. It has resulted partly from having the latter work a few hours at these times, when they have an opportunity to train the students. We hope it may be possible to extend this to other Libraries, where we sometimes receive complaints that the student staff members are not much help in finding anything.

The *Dewey Library Accessions Bulletin* is published to provide a service to those interested in the literature of industrial relations. It goes to twenty-one people at the Institute and 266 outside. A flattering reference to it in the May, 1962, *Personnel Journal* has resulted in a series of new requests.

GENERAL LIBRARY

The General Library Collection is mostly in the Hayden basement. Some of the old Central Library is here, along with general books and periodicals. The Library has no staff of its own but is serviced by the Circulation Department and the Humanities Librarian.

HUMANITIES LIBRARY

The Humanities Library has branches for reserve books and music. It has a total staff of six and shares the Hayden basement stacks with the General Library collection and the second floor reading room with the Reference and Circulation Departments. The Union Catalog is in the reading room and the administrative and most of the technical service departments open off it. The Humanities Library proper serves the Departments of Air Science, Humanities, Military Science, Modern Languages, and the Political Science section of the Department of Economics.

The collections in Humanities are probably the poorest in quality of those of any of the Schools. This is partly because of new programs with increased graduate work resulting in higher demands. The budget has shown a gradual improvement, but large non-recurring appropriations are needed to fill in a backlog in such new fields as linguistics and psychology. These special funds have an unfortunate side effect that has to be borne in mind. While we can buy badly needed items, money is not usually provided for the extra staff needed to order, catalog, and put them on the shelves. Ideally, at least half the new appropriation should go for staff, for it is well known that the cost of processing the average book is higher than its purchase price.

MUSIC LIBRARY

The Music Library in the east wing of the Hayden Building has a staff of two. A library of recordings and scores as well as books, it serves the music section of the Humanities Department. It provides a place for work by students and faculty, and serves as a place of relaxation for many who come to listen to daily concerts of recorded music and occasional live performances. It is a pleasure to report that most of the upholstered furniture in the Music Library and in the other public areas of the Hayden building has now been re-covered under a three-year program.

It is not easy to provide more seats or more shelving in the Music Library, for nearly every inch of wall space, including an unused entryway, has been covered with shelves and any more will make the room less attractive. Yet the demand keeps increasing, and use is so heavy that expansion is vital. There is space (600 square feet) in the form of a shipping and receiving room next door which could be taken for expansion, and unless there is some possibility that the Music Library may move to another building, serious consideration should be given to this matter. The shipping room ceiling is high enough to provide for a mezzanine as well as a ground floor; together they would add 33 per cent to the area of the present Library.

RESERVE BOOK ROOM

The Reserve Book Room, with a staff of two and one-half, primarily serves undergraduates taking subjects in the School of Humanities, with a scattering of reserves from engineering and the sciences. It is heavily used as a study hall too. Its location in the north wing of Hayden means that it is close to the East Campus dormitories and the Walker dining hall. Refugees from the noise of the dormitories find the room a quiet place to study. This year it was again kept open until 1:00 a.m weekday mornings and extended to 3:00 a.m. for the last two weeks before examinations.

Total use of reserve books shows a sharp increase: 43,200 were borrowed this year for use in the room and outside, compared with 32,058 last year. Forty-five books out of a total of over 5,000 disappeared, the heaviest loss being in Problem Solutions for 8.02, where seven out of twenty copies vanished.

ARCHIVES

The Institute Archives were started last year and occupy the mezzanine of the Reserve Book Room and the basement below. They started off in a burst of activity connected with the Centennial and have proven their worth again this year. A surprising number of people both inside and outside of the Institute are interested in delving into our history, whether it be the *Technology Review* preparing its "yesteryears" section or public relations people from industry writing biographies of their executives. There still remains a quantity of uncataloged papers, with new ones coming in every day. Films and tape recordings have started to arrive, raising questions as to how they can best be indexed and stored. Students' records from the Bursar's Office are on microfilm; probably the Medical Department and the Registrar's Office will also wish to use our facilities. Some of these things will need to be kept confidential, but this is a problem common to all university archives. Eventually the Institute will need a policy for referring all records of possible historical value to the Archives for sorting and retention or destruction.

LIBRARY DEPARTMENTS

ACQUISITIONS DEPARTMENT

The Acquisitions Department orders materials, does bookkeeping on Library accounts, checks materials in when they arrive, pays for them, and sends them along to be cataloged. Its Order Section has seen a 3 per cent increase this year in orders placed; it added 30,570 items to the Libraries through purchase, gifts, and exchanges and discarded 340. Another 5,000 or so came directly to individual Libraries.

Bookkeeping procedures were considerably simplified during the year, and the Head of the Department has worked closely with the Institute Accounting Department in order to take advantage of the mechanization which the latter is gradually introducing. A good deal of duplication will be eliminated within the next year or so.

Journals and serials are checked in as they arrive at a central file, about 50,000 individual issues in the last year. Some sort of mechanization should be possible here. Various types of equipment are being investigated and a new position has been authorized to head up this section.

This year the processing of technical reports was moved into the Acquisitions Department. As mentioned above, this type of literature is rapidly growing in importance. But it presents special problems: reports are not identified, as books and journals are, with a regular publisher from whom they can be ordered; they go out of print quickly, and the sponsoring projects are often short-lived. The National Science Foundation, in an effort to remedy this situation within the government, has arranged to release to a dozen depository libraries throughout the country, microfilms of some 40,000 unclassified reports from government-financed projects each year, and M.I.T. has been chosen as the Regional Technical Reports Center for the New England area. Under this arrangement we set up an information service covering reports and sell microfilms or paper prints of these reports at our current prices to anyone who requests them. We are happy to have financial assistance from the National Science Foundation for carrying on this work. While this does not solve what has come to be called "the technical report problem," it is a step in the right direction.

Exchanges with other libraries, particularly in Russia, also fall within this Department. We continue to receive many of the books and journals we need from the Soviet Union by this means. Of 430 monographs requested from Russian libraries, we have been able to get 330. In return, we have sent out American books and journals valued at about $11,000.

BINDERY DEPARTMENT

The Department has a staff of only three and one-half, responsible for repair and paper binding and supervision of work on theses, journals, and foreign books sent to commercial binderies—6,323 in 1961-62, as compared to 6,069 in 1960-61. Some thirty thousand items a year pass through this section for anything from minor jobs like lettering to complete rebinding and restoration of rare old volumes. Careful schedules and regular quotas for binding from each library have been introduced to try to reduce the time required for binding work.

CATALOG DEPARTMENT

The Catalog Department has a staff of thirteen and one-half, whose job it is to classify each new volume according to its subject matter and describe it in the catalog so it can be found when needed. This year 12,208 English titles were processed, including 1,349 M.I.T. theses. Other languages account for a remarkably small number: French, 362; German, 353; Russian, 263; and a total of seventeen other languages, only 181 titles. In addition, 466 musical scores and 388 recordings were cataloged. This total of 14,221 compares with 13,082 in 1961-62 and 11,158 in 1959-60.

New works are not being cataloged as fast as they come into the

Library. As mentioned earlier, increases in funds for book purchase through special appropriations have resulted in cataloging delays. We do not have enough staff. There is hope that a new machine which has been designed by Edgerton, Germeshausen & Grier, working under contract to the M.I.T. Libraries through a grant from the Council on Library Resources, will eliminate much of the clerical work in the Department. It is designed to prepare a complete set of author, title, and subject cards, with any desired number of each, and from a single information input, this part of the process will be so rapid that as many as twenty-five cards, complete with tracings and added entries, will be prepared in the time it takes to enter information for the following set of cards. The machine will handle its information on tapes which can be used to duplicate cards, to make accessions lists and bibliographies, and will serve in systems for machine retrieval of information.

As the year ends a proposal to build a prototype machine has been prepared with the aid of Edgerton, Germeshausen & Grier and forwarded to Council on Library Resources. The price is much higher than originally expected, so the problem will be to convince the Council that paying the development cost will result in a machine that will pay for itself by the savings in time and labor that it will bring in cataloging departments throughout the country. We believe it will.

Since last November the Catalog Department has changed the system of assigning call numbers to books, so that henceforth each volume will have a unique number. This first step will be followed by a second which is more difficult and has far-reaching implications. It has been recommended by the Library staff, and approved by the Executive Board of the Faculty Committee on the Libraries, that we change from the Dewey to the Library of Congress classification system. The latter is more and more widely used in this country and seems more suitable for collections as large as ours. While it is not up-to-date in many fields of science, it is better than Dewey in this respect.

CIRCULATION DEPARTMENT

The Circulation Department, which has previously serviced the General and Humanities Libraries from the second floor reading room of the Hayden building with a staff of seven, has now been moved, along with circulation activities for the Science Library, to a new lobby at the entrance to the latter. This will result in a department which will probably handle 125,000 volumes next year. It should bring economies in staff, particularly in slack periods. We hope in the near future to make use of some mechanization in the process whereby books are charged out and returned and overdue notices sent.

The rest of the circulation activity is distributed among the different libraries and figures for the year have been collected in the table at the front of this report. It may be of interest that of the 241,512 volumes borrowed, 4,540 went to 1,105 holders of Library Privilege Cards which are issued to members of companies in the Industrial Liaison plan, the Associates Program, and the Library Membership Plan for Industry; to contributors to the Industrial Relations Section; and to individuals who for one reason or another were given complimentary cards or purchased them at $50 each. This number is up considerably over last year, when only 861 cards were issued to outsiders.

Of course, our service to industry does not stop there. A total of 1,059 volumes were borrowed by industrial libraries, and 5,434 orders from industry and government—almost all the former—were filled by the Microreproduction Laboratory.

The reciprocal agreement with the Harvard Medical School Library is working satisfactorily. Twenty-two from the Medical School used our facilities; 21 of our people used theirs.

MICROREPRODUCTION LABORATORY

No other department of the Libraries shows the startling increase in work of the Microreproduction Laboratory. Production of paper prints is up 87 per cent, from 175,752 to 328,396; exposures of negative microfilm is up 93 per cent from 207,139 to 399,879. Orders from M.I.T. sources are up 79 per cent, from other educational institutions 16 per cent, and from industry 44 per cent. Orders from United States Government agencies have decreased 60 per cent.

A high-speed microfilm processor and a Copyflo camera for continuous strip production of paper prints from microfilm have made possible these increases, but much overtime work has been necessary this year to keep up with the demand.

The Laboratory is working with other departments and laboratories at the Institute, recommending special types of film for certain purposes, processing bubble chamber and computer output films, etc. It is also filming records for the Accounting Office and the Registrar's Office and is studying the possibility of doing Medical, Dean's Office and D.S.R. records.

A grant of $27,000 from the Library Technology Project of the American Library Association is providing for research into a new type of indexing system for roll microfilm. A flash tube will project information which is legible on the reader while the film is in motion, simplifying the problem of finding the desired page and perhaps permitting us to store microfilm in thousand-foot reels instead of the present short lengths.

A well-equipped laboratory for photography and reproduction is essential to any library. We are proud of ours, which is probably the best of any university.

REFERENCE DEPARTMENT

The Reference Department, with a staff of six, provides telephone, mail, and in-person information and reference service. About two-thirds of the inquiries are concerned with a particular publication: Do we have it? Has it been translated? Who is the author? Where can I get it? Some 20 per cent ask the Department to provide a fact, a name, or a property of a substance. Most of the other questions ask what information can be found about a particular subject. Two-thirds of the total 22,700 inquiries handled last year were from M.I.T. people, one-third from outside.

The Department also instructs faculty and students in how to use the catalog and various reference books, abstracts, and indexes, and it has charge of borrowing from and lending to other libraries. We borrowed 1,232 items, and 1,714 were sent out in response to requests, 60 per cent of the latter to industrial libraries, 40 per cent to non-profit institutions and government libraries. Of the loans to industry, three-quarters went to 22 members of the Industrial Liaison Program and about 20 per cent to 18 libraries in the Membership Plan for Industry.

To inform industrial librarians about the services we can offer them and those we cannot, a meeting of 89 librarians from seventy firms was held at the Institute on October 11, 1961, under the auspices of the Reference Department. It was highly successful and has paid dividends in improved mutual understanding.

Another activity of the Reference Department is to serve as a clearing house on M.I.T. publications. The Department probably has more information than anyone else about what is being and has been published by departments, laboratories, projects, and individuals in the Institute. This year 2,044 orders were clarified and forwarded to the proper destination.

GIFTS

As in other years, friends of M.I.T. have given many volumes and numerous other items to the libraries. We received, for instance, the books of the late Professor Edward R. Schwarz of the Department of Mechanical Engineering and those of the late Jack Lair of Wellesley. Professor Joseph Hudnut, former Dean of the Graduate School of Design at Harvard University gave his collection of 2,776 slides, together with cases to house them; and the Raytheon Manufacturing Company gave us a large number of M.I.T. technical reports, many of which we did not have. A fine collection of autographs came from Mrs Harry Tomkinson of Revere. A complete list of donors has been published separately; we appreciate their kindness and generosity to us.

We were able to give a considerable amount of material to other libraries such as the United States National Museum and the Bologna Center of the Johns Hopkins University.

SPECIAL PROJECTS

Under a grant from the National Science Foundation to improve our coverage of Chinese science as a national resource, we are collecting all possible current science publications from Mainland China and a few social science journals. A Union List of the holdings of major libraries outside China is being prepared, since the information now available is fragmentary and is particularly poor for science and engineering. The plan is to prepare a file of punched cards which will be kept up to date so that new lists can be published periodically.

In connection with the Chinese project, Professor William N. Locke, Director of Libraries, travelled to the Far East, Russia, Scandinavia, and Europe this spring. His trip was successful in establishing purchases and exchanges on a basis of personal contact, not only for Chinese but also for Slavic material. There has been a marked improvement in the receipt of both since his return, with Hong Kong not surprisingly the best source for older Chinese material.

New Chinese journals are difficult to get. Apparently they can be had only by exchange with Peking, and then not more than a dozen titles or so. The demand in the United States, though never heavy, is increasing; this has been noticed in our Dewey Library and in the Reference Department. Industrial libraries, too, report that they are getting inquiries for more and more Chinese references. England and Japan seem to be the only other countries where there is any interest. Both have little better luck than we in getting the current scientific publications.

It is difficult to compare our Library with those abroad, because almost without exception the good scientific libraries of the rest of the world are government-run, either directly or in state universities. Having government financing in countries where there is a tradition of respect for the intellectual pursuits far higher than in the United States, these libraries are able to offer positions rivaling industry in salary and status. As a result, they attract and hold scientists and engineers to work with the literature, seeing to it that the library keeps up to date in all fields. The University of Uppsala has five Ph.D's on its staff, two of them in sciences. Much of the spottiness of the collections at M.I.T. can be traced to the fact that book selection is done on a spare-time basis by faculty advisers or has been left to librarians who may not have had adequate subject knowledge. Recently we have done much to improve this by bringing in staff with better subject knowledge.

In addition to the grants and research projects mentioned elsewhere, Mr. Boris I. Gorokhoff, a Russian specialist, is studying Russian scientific information and its dissemination there and abroad; and Dr. Myer M. Kessler, a physicist formerly on the staff of the Lincoln Laboratory, is investigating systems for the automatic sorting of scientific documents. This is the first step in a larger program for developing a test environment in the Boston area for the evaluation of several new techniques to improve the flow of scientific information. Both programs are financed by National Science Foundation grants.

STAFF ACTIVITIES

Only a few of the professional activities of the staff can be mentioned here. One involved over twenty members, who took part in organizing and running the annual meeting of the American Documentation Institute under the chairmanship of the Director of Libraries. M.I.T. was host to the four-day convention, which had a registration of over 900. The local committees included twenty librarians and documentalists from the industrial community, in addition to the M.I.T. group.

Karl S. Bynoe, Associate Reference Librarian, was selected as one of the 72 information specialists to man the Library 21 exhibit at the Seattle World's Fair; Mrs. Irma Johnson, Reference Librarian, represented M.I.T. at the First Governor's Conference on Libraries in Massachusetts on April 12, 1961, during National Library Week; Miss Katherine Murphy, Associate Reference Librarian, spent the year at the Research Library of the Associated Electrical Industries in England, where she took the place of Miss Barbara Burton, who has worked with us throughout the year in an exchange which has proven both pleasant and valuable.

UNOFFICIAL LIBRARIES

Along with what I have called the official Library system, there is a rapidly increasing number of small libraries or reading rooms throughout the Institute. In addition, there are the document rooms —*cum* libraries—in projects large and small.

There is a long history of attempts by faculty committees to decide how much proliferation of small libraries is desirable. Collections bought on project funds, supervised by people paid on the project, and carrying overhead are quite different in nature from libraries set up by academic departments or sections for their staff and students. The latter are usually financed from general funds. They are more accessible to a special group than any of the main libraries, but they serve only that group. The question then is, What is the best use of Institute funds—to organize larger libraries covering many fields and open to the whole community for long hours, or to fragment the libraries for the maximum benefit of fewer users?

It is hoped that the Long Range Planning Committee for Libraries will have something to say on this question of the most effective use of Institute funds for libraries.

IN CONCLUSION

Lest it seem that the tone of this report is pessimistic, the other half of the picture should be painted. The load is heavy. The Libraries are working at capacity. But the collections are in better shape than they have been for years, and we have the most competent staff we have ever had. It is only the necessity of facing up to a continuing increase of 10 per cent a year all along the line that gives us pause.

The Libraries have to grow with M.I.T. We have to work toward the high standard set by the Institute in other fields, building quality of collections and quality of service.

WILLIAM N. LOCKE

The MIT Press

During the last fiscal year the M.I.T. Press moved into new offices in Building 20, doubled its space and its staff, and published seventeen books. At the end of the year there were 118 titles in print, and a staff of a dozen people were working on about twenty books in various stages of production. Sales were up about 12 per cent from the previous year.

These books were published during 1961-62:

ROSENBLITH, WALTER A., editor. *Sensory Communication.* 1961. 844 pages, $16.00.*
The proceedings of an international symposium held at M.I.T. in 1959, presenting the experimental results and theoretical discussions of 42 life scientists, physical scientists, and communications and computer engineers, all concerned with problems of sensation and perception.

PAYNTER, HENRY M. *Analysis and Design of Engineering Systems.* 1961. 325 pages, $10.00.
Class notes for M.I.T. subject 2.751, giving a practical and theoretical background for engineers who deal with complex systems which operate simultaneously in several media and over a broad band of frequencies.

KIPINIAK, WALERIAN. *Dynamic Optimization and Control: A Variational Approach.* 1961. 233 pages, $4.95.*
A variational approach to the synthesis of feedback control systems, which formulates the theory of dynamic optimization, develops methods of computing optimum control laws, and illustrates these methods with a number of practical examples.

DEAN, ROBERT C., JR., editor. *Aerodynamic Measurements.* Seventh Printing, 1961. 272 pages, $10.00.
Theory and practice of the measurement of temperature, pressure, humidity, and velocity of flowing fluids, including hot-wire anemometry, mass-flow measurement, and measurement of time-varying quantities.

FORRESTER, JAY W. *Industrial Dynamics.* 1961. 464 pages, $18.00.*
A new computer-based approach to the study of how a corporation's structure and policies affect its growth and stability. Analyzes the managerial problem by constructing logical models of industrial systems and by manipulation of variables, computing the effects of new information and of policy choices upon the dynamic characteristics of the organization.

* Published jointly with John Wiley and Sons.

PUGH, ALEXANDER L., III. *DYNAMO User's Manual.* 1961. 64 pages, $2.00.
Complete instructions for programming industrial-dynamics problems on either the I.B.M. 704, 709, or 7090. The companion book to Forrester's *Industrial Dynamics.*

JAKOBSON, ROMAN, C. GUNNAR M. FANT, and MORRIS HALLE. *Preliminaries to Speech Analysis: The Distinctive Features and Their Correlates.* Fourth Printing, 1961. 58 pages, $2.00.
An attempt to describe the ultimate discrete components of language, their specific structure, and their articulatory, acoustic, and perceptual correlates, and to survey their utilization in the world's languages.

VYGOTSKY, LEV S. *Thought and Language.* 1962. 168 pages, $4.95.*
An English translation of a Russian psychologist's study of the development of thought and speech in the child. With an introduction by Jerome S. Bruner. Edited and translated by Eugenia Hanfmann and Gertrude Vakar.

KOLM, HENRY H., BENJAMIN LAX, FRANCIS BITTER, and ROBERT G. MILLS, editors. *High Magnetic Fields.* 1962. 752 pages, $15.00.*
Eighty-eight selected papers presented at the International Conference on High Magnetic Fields at M.I.T., reporting on present work in generation and use of very high or very special magnetic fields.

GREENBERGER, MARTIN, editor. *Management and the Computer of the Future.* 1962. 340 pages, $6.00.*
Eight lectures and extended discussions by leading figures in the communication sciences on the future uses of computers in activities related to management: their application to decision making, to educational processes, to libraries of the future, to the simulation of human thought, and in other areas.

CHANDLER, ALFRED D., JR. *Strategy and Structure: Chapters in the History of the Industrial Enterprise.* 1962. 463 pages, $10.00.
A study of the evolution of the new multidivisional, decentralized structure of American big business, with detailed case studies of du Pont, General Motors, Jersey Standard, and Sears, Roebuck and a briefer treatment of comparable changes in 70 other large corporations.

ENOS, JOHN L. *Petroleum Progress and Profits: A History of Process Innovation.* 1962. 352 pages, $9.50.
A history and economic analysis of innovations in petroleum cracking in America since 1913, which gives details of the innovations, their environment, and the men responsible for their development and adoption and which measures the profits from this progress and shows how they were divided among inventors, companies, and consumers.

SCHMITT, FRANCIS O., editor. *Macromolecular Specificity and Biological Memory.* 1962. 119 pages, $3.00.
Summary statements of 25 lecturers at M.I.T. exploring the possibility that memory involves a chemical writing of experience in macromolecular code within the cells of the brain. A multidisciplinary attempt to bridge the gap between molecular and systems analysis.

MASSY, WILLIAM. *Planning in Marketing: A Selected Bibliography.* 1962. 64 pages, $2.00.

* Published jointly with John Wiley and Sons.

LWOFF, ANDRE. *Biological Order*. 1962. 128 pages, $4.50.
Lectures on structural and functional order in living forms—from the cell, regarded as an integrated system of regulating mechanisms, to the organism, a disciplined society of molecules. The third series of Compton Lectures.

STRUVE, OTTO. *The Universe*. 1962. 159 pages, $4.95.
The cosmos as it appears to contemporary astronomers: the authenticated features, the reasonable surmises, and the boldest hypotheses—accompanied by the logic of discovery, the unfolding of the evidences, and the present status of rival theories. Also, a historical summary of radio astronomy, and many recent photographs.

LYNCH, KEVIN. *Site Planning*. 1962. 320 pages, $8.00.
The art of arranging the external physical environment in all its detail: the analysis of site and purpose, land use and circulation design, visual form, climate, site engineering, landscaping, plus such special topics as housing, shopping centers, and planning for institutions.

For many years the M.I.T. Press has distributed most of its important technical books through John Wiley and Sons of New York, under a joint publication arrangement. Through this unique program of cooperatively administered publication, Wiley has supported scholarly work in science and technology, and M.I.T. has enjoyed the advantages of skillful professional distribution of its books.

The time has now come, the M.I.T. Press Board has concluded, for the M.I.T. Press to discontinue joint publication and to undertake a full program of scholarly publishing under its own imprint, with complete promotion and sales facilities of its own. In recent years the Press has done all of its own design and production anyway, and it has been increasingly active in promotion and distribution. We have now decided to take the last step toward independence—by taking over complete marketing responsibility.

This step was recommended by a committee of experts who studied our operations two years ago. It has been considered at length by the M.I.T. Press Board, and it has cordial support of John Wiley and Sons. Since March, 1962, the Press has distributed all of its new titles, and in January, 1963, it will take over the distribution of joint titles formerly handled by Wiley.

Preparations for a substantial increase in the distributing end of our activities have already been made. New arrangements for storage and shipping of our books have been completed and are already in operation. Our bookkeeping system is being reorganized. Sales policies have been established and agreements negotiated with agents to represent us in the foreign and domestic book trade. Our own staff is in-experienced in sales, but we have good men working with us. We have two or three years of experience in promotion, and our production and editorial departments are experienced and strong. The M.I.T. Press is now in a good position to establish itself as a leading university press specializing in scholarly publication in science and technology.

LYNWOOD BRYANT

National Magnet Laboratory

The major efforts in the second year of existence of the M.I.T. National Magnet Laboratory have been concentrated on the construction of the magnet laboratory, research and development on high-field magnets, and the expansion of the solid-state research program using the existing 1.7 megawatt magnet facility. In addition there has been an increase in the cooperative programs with Lincoln Laboratory, M.I.T. faculty, and scientists from other laboratories.

The new National Magnet Laboratory building on Albany Street is nearly complete, and offices and auxiliary laboratories will be occupied during the summer of 1962. By late fall the eight megawatt motor generator power supply, the river water cooling system, and the first 250 kilogauss magnet should be ready for test. Full operation with ten or more magnets of various designs is scheduled for early 1963. The existing 1.7 megawatt magnet laboratory providing fields of about 100 kilogauss has been operated on a two- and three-shift schedule to accommodate as many experiments as possible.

Experimental and theoretical work on the Faraday and Voigt effects has provided new information on the electronic band structure of semiconductors. Studies of the optical properties of paramagnetic and antiferromagnetic materials in intense magnetic fields have led to new knowledge of their energy level schemes. A new technique for measuring the critical field of antiferromagnetic materials by observing the rate of change of susceptibility has been developed. This so-called "spin flop" experiment should prove useful in the study of a wide range of these materials. The Mössbauer effect is being used to study several problems in solid-state physics. A search for the Dirac magnetic monopole in magnetic ore bodies has been initiated using a portable pulsed magnet. In these and other experiments the usefulness and advantages of more intense fields are clearly demonstrated.

New research results have also been obtained by several outside groups using the intense fields available in the Laboratory. For example, the effective mass of the heavy hole in diamond was measured for the first time by a Lincoln Laboratory group. Another Lincoln Laboratory group has studied electron tunnelling in intense fields and has shown that this experiment can be used to elucidate the electronic band structure of semiconductors. A continuing joint program of Lincoln and N.M.L. on the magneto-optical properties of bismuth, graphite, and indium antimonide is contributing much to the knowledge of the band structure of these materials. A group from the Raytheon Research Laboratory has studied magnetoresistance in germanium and silicon in fields up to 90 kilogauss. A steady increase in such cooperative programs with outside groups is expected when the higher fields of the new laboratory are available.

A number of special-purpose magnets have been designed and built. A continuing program of magnet design and development is planned so as to provide the most useful magnets possible for the research program. It appears that intense-field, large-volume superconducting magnets will be more difficult to make than was thought a year ago. This conclusion arises from a theoretical and experimental study here which has revealed basic mechanisms which reduce the critical current in superconducting windings. A new 100-kilojoule capacitor bank has been built to drive pulsed magnets for a variety of experiments which require fields in the range of 100 to 1000 kilogauss.

In November 1961, the Laboratory was host to an International Conference on High Magnetic Fields, sponsored by the Air Force Office of Scientific Research. The world-wide interest in this research area is attested to by the attendance of about 800 persons. The proceedings were published in March, 1962, by the M.I.T. Press.

The total personnel at the academic year's end has increased to 44, including 21 staff members.

BENJAMIN LAX

Summer Session

The three principal components of the 1961 summer session consisted of a series of Special Summer Programs for professional men and women in industry and government, a limited number of regular academic subjects, and professional conferences or symposia.

The one- and two-week Special Summer Programs were again well supported, as shown by a total enrollment of 1,412 people in 26 Programs. The average registration per Program represented a decrease from the record enrollment in 1960, but the advance registration for 1962 indicates that this trend was only temporary. As before, programs which involved laboratory sessions, such as these conducted by Professors Nathan H. Cook, Richard C. Lord and William M. Murray, proved to be so popular that it was necessary to reject many well-qualified applicants. The total registration in a program is restricted either when laboratory facilities are limited or when it is desired to conduct the Program on a seminar basis. Also, in accepting applicants we attempt to insure that a prospective registrant has the background necessary to benefit fully from the Program.

It is of interest to note that the appeal of the summer series is indeed widespread. The 1961 programs were attended by representatives from over 300 industrial firms as well as from many governmental agencies and educational institutions. Through a grant from the Ford Foundation it was possible to offer special fellowship assistance to meet the expenses of engineering faculty from sister institutions.

The total registration for regular academic subjects has increased only slightly during the past five years, since we have maintained a policy of limiting this phase of summer instruction. Some second-term subjects are presented in the summer so as to assist undergraduates who have not been able to complete all of the required academic work during the regular year. In addition, subjects are offered in electrical and mechanical engineering and in aeronautics and astronautics for students in cooperative courses. Many graduate students who are working on theses remain in residence during the summer. This latter group comprised about two-thirds of the total enrollment of 1,668 students.

Throughout the summer the Institute was host for a number of professional conferences and symposia. The largest of these was the International Hypersonics Conference under the joint sponsorship of the American Rocket Society and M.I.T.

Every summer we present a series of events of an entertainment nature for the Summer Session registrants and staff. In 1961 there were three major productions in Kresge Auditorium which were received by large and enthusiastic audiences.

JAMES M. AUSTIN

Vice President

As has been our custom, we consolidate here the reports on three activities in which the line of responsibility for policy matters runs from the Corporation and the President through the Vice President. These groups, known as the Defense Laboratories, are the Operations Evaluation Group, the Instrumentation Laboratory, and the Lincoln Laboratory.

OPERATIONS EVALUATION GROUP

This year's report on the first of these, the O.E.G., can be very brief and will sound a somewhat nostalgic note. On the twentieth anniversary of the founding of this first organized effort in military operations analysis, managed by M.I.T. since 1945, we passed our responsibility to the Franklin Institute of Philadelphia. As recorded in these pages last year, we joined with the Navy in examining the possibilities of consolidating its operations research efforts in several fields, including naval plans and policy, which we and the Navy agreed went beyond the proper province of a university. At the conclusion of this survey, the Navy decided that the consolidation was desirable and practicable and chose the Franklin Institute as the central contractor. We were pleased to help in all possible ways in the change of command, as we had been pleased to serve during the years preceding. The change of management and the concurrent re-orientation of the work introduced problems for some of the professional staff, especially for those located in Cambridge, but in the end more than 80 per cent of the total made the transfer. Dr. Jacinto Steinhardt, who headed this activity for M.I.T. throughout our tenure with office in Washington, has accepted a professorship at Georgetown University and the post of Scientific Advisor to the President. He has gone with the best wishes and thanks of all concerned. The Navy and Franklin Institute have our assurance of continued assistance in the reconstituted endeavor as we may be called upon.

THE INSTRUMENTATION LABORATORY

The principal event of the year in the Instrumentation Laboratory was the undertaking of a major task in the Apollo Project of the National Aeronautics and Space Administration. The pioneering work of the Laboratory in the use of inertial techniques for the navigation of manned aircraft and the guidance of ballistic missiles, leading naturally into the realm of space, made it highly desirable from the points of view of both the government and the Laboratory that the Laboratory's services be made available to the N.A.S.A. program. At the request of N.A.S.A., therefore, and in accordance with a plan for absorbing the new work mainly by phasing out existing projects at suitable stages of completion, M.I.T. accepted the responsibility for designing the navigation system for the over-all Apollo spacecraft and supplying the necessary prototype equipment.

The program is organized to lead step-by-step from orbital flights of the earth to exploratory orbits of the moon, the landing of men from moon orbit, and their recovery and safe return to earth. The development of the navigation system will require not only further advances in inertial techniques for navigation but new investigations in many technical fields, including optics, data-processing, astrodynamics, human factors, and the geophysics of the earth and the moon. Because of the breadth of the required research and because the restrictions of security classification will be fewer than has necessarily been the case for comparable work in ballistic missiles, we expect to see a considerable expansion in the Laboratory's direct service to education. The Laboratory supported during the past year thesis research for 49 graduate students in four departments, including nine doctoral candidates. These numbers should rise substantially and the departmental coverage should expand.

Meanwhile, with control being exercised over the physical growth of the Laboratory, it is estimated that with an increase of $6.6

million in Apollo charges during the coming year, total Laboratory expenditures will rise by only about \$2 million. Moreover, we expect to exercise this restraint without denying the Laboratory's services to military programs in those places where its special talents are most valuable.

We are greatly assisted in our policy of size-control by N.A.S.A.'s willingness to accomplish the maximum of the related industrial work through the medium of direct contracts with companies chosen by N.A.S.A. We are thereby relieved of a great deal of management responsibility that might otherwise rest on us for funding and administering this work under sub-contract while still retaining technical control commensurate with our responsibility for the technical success of the prototype system. Associated industrial contractors include the AC Spark Plug Division of General Motors Corporation for the inertial measurement unit and associated electronics, Raytheon Manufacturing Company for the digital computer used in the system, and Kollsman Instrument Company for the telescope and sextant required.

Notable milestones were marked in military missile developments during the year. The guidance system for the advanced 2500-mile Polaris missile, designed and developed by the Laboratory, was successfully flight-tested in late 1961. Production is underway jointly by the General Electric and Raytheon Companies. The inertial measurement unit for the Titan missile developed at the Instrumentation Laboratory has now been tested and is in production by the AC Spark Plug Division. The Pace system as developed by the Laboratory, an accurate navigation and guidance system for a hypersonic glide type vehicle such as Dynasoar, is complete and is currently undergoing flight tests.

Under sponsorship of the Navy, an improved inertial navigation system for use in both submarines and surface vessels is being developed and will be tested at sea this year. Research is being carried on to determine the applicability of inertial guidance techniques to the development of an optimum all-weather flight control capability for vehicles taking off and landing vertically. Such a system would permit VTOL aircraft to land and take off under conditions that are essentially zero ceiling. Instrumentation is being prepared for flight test in a helicopter.

The continuing development of advanced inertial components under sponsorship of the Air Force, Navy, and N.A.S.A. has led to the design of several advanced units. It is anticipated that one or more such units will be put into production for advanced versions of current ballistic missiles.

THE LINCOLN LABORATORY

Two individual examples will serve to illustrate the general research programs that provide the foundation for all the Lincoln Laboratory's other projects: research on a new type of diode with remarkable promise for communication in the optical region of the electromagnetic spectrum where the potentially available bandwidths stagger the imagination of the microwave engineer; and development of a new digital computer (small, economical, and very versatile), the first general-purpose computer specifically designed for use as a laboratory instrument like an oscilloscope or a voltmeter.

In the new science of radar astronomy, in which Lincoln has played a pioneering role, significant accomplishments were made on a broad front with installations in Massachusetts, Texas, and California, at frequencies from 35 to 35,000 megacycles per second. Targets included the moon, the solar corona, Venus, and the free electrons in the earth's ionosphere.

The Millstone Hill radar, after more than four years of distinguished service, has been shut down for major modifications and improvements that will bring three more planets within its range. Only two years ago, we reported here with some satisfaction that Millstone had conducted more than 100 tracking operations on missile launches and satellites in a six-month period; this year, in an equal period and as an activity that was only incidental to Millstone's research functions, an Air Force team conducted some 3,700 tracking operations, with a record of 88 in a single seven-hour shift.

The first attempt to establish an orbital belt of small metal fibers (microwave dipoles) for the Project WEST FORD communications experiment was unsuccessful, but the cause has been ascertained and preparations are being made for a second attempt. Meanwhile, the ground terminal equipment developed for this experiment has been used for various purposes, including a detailed study of the radar reflectivity of the moon, the use of the moon as a reflector for high-capacity long-range radio relay communication, and the transcontinental transmission of a television picture by way of the Echo I balloon.

The technical development of a communication technique to convey messages to submerged Polaris submarines even under exceptionally adverse conditions was completed and its feasibility demonstrated at sea in a period of only ten months.

The successful performance of the worldwide communication and tracking network for Project Mercury, in the course of the first manned orbital flights, marked the close of Lincoln's participation in this project and a transition to the design of an integrated tracking-communication system for the follow-on Project Apollo.

The largest single subject area in Lincoln's applied research effort is that of the detection and discrimination of ballistic missiles, to which 40 percent of the staff and 50 per cent of the total budget are currently committed. This large ratio of funds to personnel reflects the administrative position of the Laboratory as scientific director of Project PRESS, a large field measurement program, which necessitates the supervision of substantial subcontracts for the procurement of equipment and operational services from industry. This work has necessitated an expansion of the Laboratory staff, the construction of a new 80,000-square-foot laboratory building in Lexington which was completed and occupied this year, and the establishment and operation of rather elaborate field measurement facilities in several locations, including Arbuckle Neck, Virginia, and Roi-Namur Island of Kwajalein Atoll in the Pacific Ocean. In the last location, we receive major assistance from the Radio Corporation of America.

The observance of Lincoln's tenth year of operation was marked by a special issue of *The Technology Review* which presented a comprehensive survey of the Laboratory's activities and its relationships within the greater M.I.T. community, and by eight Decennial Lectures by distinguished scientists and engineers from all over the world. The lectures were published as a commemorative contribution to the fields of advanced electronics which are the Laboratory's principal concern.

SOME COMMENTS ON FEDERAL FUNDS IN UNIVERSITY RESEARCH OPERATIONS

A certain amount of public interest centers from time to time on the flow of federal funds to universities, usually in terms of these amounts as fractions of total university budgets, occasionally in terms of the technical projects they represent which might otherwise have been performed by industry. Occasionally, it might be added, erroneous conclusions are drawn on one or both counts by failure to recognize the great differences among purposes for which these funds are transferred to the universities, or to note where the money goes upon receipt by them. The following data on M.I.T. during the fiscal year ending last June 30, may be of interest in making clear our particular situation.

As noted earlier, it is our policy that the costs of industrial firms involved in the government work of our major research centers shall to the maximum practical extent be covered by contracts directly between the government and the companies concerned. Even so, of the approximately \$66 million of federal funds expended in the operation of the Defense Laboratories here reported upon, half went directly into procurement of goods and services from industry.

Of the \$45.8 million of operating costs of the Institute proper, excluding the Defense Laboratories, \$21.5 million, or 47 per cent was supplied by Federal grants and contract reimbursements for academic research.

JAMES MC CORMACK

Vice President and Treasurer[1]

The Institute's financial affairs for 1961-62 are summarized in the following exhibit.

	1961-62	*1960-61*	*Change*
Educational and general activities	$31,033,000	$29,889,000	+$1,144,000
Sponsored research:			
General departmental and interdepartmental research	24,621,000	20,314,000	+ 4,307,000
Major laboratories, special departmental, and other research	66,472,000	56,996,000	+ 9,476,000
Total funds	134,875,000	122,657,000	+12,218,000
Plant assets	51,856,000	49,269,000	+ 2,587,000
Gifts and bequests	17,691,000	14,584,000	+ 3,107,000
Investments — market value	186,721,000	191,252,000	— 4,531,000
Investments — book value	132,719,000	121,706,000	+11,013,000

[1] The complete report of the Treasurer, including schedules supporting those printed on the following pages; the list of gifts, grants, and bequests received during the year 1961-62; and reports of the Technology Loan Fund, M.I.T. Pension Association, Supplementary Retirement Plan, and Retirement Plan for Employees is published separately and may be obtained on request from the Office of the Treasurer.

OPERATIONS

The operations of the Institute in 1961-62 and in 1960-61 are set out in the following exhibit.

	1961-62	*1960-61*
REVENUES AND FUNDS		
Tuition and other income	$ 9,246,000	$ 9,054,000
Endowment investment income	1,887,000	1,832,000
Gifts, investment income, and other receipts	6,957,000	8,270,000
Allowances for indirect expenses	10,847,000	8,802,000
Dining and student housing	2,096,000	1,931,000
Total	**$31,033,000**	**$29,889,000**
EXPENSES		
Academic departments	$11,876,000	$12,299,000
General and administration	12,648,000	10,915,000
Plant operations	4,413,000	4,744,000
Dining and student housing	2,096,000	1,931,000
Total	**$31,033,000**	**$29,889,000**

The decrease in gifts, investment income, and other receipts and in academic expenses in 1961-62 was largely due to a reclassification of grants included for the first time in sponsored research. For the fourth year the Faculty Salary Adjustment Fund was applied to teaching salaries, and the Industrial Liaison Program continues to contribute substantially to operating revenues.

In addition to endowment investment income as included in revenues and funds in the above table, income on other invested funds makes up an important part of gifts, investment income, and other receipts. Investment income of scholarship and fellowship funds is reflected in tuition revenues.

Contract allowances for indirect expenses increased to meet a part of the additional general and administration expenses and normal plant operating expenses accompanying the increase in direct sponsored research activity. Total plant operations were lower due to a reduction in special alteration and space change expenses. Direct departmental and interdepartmental sponsored research expenses increased from $15,687,000 to $19,440,000 in 1961-62, and the direct sponsored research expenses of the Lincoln Laboratory, Instrumentation

Laboratory, and Operations Evaluation Group increased from $49,-330,000 to $57,480,000.

Total operations of the Institute including all activities increased to $110,317,000 in 1961-62 from $97,449,000 in 1960-61. In 1956-57 total operations were $69,588,000, and in 1951-52 they were $32,518,000.

GIFTS

The gifts for 1961-62 are compared to 1960-61 in the following table.

	1961-62	1960-61
Gifts for endowment	$ 2,764,000	$ 1,308,000
Gifts for buildings	375,000	1,033,000
Gifts for current use — invested	9,595,000	7,372,000
Industrial Liaison Program	2,043,000	1,373,000
Other funds for current use	2,914,000	3,498,000
Total gifts	**$17,691,000**	**$14,584,000**

Gifts for faculty salaries in the humanities, for the Class of 1922 Endowed Professorship, for the improvement of engineering education, for the earth sciences, for basic research, for the women's residence, and for student aid made up a part of the gifts and bequests received by the Institute during the year for the Second Century Fund. Industrial grants continue as a major source of support for the Fund in 1961-62. Bequests were over $1,500,000 during the year.

The gifts directly to the Alumni Fund of $362,000 are included in gifts for current use–invested and made up a part of the total credited to the Alumni Fund. The list of gifts, grants and bequests to the Institute for the year 1961-62 in Section II of this report includes contributions credited to the Second Century Fund amounting to $13,175,000.

FUNDS

Endowment and other funds increased by $12,218,000 during 1961-62.

	1961-62	1960-61
Endowment for general purposes	$ 38,243,000	$ 37,793,000
Endowment for designated purposes	32,861,000	29,795,000
Total endowment funds	**$ 71,104,000**	**$ 67,588,000**
Other funds	63,771,000	55,069,000
Total funds	**$134,875,000**	**$122,657,000**

The increase in endowment funds for designated purposes largely represented greater capital resources for faculty salaries and undergraduate student aid. The very substantial increase in other funds from $55,069,000 to $63,771,000 was due primarily to additions received during the year for future educational plant and operating expenses. On June 30, 1962, investment income set aside for 1962-63 was $5,250,-000, and unallocated investment income was $2,880,000. The general investments gain and loss account on the same date was $7,923,000. Including retirement funds, the total book value of the funds on June 30, 1962, was $163,422,000.

INVESTMENTS

The investments of the Institute on June 30, 1962, and June 30, 1961, are presented in the following table, which is exclusive of the investments of the M.I.T. Pension Association, the Supplementary Retirement Plans, and the Retirement Plan for Employees.

	June 30, 1962		*June 30, 1961*	
	Book Value	*Market Value*	*Book Value*	*Market Value*
General investments:				
Bonds	$ 62,528,000	$ 61,869,000	$ 63,162,000	$ 62,032,000
Stocks	34,241,000	86,070,000	30,348,000	97,601,000
Real estate	13,505,000	13,505,000	11,747,000	11,747,000
Commercial paper	1,482,000	1,482,000	2,948,000	2,948,000
Special interest bank accounts	6,056,000	6,056,000	—	—
Total	**$117,812,000**	**$168,982,000**	**$108,205,000**	**$174,328,000**
Special investments	10,995,000	13,828,000	9,996,000	13,419,000
Student notes receivable	3,912,000	3,912,000	3,505,000	3,505,000
Total	**$132,719,000**	**$186,721,000**	**$121,706,000**	**$191,252,000**

Funds sharing in the income from the general investments earned 6.44 per cent on the average book value compared to 6.29 per cent last year. Five per cent was allocated to funds in 1961-62. The total income on the general and special investments in 1961-62 was $6,581,-000, compared to $5,957,000 in 1960-61. Of the total investment income of the year, $1,887,000 was used directly for current expenses; $1,378-000 was added to balances of expendable funds which in turn were used for current operating expenses to the extent of $2,878,000; and $756,000 was added to funds for scholarships, loans, and buildings. Investment income was also added to endowment principal, and investment income was accumulated as in former years.

The proportion of the general investments in bonds at market value was 35.6 per cent on June 30, 1961, and 36.6 per cent on June 30, 1962. The proportion of investment income from bonds decreased from 42.1 per cent to 41.7 per cent. At market values, the proportion of the general investments in common stocks decreased from 55.7 per cent on June 30, 1961, to 50.4 per cent on June 30, 1962. Investment income represented by dividends on common stocks increased from 47.1 per cent in 1960-61 to 47.9 per cent in 1961-62.

The investments of the M.I.T. Pension Association, the Supplementary Retirement Plans, and the Retirement Plan for Employees on June 30, 1962, and June 30, 1961, are presented in the following exhibit.

	June 30, 1962		*June 30, 1961*	
	Book Value	*Market Value*	*Book Value*	*Market Value*
Pension Association	$15,752,000	$20,082,000	$13,260,000	$18,994,000
Supplementary Retirement Plan — Fixed Benefit	8,030,000	8,628,000	6,687,000	7,546,000
Supplementary Retirement Plan — Variable Benefit	574,000	532,000	—	—
Retirement Plan for Employees	4,023,000	4,129,000	2,667,000	2,853,000
Total	**$28,379,000**	**$33,371,000**	**$22,614,000**	**$29,393,000**

PLANT FACILITIES

As pointed out last year, a growing part of the plant assets of the Institute includes plant being financed on a long-term basis from future sources of income and contributions, as shown on the balance sheet of the Institute on June 30, 1962. During the year the educational plant increased from $49,269,000 to $51,856,000, attributable to work in progress on construction and additions to plant to be amortized from current revenues. To accommodate the sponsored research program, additional space was leased during the year.

Vice President and Treasurer

GENERAL

An important development during the year was the addition of real estate investments that ultimately will become a part of the educational plant, The Atomic Energy Commission, through the General Services Administration, made available for Institute use the Hood Building property located on Massachusetts Avenue.

JOSEPH J. SNYDER

AUDITOR'S CERTIFICATE

To the Auditing Committee of the
Massachusetts Institute of Technology:

We have examined the financial statements of Massachusetts Institute of Technology:

Schedule A—Balance Sheet as at June 30, 1962.

Schedule B—Sources of Revenues and Funds Used to Meet Expenses of Current Operation for the Year Ended June 30, 1962.

Schedule C—Statement of Funds for the Year Ended June 30, 1962.

Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances. We used auditing procedures other than direct confirmation to establish the validity of certain U.S. Government receivables.

In our opinion, said statements present fairly the financial position of Massachusetts Institute of Technology at June 30, 1962, and the results of its operations for the year then ended, on a basis consistent with that of the preceding year.

LYBRAND, ROSS BROS. & MONTGOMERY

Boston, Massachusetts, September 7, 1962

REPORT OF THE AUDITING COMMITTEE

To the Corporation of the Massachusetts Institute of Technology:

The Auditing Committee reports that Lybrand, Ross Bros. & Montgomery were engaged to make an audit of the books and accounts of the Institute for the fiscal year ended June 30, 1962, and their certificate is submitted herewith.

Respectfully,

THEODORE V. HOUSER
WILLIAM WEBSTER
GILBERT M. RODDY, *Chairman*

BALANCE SHEET June 30, 1962

Schedule A

INVESTMENTS

General investments:			
U. S. Government bonds		$ 24,618,900	
Other bonds		37,908,972	
Preferred stocks		897,419	
Common stocks		33,343,581	
Real estate (including $4,988,444 devoted to Institute use) and mortgages		13,505,274	
Commercial paper		1,481,708	
Special interest bank accounts		6,056,299	
	(A-1)		$117,812,153
Investments of funds separately invested	(A-2)		10,995,168
Students' notes receivable	(A-13)		3,911,905
Total investments			$132,719,226
Less temporary investment of general-purpose cash			1,217,629
			$131,501,597

CURRENT AND DEFERRED ASSETS

Cash:			
General purposes		$ 3,078,479	
Restricted to certain contracts		249,146	
Students' safe-keeping deposits		65,783	$ 3,393,408
Temporary investment of general-purpose cash			1,217,629
Accounts receivable:			
U. S. Government	(A-14)	$ 5,161,785	
Other	(A-14)	1,008,949	6,170,734
Contracts in progress, principally U. S. Government	(A-15)		13,981,770
Deferred charges and other assets	(A-16)		3,299,119
Advance for purchase of educational buildings			713,102
			$ 28,775,762

EDUCATIONAL PLANT

Land, buildings, and equipment	(A-20)	**$ 51,855,773**
		$212,133,132

BALANCE SHEET June 30, 1962

Schedule A

INVESTED FUNDS			
Endowment funds:			
Income for general purposes	(A-3)	$ 38,242,796	
Income for designated purposes	(A-4)	32,860,781	$ 71,103,577
Student loan funds	(A-5)		5,197,751
Building funds	(A-6)		1,946,706
Other expendable funds:			
General purposes	(A-7)	$ 7,716,160	
Designated purposes	(A-8)	24,548,848	32,265,008
Unexpended endowment income for designated purposes	(A-4)		2,008,399
Agency and annuity funds	(A-9 and A-10)		2,927,139
General investments — gain and loss account	(A-11)		7,922,733
Investment income authorized for distribution to funds	(A-12)		5,250,000
Unallocated investment income	(A-12)		2,880,284
			$131,501,597
CURRENT LIABILITIES AND FUNDS			
Accounts payable		$ 3,268,578	
Accrued wages and vacation allowances		1,686,367	
Withholdings, deposits, and other credits	(A-17)	1,628,338	
Students' advance fees and deposits	(A-18)	444,618	
Students' safe-keeping deposits		65,783	
Advances by the U. S. Government for certain research contracts		15,106,348	
Total current liabilities			$ 22,200,032
Contingent liability, $650,000: the Institute, a participant in a Cambridge real estate development trust, has deposited $1,000,000 in U. S. bonds as collateral securing payment of note obligations by the trust.			
Grants for sponsored research			3,202,180
Gifts and other receipts for current expenses	(A-19)		3,373,550
			$ 28,775,762
EDUCATIONAL PLANT CAPITAL			
Notes payable to banks			$ 1,140,000
Dining facilities bonds, 3⅛% due 1962-1999 ($655,000 U. S. bonds are in escrow as collateral)			400,000
Advanced from general purpose cash			713,102
Endowment for educational plant	(A-21)		49,602,671
			$ 51,855,773
			$212,133,132

STATEMENT OF FUNDS for the year ended June 30, 1962

Schedule C

		Balance June 30, 1961
Endowment funds:		
Income for general purposes	(A-3)	$37,792,955
Income for designated purposes	(A-4)	29,795,036
Student loan funds	(A-5)	4,705,601
Building funds	(A-6)	1,672,868
Other expendable funds:		
General purposes	(A-7)	2,382,068
Designated purposes	(A-8)	23,959,286
Unexpended endowment income for designated purposes	(A-4)	1,756,607
Agency and annuity funds	(A-9, A-10)	2,853,860
General investments — gain and loss account	(A-11)	7,740,701
Investment income authorized for distribution to funds	(A-12)	4,750,000
Unallocated investment income	(A-12)	2,023,380
Total invested funds		**$119,432,362**
Gifts and other receipts for current expenses	(A-19)	3,224,449
		$122,656,811

Gifts received during the year

Receipts from foundations and agencies for student aid

Net realized gain on investments

Appropriations from research contract allowances

Fees, services, and other receipts

Endowment investment income used to meet expenses of current operations

Gifts, investment income, and other receipts used to meet expenses of current operations

Scholarship and fellowship awards

Expenditures for buildings added to educational plant

Direct research costs charged to gifts designated therefor

Deferred equipment — Cooperative Computer

Expenditures of service activities and other charges to funds not representing operating

* Investment income on endowment funds for designated purposes is included under the caption "Unexpended endowment income for designated purposes."

Gifts and Other Receipts	Investment Income	Transfers In-(Out)	Expenses	Other Charges	Balance June 30, 1962
$ 22,052	$1,891,686	$(200,994)	$1,262,903	....	$38,242,796
2,742,565	*	362,313	....	$ 39,133	32,860,781
434,026	72,554	11,917	23,847	2,500	5,197,751
377,339	81,453	533,749	11,855	706,848	1,946,706
5,418,062	173,897	423,168	681,035	....	7,716,160
5,031,123	1,203,970	(311,038)	2,197,015	3,137,478	24,548,848
31,854	1,660,111	(250,182)	624,151	565,840	2,008,399
221,405	140,654	(153,970)	10,150	124,660	2,927,139
182,032	....	....	....	....	7,922,733
....	(4,668,749)	5,168,749	....	....	5,250,000
....	6,025,653	(5,168,749)	....	....	2,880,284
$14,460,458	**$6,581,229**	**$414,963**	**$4,810,956**	**$4,576,459**	**$131,501,597**
7,058,964	....	(414,963)	4,032,870	2,462,030	3,373,550
$21,519,422	**$6,581,229**	....	**$8,843,826**	**$7,038,489**	**$134,875,147**

$17,691,280
672,133
36,870
962,659
2,156,480
$21,519,422

....	$ 1,887,054
....	6,956,772
	$ 8,843,826

....	$1,988,037
....	2,383,791
....	662,187
....	644,513
expenses....................................	1,359,961
	$7,038,489

SOURCES OF REVENUES AND FUNDS USED TO MEET EXPENSES OF CURRENT OPERATION
for the year ended June 30, 1962

Schedule B

EDUCATIONAL AND GENERAL

Sources of revenues and funds used

Tuition and other income	(B-1)	$ 9,246,140
Endowment investment income	(B-2)	1,887,054
Gifts, investment income, and other receipts	(B-2)	6,956,772
Contract allowances for general and administration expenses and plant operation expenses (see below)	(B-3)	10,846,859
Dining and student housing	(B-7)	2,095,856
		$31,032,681

Expenses of current operation

Academic departments	(B-4)	$11,876,465
General and administration	(B-5)	12,647,641
Plant operation	(B-6)	4,412,719
Dining and student housing	(B-7)	2,095,856
		$31,032,681

SPONSORED RESEARCH

Revenues

General departmental and interdepartmental research		$24,621,286
Major laboratories and special departmental research:		
Lincoln Laboratory		40,685,720
Instrumentation Laboratory		23,067,458
Other research:		
Operations Evaluation Group		2,719,260
	(B-3)	**$91,093,724**

Expenses

Salaries and wages	(B-3)	$37,311,800
Materials and services	(B-3)	30,801,077
Subcontracts	(B-3)	8,807,267
Research administration and general expenses	(B-3)	2,364,050
Allowances for general and administration expenses and plant operation expenses	(B-3)	10,846,859
Allowance for use of facilities and other reserves	(B-3)	962,671
		$91,093,724

Vice President, Operations and Personnel

The area of responsibility of the Office of the Vice President, Operations and Personnel includes the provision of staff support in all non-teaching personnel activities; the planning, construction, maintenance, and operations of the physical facilities of the Institute; the operations and development of the housing and dining activities on the campus; and the operations of certain administrative services to the Institute community. As the Institute has continued to expand, particularly with the impetus of the Second Century Fund objectives, the various officers directly charged with these activities have experienced a busy and interesting year.

PERSONNEL

This past year saw a continued increase in personnel at the Institute with total employment, exclusive of faculty and academic staff, reaching a figure of 5,930 on June 30, 1962, an increase of 420 or approximately 7 per cent since the previous June 30. All areas of the Institute shared in this growth.

Turnover rates among all groups of employees continued at a satisfactory level. The Institute's wage and salary structure enabled it to attract sufficient competent people to fulfill its expanding needs, although professional research staff and office clerical employees continue to be in short supply.

This was the second year of two-year agreements with the various unions which represent a total of about 2,000 hourly employees at the Institute. At the end of the year agreement had been reached on the terms of a new two-year contract with the Building Service Employees Union, which represents maintenance employees under separate contracts in Cambridge and at Lincoln Laboratory. Agreement was reached a few days later with the Independent Union of Plant Protection Employees, which represents security guards at the Lincoln Laboratory. The contract with the Cooks and Pastry Cooks Union, which represents dining service employees, was extended through the summer, with a new contract to be negotiated in the fall. No agreement was reached by June 30 with the M.I.T.'s Employees' Union, which represents laboratory service employees throughout the Institute. A work stoppage by this union occurred on July 1, but a contract was agreed to on July 24, and the membership returned to work on July 25, 1962.

CONSTRUCTION ACTIVITIES

This year has seen the first phase of the largest and most concentrated period of construction in M.I.T.'s history since its move to Cambridge in 1916. A brief description of the major elements of this activity are found in the President's report to the Corporation. In addition to these, there have been important interior space renovations which have contributed greatly to the teaching and research programs. The planning and execution of this physical growth is an involved and painstaking process and commands the attention and selfless efforts of many people representing all elements of the Institute community.

PLANNING

The Planning Office has been deeply involved this year in the evolution of the detailed plans for the construction now underway. In addition, other projects are now under preliminary planning and will require major attention during the next year.

As part of our long-range planning effort, the Planning Office, with the guidance of the Long Range Planning Committee, has articulated more precisely the general concepts for the development of the Institute's academic expansion in both the North and East Campuses. It has worked on the concept of a Graduate Center for M.I.T. and its locational requirements, reviewed and discussed questions relating to the need for additional housing resources to serve the Institute community, and prepared planning studies and location alternatives for proposed academic facilities in a manner consistent with M.I.T.'s fundamental planning objectives.

In the realm of community liaison, the Planning Office has worked closely with the planning and redevelopment agencies of both Cambridge and Boston on problems relating to zoning, traffic and circulation, neighborhood improvement, student housing, and recreation facilities.

PLANT OPERATIONS

In addition to the normal activities of maintaining and servicing the Institute's physical facilities, considerable time has been spent over the past months in preparation and planning for the operations of the physical plant as it continues to grow more complex in its activities and requirements and as it will increase in size upon completion of the major facilities now under construction and planning. Increased requirements for power and other services, especially in our laboratories, call for expansion and replacement of our utility distribution systems and power plant capacities. The accounting and cost procedures involved in the maintenance and service operations are also undergoing substantial revision and modernization.

The upgrading of older Institute buildings to meet modern standards of fire prevention accounts for the largest portion of the safety budget. The Office of the Safety Engineer is continuing its work with fraternities and other off-campus student groups. Consultation and inspection of living facilities is available upon request, and information is given to assist these groups in the elimination of unsafe conditions and fire hazards.

STUDENT SERVICES

Housing. Continued improvements to the residence houses have been made this year; this extends the program of the past several years, which began with the renovation and refurnishing of the East Campus Houses and the Senior House during the period 1958-1960. Extensive renovations this year in the Burton-Conner dormitories were financed through the Alumni Fund and yielded a greatly improved ground floor area as well as improved shower and toilet facilities, student government offices, a house library, and a relocated and redecorated Troost Lounge. In Baker House, a new house library and a seminar-meeting room were constructed. The main entry and desk areas of the East Campus dormitories were remodeled and modernized, and at the Senior House initial steps were taken to provide a House meeting room and recreational and lounge areas.

Dining. A major step in the expansion of Institute dining facilities was taken last fall with the opening of the Burton House Dining Room. This facility provides dining service to the 560 residents of the Burton-Conner dormitories and in addition is utilized for study and social purposes. The Macomber and Fabyan Memorial Rooms in the Graduate House were redecorated and refurnished and again provide first-rate meeting and dining accommodations.

ADMINISTRATIVE SERVICES

The consolidation and reorganization of the Graphic Arts Service in the building at 211 Massachusetts Avenue continued during the past year. The Letter Shop, which provides addressing, typing, and mimeograph service has now been fully integrated into this operation, which has traditionally rendered excellent photographic and printing services. In addition, the Graphic Arts Service has assumed responsibility for central bulk mailing services for the Institute community; during the first six months of its operation, this group processed over a million pieces of mail.

The Audio-Visual Service is working with members of the faculty on new and improved audio-visual aids to teaching. The advent of new buildings and programs is calling for expanded services in this area.

The growth of the Institute, current and projected, has made significant demands on the Institute's telephone system. It was necessary this year to add a new switchboard to our facilities and to acquire more space for necessary telephone equipment. The completion in the near future of the new facilities now under construction will require still further modification and enlargement.

PHILIP A. STODDARD

Other Administrative Officers

School for Advanced Study

The School for Advanced Study comprises the Institute Professors, the Sloan Foreign Postdoctoral Fellows, and a number of other Fellows nominated by members of the M.I.T. faculty.

Out of approximately 25 nominations received from faculty members, 10 scholars were invited to M.I.T. for the 1961-62 academic year as Sloan Foreign Postdoctoral Fellows. These Fellows came from eight countries: Chile, France, India, Israel, Italy, Poland, Sierra Leone, and the United Kingdom; during their residence here they worked in the Departments of Architecture, Biology, Chemistry, Geology and Geophysics, Mechanical Engineering, and Physics. Five of these scholars will return to their own countries at the end of the year, while five will remain to do further work at M.I.T.

The faculty nominated 38 other persons as Fellows of the School for Advanced Study for the academic year 1961-62. Most of these held postdoctoral fellowships, while some were professors on sabbatical leave from their own universities. Nine of these Fellows came from the United States, ten from Japan, and the rest from Austria, Belgium, Brazil, Canada, Chile, Germany, India, New Zealand, Poland, United Arab Republic, United Kingdom, and Yugoslavia. They worked in the fields of biology, chemistry, chemical engineering, crystallography, electrical engineering, food technology, geology and geophysics, humanities, industrial management, international studies, mathematics, mechanical engineering, metallurgy, meteorology, nuclear engineering, and physics.

Other Administrative Officers

Monthly dinner meetings were again held during the academic year. These meetings had been most popular with the Fellows during previous years, and the attendance was once again very good. At each meeting there was an after-dinner speaker, chosen to represent advances of scholarship along new and fruitful directions. The speakers and their subjects were: Professor William von Arx from the Woods Hole Oceanographic Institute on "The Levels of Sea Level at Sea"; Professor Dayton E. Carritt of the Department of Geology and Geophysics and Woods Hole Oceanographic Institute on "The Adventures of a Web-Footed Chemist"; Professor Roman Jakobson, Institute Professor at M.I.T. and Samuel Hazard Cross Professor of Slavic Languages at Harvard University, on "The Problem of Invariance and Variables in the Science of Language"; Professor Francis Bitter of the Department of Geology and Geophysics on "Discoveries with Magnets"; and Professor Cyril S. Smith, Institute Professor, on "Artistic Metalwork and the Science of Metals."

During the latter part of the academic year, the Director spent three months aiding the Institute of Physics and Mathematics of the University of Chile in organizing a research program in x-ray crystallography. Professor Antoine M. Gaudin of the Department of Mettallurgy was appointed Acting Director for that time.

MARTIN J. BUERGER

Department of Air Science

During the school year the new Air Science subjects— Principles and Techniques of Leadership (AS41), Global Geography (AS42), U.S. Air Force Weapons Systems (AS21), and Aerospace Research Vehicles and Systems (AS22)—were implemented, hereby completing the transition to the "new" program. They were enthusiastically received by the students and were considered to be extremely successful by the faculty. Students were required to criticize the new courses, and their comments were generally favorable with minor constructive criticism that will enable us to improve our program during the ensuing years.

The Air Science 41 program entailed three major phases: communicating and instructing; management, leadership principles and techniques; and human relations and managerial psychology. The Air Science 42 program is primarily global geography, with emphasis on student term papers and oral reports. The Air Science 21 and 22 subjects consisted of a series of motivational lectures, largely given by engineering and technical officers from the Electronics Systems Division and Cambridge Research Laboratories at L. G. Hanscom Field.

DEPARTMENT OBJECTIVES

The Department objectives for the year were to increase the academic content of all credit subjects offered. Increased emphasis was placed on the development of leadership abilities, to augment the qualifications of our graduates. Numerous individual student interviews were conducted by all of the officers assigned to the Department.

The subjects entitled Evolution of Warfare, Foundations of Air Power, Research and Development in the U.S. Air Force, and Preparations for Command and Staff Positions (all inaugurated in 1960-61), were refined and the academic content was further enriched.

It is extremely gratifying to report that we increased our freshman enrollment from 26 during the preceding year to 52 this academic year. These freshmen successfully passed the Air Force general service physical examination, and there is every reason to believe most of these men will ultimately be commissioned in the Air Force.

CADET ACTIVITIES

In order to increase the *esprit de corps* among our students and to familiarize them with some of the Air Force's activities, we sponsored visits to Wright-Patterson Air Force Base, Otis Air Force Base, and L. G. Hanscom Field. Most of our students were given voluntary orientation flights in military aircraft. We reactivated a rifle team which placed in the middle of the New England area competition this year, and which we believe will be the nucleus of an excellent rifle team for the future.

On Military Day, seventeen Air Science cadets received awards for outstanding academic and leadership performance. President Julius A. Stratton headed the reviewing party of distinguished dignitaries who presented the awards.

M.I.T. AIR SCIENCE GRADUATES

Ten students finished the academic phase of their Air Force training. Two were designated Distinguished Air Force R.O.T.C. Graduates and have indicated they will accept regular Air Force commissions upon reporting to active duty. One of the graduates was designated a Distinguished Air Force R.O.T.C. Student. Three graduates have been accepted for flying training. Six graduates have been granted educational delays to accept graduate fellowships. Other graduates received active duty assignments compatible with their academic degrees.

JACK D. ALEXANDER

Department of Military Science

The partial mobilization of our country's reserves, ordered by the President in July, 1961, did not create the expected greater student interest in the Army R.O.T.C. program, although there was a greater over-all interest in the R.O.T.C. program as evidenced by larger enrollments in the other services. Registration in the Army's basic course fell slightly for the fourth consecutive year since the program became voluntary in 1958.

	1960-61		*1961-62*	
	Beginning of year	*End of year*	*Beginning of year*	*End of year*
Basic Course				
Freshman	68	52	55	38
Sophomores	52	39	44	35
Advanced Course				
Juniors	25	25	28	28
Seniors	64	61	26	27
Total	**209**	**177**	**153**	**128**

Reserve commissions were granted as follows: five in the Corps of Engineers, seven in the Signal Corps, eight in the Ordnance Corps, two in the Chemical Corps, and one in the Quartermaster Corps. One regular commission was awarded in the Ordnance Corps. This was a substantial drop from the 71 commissioned in 1960-61, who were the last entries in the R.O.T.C. program under the required plan.

Our graduates continued the excellent record of M.I.T. at the orientation courses at the service schools to which they all are assigned as their initial duty. Of a total of 88 M.I.T. graduates who completed such courses at six different Army service schools between June, 1961, and June, 1962, 71 per cent ended in the upper third of their classes.

Obtaining an Army R.O.T.C. curriculum that is more acceptable to M.I.T. still remains a problem. The proposed new R.O.T.C. legislation which we anticipated implementing by September, 1962, still has not yet been presented to Congress. Therefore, the anticipated implementation of a new curriculum by September, 1962, or 1963 at the latest, is again postponed. The lack of firm data on the new program makes it impractical for a new curriculum to be processed through the faculty now, for it is unlikely that the Army would authorize any major changes in our curriculum before the proposed legislation is formalized. This means the continuation for another year of a program which is not entirely satisfactory to the students or the faculty.

Student activities were revitalized and expanded with major activities being: a very successful Military Ball, sponsored by the cadets of all three R.O.T.C. programs, held in February; visits by engineer cadets and others to witness Corps of Engineers planning and operations at Fort Devens, New York Harbor, and Fort Belvoir, Virginia; visits by Ordnance cadets to the Springfield Arsenal for a general orientation in Ordnance Corps manufacturing; and increased participation in Pershing Rifle activities, including the New England Regional Drill Meet of the 12th Pershing Rifle Regiment, in which our company was named the "most improved" company.

IRVING W. FINBERG

Department of Naval Science

One of the most encouraging aspects of this academic year has been the sharp increase in our freshman class enrollment—from 29 last year to 48. Thus we look forward to the Class of 1965 becoming the first to meet our goal of 25 graduates that the Navy would like to commission each year from the M.I.T. program. Seventeen seniors were commissioned this year, fourteen in ceremonies at Kresge Auditorium and and three more aboard ship after completing summer cruise requirements.

In addition to the 17 seniors, the N.R.O.T.C. program at the end of the academic year included 23 juniors, 20 sophomores, and 35 freshmen, a total of 95 undergraduates. This unit also administered 73 postgraduate officers of the U.S. Navy, U.S. Coast Guard, U.S. Marine

Corps, and three foreign countries, plus 13 Naval Enlisted Scientific Education Program (NESEP) undergraduates. Five members of this last group were graduated, representing the first graduates from this special Navy program at M.I.T. One member of the group received a Master's degree under the combined Bachelor's/Master's Honors Program. Including the eight members of the staff, our total strength was 201 persons.

Again this year as in the past many of the newly commissioned ensigns from the N.R.O.T.C. program have requested and been granted deferment from active duty in order to complete postgraduate education. This year eight ensigns received deferments, which is an indication of the importance attached to this training by the Navy and an indication of the quality of the M.I.T. students completing the curriculum. Most of these deferments will be for Master's degrees, although a limited number of the more highly qualified of this group will receive further deferment to complete Doctoral degrees. By far the largest majority of these men are continuing their studies at M.I.T.

An important change in the curriculum, making Introduction to Psychology (14.70) a requirement for all N.R.O.T.C. students as one of their M.I.T. electives, was approved during the year by the M.I.T. faculty and the Navy to become effective with the Class of 1965. This will obviate the need for special instruction in psychology in Naval Industrial Management and Leadership, as is now the practice.

In other events during the year, I relieved Captain George L. Street as Commanding Officer and Professor of Naval Science. Congress approved legislation which extended the active duty requirement of our N.R.O.T.C. graduates from two to three years; this change may affect the incoming freshman class and subsequent classes.

LEWIS E. LARSON, JR.

Secretary of the Institute

The principal development effort during the past year has been focused on the Second Century Program. Members of the Corporation continued to lend their support in many ways. Their identification and appraisal of prospects, their guidance in presenting the Program, and, in some instances, their active participation in solicitation all contributed to substantial grants. All of this was in addition to their own most generous financial support of the Program. Personally, and through their foundations, members of the Corporation have given $15.7 million. This is reported on good authority to be the largest amount given by any board of trustees in any of the major university campaigns in recent years.

But the contributions made by members of the Corporation were not confined to development activities. Through standing and visiting committees, and individually in other ways, they counseled on the educational, research, and fiscal problems. They met fully the requisite composition of what has been defined as an ideal board of trustees: doers, thinkers, and givers. M.I.T. is indeed fortunate in having members who can be put in all three categories.

As a matter of record the Corporation met formally in the four regular quarterly sessions. In one action of note, the Corporation authorized the degree of Doctor of Philosophy in Psychology. More time has been given at the meetings this year to oral visiting committee reports. Perhaps as a corollary, there has been some discussion of how the present visiting committee procedures might be made more effective, even though the present system works well. In fact, inquiries come regularly from other institutions about the M.I.T. system; these stem from complimentary comments about our visiting committees by alumni and presidential appointees as well as by Corporation members. Ways of improving the system will be actively explored in the coming months.

Cecil H. Green, Horace W. McCurdy, and John J. Wilson were elected to life membership. Horace S. Ford, Alfred L. Loomis, Ralph Lowell, and Harold B. Richmond requested emeritus status.

ROBERT M. KIMBALL

Development Office

The Development Office has again this year been completely immersed in a great capital campaign—M.I.T.'s Second Century Fund.

The year has seen significant achievements, with $59,079,622 having been reached in gifts or pledges against our $66 million goal. In addition, other money has been given as the result of S.C.F. solicitation but not for objectives of the Program.

Some further statistics: of the money given or pledged for objectives of the Program, alumni account for $18,375,905; corporations, $15,878,155; foundations, $18,196,386; and non-alumni, $3,714-914. In addition, $2,909,105 has been received from bequests. Other miscellaneous gifts from clubs and associations bring the total to that given above.

It is particularly gratifying to see that the business world appreciates what M.I.T. is doing and has played such a significant part in its Program.

In a sense it is unfortunate that we have to write of success in terms of dollars, since they are just a way of keeping score. What are really significant and much more to the point are the various parts of our Program which are now either under way or assured of accomplishment. For example, three great centers for graduate study and research are either being built or are in the advanced planning stages. They are the Centers for Earth Sciences, Materials Science and Engineering, and Life Sciences. No limits can be placed on the contributions which will some day be made to humanity through the students trained in these centers and the discoveries made there. Those who have helped establish these centers have indeed planted seeds of untold importance to this country and the world.

Funds have been provided for student aid, for endowed professorships, for improving and advancing our undergraduate education, and for supporting basic research.

During the year, Mrs. Stanley McCormick was announced as the donor of more than $2 million for our new women's residence, already well under construction.

This year marked the completion of the Area Campaign in which the bulk of our alumni played a significant part in the S.C.F. John J. Wilson '29, General Chairman, announced on Alumni Day that under the leadership of Philip Peters '37, Gregory Smith '30, and Joseph Harrington, Jr. '30, $8,250,000 had been raised. Credit is especially due to Donald P. Severance, who provided dedicated staff direction for the Area Campaign; he was aided by the hard work of D. Hugh Darden and Douglas F. G. Haven. All three were indefatigable in the difficult and demanding experience of keeping a large general solicitation moving to its completion.

By the end of the fiscal year, the field offices established in Boston, New York, Philadelphia, Cleveland, Chicago, Dallas, San Francisco, and Los Angeles had been closed, the District Directors discharged, their staffs disbanded, and the furniture disposed of. Space limitations preclude my paying individual tribute to each of our District Directors for the help he gave the Program. Collectively they were a vital element in the Area Campaign.

A comment or two about the costs of the campaign may be of interest. According to a study by a well-known firm of the capital campaigns of twenty-one educational institutions selected at random, the average cost was 5.3 per cent of the total amount obtained. As of the end of our fiscal year, our cost is comfortably under 3 per cent of the money actually raised.

Finally, I must again pay tribute to the 11,587 donors and the 4,650 alumni volunteers who together helped insure that their school was given many of the tools required to maintain its position of leadership as it begins its second century of service.

Much remains to be done. Although it would seem from the figures given above that some $7 million still must be raised, the actual total is even higher because certain objectives have been oversubscribed. During the balance of the year, the Development Office will be working hard with members of the Institute family to complete the job.

JOHN W. SHEETZ, III

Office of Public Relations

Special effort was made during the past year to give greater attention to the interpretation of the expanding educational and research activities of the Institute. At the request of the Industrial Liaison Program, publication was resumed of a bulletin on research, *M.I.T. Reports on Research,* edited by William T. Struble, intended primarily for distribution among industrial executives.

Our educational television program, The M.I.T. Science Reporter, was greatly improved; John T. Fitch of the Class of 1952, served as host during much of the year. Enthusiastic acceptance in other cities increased prospects for its distribution by the National Educational Television Network.

One or more publications of the Office of Publications were selected by juries for regional and national exhibits—the Art Directors Club of Boston, Design and Printing for Commerce of the American Institute of Graphic Arts, Creativity on Paper, and the Type Directors'

Club of New York. Special citations were awarded by the American College Public Relations Association for a number of publications and for the total 1961-62 program of publications. Walter Plata, German designer who was a visiting faculty member of the Rhode Island School of Design during the year, was associated with the Office of Publications for several months.

FRANCIS E. WYLIE

Alumni Association

From the start of the Alumni Fund in 1940 up to June 30, 1962, total alumni benefactions to M.I.T. amounted to $46,339,910, of which sum $5,966,037 represented contributions received directly through the Fund. For the past two years the Alumni Fund has conducted no personal solicitation because of the Second Century Fund. Nevertheless, for the year 1960-61, $575,596 was received through the Fund from 12,254 contributors; and for 1961-62, $414,473 from 10,639 contributors.

During 1961-62 no change took place in the roster of 94 M.I.T. clubs, headed by those founded at Chicago in 1887 and at Denver in 1891. Notable decennial anniversaries of M.I.T. clubs occurring during 1961 included: the sixtieth of Cincinnati; the fiftieth of Worcester, St. Louis, Minneapolis, Tokyo, Manchester, and Schenectady; the thirtieth of Toledo; the twentieth of Buenos Aires; and the tenth of Brussels, and San Juan.

In the twelve months ended April 30 last, 87 members of the Institute staff and Alumni Council attended meetings of 66 different M.I.T. clubs.

Included in the notable alumni gatherings during 1961-62 was the National M.I.T. Alumni Night held Thursday, October 19. On this occasion over 3,300 alumni and friends attended simultaneous M.I.T. club meetings in 45 cities, at which 42 members of the M.I.T. faculty and staff were present as speakers. These meetings, which were organized on behalf of the Second Century Fund, included a half-hour closed circuit telephone broadcast from Cambridge entitled "The Voice of Technology."

A census of our membership rolls taken last March 31 showed a total of 67,338 names, 52,130 or 77.4 per cent being carried in living status and 15,208 or 22.6 per cent as deceased.

Four per cent of the living alumni—that is, a total of 2,119—were 50 or more years out of the Institute; 23 per cent were 31 to 50 years out; 42 per cent were 11 to 30 years out; and the remaining 31 per cent were 10 years or less out.

In this summary notice should be taken of the "loan" for a second year of two members of the Association resident staff to the organization of the Second Century Fund, namely, Donald P. Severance '38, Secretary-Treasurer of the Association, and Douglas F. G. Haven '52, Regional Director of the Alumni Fund. Following the announcement on Alumni Day that the Second Century Fund Area Organization had exceeded its $8 million quota, both of these officers returned to full-time status with the Association and Fund. On June 30, Mr. Severance succeeded the undersigned as Executive Vice President of the Association, and Volta Torrey, Editor of *The Technology Review*, succeeded him as Publisher.

It would not be appropriate to close this report without expressing my personal gratitude to the thousands of alumni who, devoted to the Institute and its ideals, have made my fifteen years as Executive Vice President of the Association so rewarding.

HAROLD E. LOBDELL

Registry of Guests

The Registry of Guests in 1961-62 received a total of 660 short-term foreign visitors. This figure does not include a large number of foreign delegates who attended conferences at the Institute and were not scheduled through this office.

The visitors came from 70 different lands, among them Iceland, Yugoslavia, Poland, the U.S.S.R., Hungary, Cyprus, Northern Rhodesia, Nepal, Borneo, Libya, Togo, and Dahomey. The representatives included, on the distaff side, the Director of the Italian Cultural Association and the Principal of the Government College for Women in Pakistan. Other visitors of special note were the Chief of the Chinese Nationalist Army, the Chief of the Division of External Affairs of the "Common Market," the Chief Mapanza of the Tongo Tribe of Northern Rhodesia, the Minister of Education of Libya, the Minister of Finance of the Government of India, the Yugoslav Ambassador to the United States, the President of the University of Tokyo, a member of the Polish Parliament, and the Robbins Committee on Higher Education in Great Britain. It is important to note that increasingly our visitors come to the Institute with a serious objective to pursue and not just as sight-seers.

The number of long-term foreign visitors appointed to the M.I.T. staff increased in 1961-62 to a total of 292, in contrast to figures of 262 in 1960-61 and of 193 in 1959-60.

The expressions of appreciation from these foreign visitors emphasize the extent to which the time and effort devoted by their M.I.T. hosts, as well as the knowledge shared, is deepening international understanding.

The establishment of the Boston Council for International Visitors in October, 1961, has added a new dimension to visitor reception in the Boston area. The council provides a central reception base, considerable resources for home hospitality, and further opportunity to ascertain more clearly in advance the specific fields of interest of prospective visitors to such institutions as M.I.T. It is anticipated that the benefits of this center will gradually draw an increasing number of visitors to Greater Boston, and hence to M.I.T.

CAROLYN B. COX

Office of Student Personnel

The gross earnings of our students for 1961-62, including all jobs on the campus and in the immediate Cambridge vicinity, were $1,541,000, of which approximately $1,500,000 came from M.I.T. funds and paid for 2,300 on-campus jobs. Only 146 off-campus jobs are included in the total gross earnings figure. With a total of 2,242 students employed, the average earnings per student were $687.

A total of $1,300,000 from M.I.T. funds was paid to 1,920 undergraduates, with average earnings of $677.

Considering the nine-month academic year only, from September, 1961, to June, 1962, $938,000 was expended from M.I.T. funds for the services of 1,715 undergraduates, who had average earnings for this period of $547.

Of the total amount earned by undergraduates during the academic year from M.I.T. funds, $750,000 was paid for student services on projects of the Division of Sponsored Research, on special research projects, in other laboratory work, in administrative office duties, and in miscellaneous departmental services. This amount is 80 per cent of the total of M.I.T. funds expended for student services in the nine-month period.

A survey conducted in August, 1962, through project supervisors and laboratory directors should develop approximately 125 new jobs for our students in the fall term of 1962.

We continue to maintain records of the performance and earnings of all present students, and our current personnel file totals 2,940. Such records for 7,500 former students remain on file to help industry, government, and other employers evaluate the experience of prospective employees.

WILLIAM H. CARLISLE

Principal Professional Honors and Activities of the Staff

School for Advanced Study

MARTIN J. BUERGER
Corresponding Member of the Austrian Academy of Science.

ROMAN JAKOBSON
Degree of Doctor Philosophiae honoris causa, University of Oslo.
Representative of the Section on Philology and Criticism to the Council of the American Academy of Arts and Sciences.

CYRIL S. SMITH
Gold Medal of the American Society for Metals.
Pfizer Prize of the History of Science Society.
Vice President of the Society for the History of Technology.

C. RICHARD SODERBERG
Annual Award of the Engineering Societies of New England.

School of Architecture and Planning

DEPARTMENT OF ARCHITECTURE

BERNARD J. FRIEDEN
Editor of the *Journal of the American Institute of Planners.*

DEPARTMENT OF CITY AND REGIONAL PLANNING

JOHN T. HOWARD
Member of the Executive Committee, Association of Collegiate Schools of Planning.
Member of the Executive Committee, Highway Research Board.

School of Engineering

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

HOLT ASHLEY
Fellow of the Institute of the Aerospace Sciences.
Silver Beaver Award of the Cambridge Council, Boy Scouts of America.

JUDSON R. BARON
Chairman of the Boston Section, Institute of the Aerospace Sciences.

RAYMOND L. BISPLINGHOFF
Chairman of the Educational Committee and of the Panel on Aeroelasticity and Structural Dynamics, Institute of the Aerospace Sciences.
Vice Chairman of the Aeronautical Engineering Division, American Society for Engineering Education.
Member of the Research Advisory Committee on Aircraft Structures, National Aeronautics and Space Administration.

CHARLES S. DRAPER
Missouri Honor Award of the University of Missouri.
Award of the National Society of Professional Engineers.

RENE H. MILLER
Secretary-Treasurer of the American Helicopter Society.

ERIK L. MOLLO-CHRISTENSEN
Fellow of the American Academy of Arts and Sciences.

GORDON C. OATES
Treasurer of the Boston Section, Institute of the Aerospace Sciences.

LAURENCE R. YOUNG
Dr. Morris Meister Award of the Bronx High School of Science.

DEPARTMENT OF CHEMICAL ENGINEERING

EDWIN R. GILLILAND
Member of the Committee on Natural Resources, National Academy of Sciences—National Research Council.
Member of the President's Science Advisory Committee.
Member of the Consultant Panel, Operations Evaluation Group, Navy Department.
Member of the Advisory Council, Oak Ridge National Laboratory.
Chairman of the Canvassing Committee, Industrial and Engineering Chemistry Award, American Chemical Society.

HOYT C. HOTTEL
Chairman of the Committee on Fire Research, National Academy of Sciences—National Research Council.
Chairman of the U. S. Committee on Flame Research.
Vice President of the Combustion Institute.

EDWARD W. MERRILL
Sigma Xi Lecturer at Boston University.
Lecturer at the Institut Francais du Petrole, Paris, September, 1961.

CHARLES N. SATTERFIELD
Member of the Committee on Chemical Kinetics, National Academy of Sciences—National Research Council.

THOMAS K. SHERWOOD
Chairman of the Planning Committee, Desalination Research Conference, National Academy of Sciences—National Research Council.
King Lecturer at the Johns Hopkins University.

HAROLD C. WEBER
Chief Scientific Adviser to the U.S. Army.
Director of the Armed Forces Chemical Association.

GLENN C. WILLIAMS
Secretary and Director of the Combustion Institute.

Member of the Research Advisory Committee on Chemical Energy Systems, National Aeronautics and Space Administration.
Member of the Advisory Committee, Ordnance Department, U.S. Army.
Member of the Research Advisory Panel, National Bureau of Standards.
Member of the Executive Committee of the Heat Transfer Division, American Institute of Chemical Engineers.

DEPARTMENT OF CIVIL ENGINEERING

ALEXANDER J. BONE
Director of the Boston Society of Civil Engineers.
Vice President of the Educational Division, American Road Builders Association.

JAMES W. DAILY
Chairman of the Committee on Hydraulic Machinery and Cavitation, International Association for Hydraulic Research.

ALBERT G. H. DIETZ
Member of the Board of Directors, American Society for Testing Materials.
Member of the Board of Governors, Building Research Institute.
John W. Derham Memorial Lecturer of the Plastics Institute of Australia.

PETER S. EAGLESON
Member of the Executive Committee, Hydraulics Section, Boston Society of Civil Engineers.

ROBERT J. HANSEN
Member of the Advisory Committee on Civil Defense, National Academy of Sciences—National Research Council.

DONALD R. F. HARLEMAN
Chairman of the Committee on Fluid Dynamics and Secretary of the Executive Committee of the Hydraulics Division, American Society of Civil Engineers.
Chairman of the Hydraulics Section, Boston Society of Civil Engineers.

FRANK J. HEGER
Member of the Editorial Committee, World Conference on Shell Structures.

MYLE J. HOLLEY, JR.
Chairman of the Structural Division, Boston Society of Civil Engineers.

JOHN A. HOOPES
J. Waldo Smith Hydraulic Research Fellowship of the American Society of Civil Engineers.

ARTHUR T. IPPEN
President of the International Association for Hydraulic Research.
Member of the Board of Directors, Boston Society of Civil Engineers.
Vice President of the International Union of Engineering Organizations.

T. WILLIAM LAMBE
Wellington Prize of the American Society of Civil Engineers.
Chairman of the Committee on Properties of Soils and Soil Deposits, Soil Mechanics and Foundation Division, American Society of Civil Engineers.

FREDERICK J. MC GARRY
Executive Committee Award of the Society of the Plastics Industry.
Vice Chairman of the Reinforced Plastics Committee, Society of the Plastics Industry.

PAUL O. ROBERTS, JR.
Member of the Executive Committee, Northeastern Section, American Society of Civil Engineers.

JAMES M. SYMONS
Member of the Board of Governors, Boston Society of Civil Engineers.

EGONS TONS
Chairman of the Committee on Fillers and Sealers in Pavements, Highway Research Board.

ROBERT V. WHITMAN
Chairman of the Publications Committee, Soil Mechanics and Foundations Division, American Society of Civil Engineers.

DEPARTMENT OF ELECTRICAL ENGINEERING

RICHARD B. ADLER
Chairman of the Technical Program Committee, International Solid State Circuits Conference, University of Pennsylvania.

JOHN BLAIR
Chairman of the Energy Sources Division, Professional Group on Electron Devices, Institute of Radio Engineers.

MARY A. B. BRAZIER
President of the International Federation of Societies for Electroencephalography and Clinical Neurophysiology.

WILBUR B. DAVENPORT, JR.
Member of the Communication Satellites Panel, Office of the Special Assistant to the President for Science and Technology.

MURRAY EDEN
Member of the Administrative Committee, Professional Group on Bio-Medical Electronics, Institute of Radio Engineers.
Editor of *Information and Control.*

RONALD A. HOWARD
Honorable mention for the Lanchester Prize, Operations Research Society of America.

DAVID A. HUFFMAN
Member of the Administrative Committee and Chairman of the Nominations Committee, Professional Group on Information Theory, Institute of Radio Engineers.

ARTHUR L. LOEB
President of the Netherlands Academic Circle.

ALAN L. MC WHORTER
Associate Editor of *Transactions on Electron Devices.*

EDWARD F. MOORE
Gordon McKay Visiting Lecturer on Applied Mathematics, Harvard University.

WILLIAM T. PEAKE
Chairman of the Boston Section, Professional Group on Bio-Medical Electronics, Institute of Radio Engineers.

W. KEITH PERCIVAL
Member of the Board of Editors, *Mechanical Translation.*

WALTER A. ROSENBLITH
Weizmann Memorial Lecturer at the Weizmann Institute of Science, Rehovoth, Israel.
Lecturer at the Inauguration of the TATA Institute for Fundamental Research, Bombay, India.

Member of the Life Sciences Panel, Office of the Special Assistant to the President for Science and Technology.
Member of the Council, International Organization of Pure and Applied Biophysics.

CAMPBELL L. SEARLE
Chairman of the Semiconductor Electronics Education Committee, Educational Services, Inc.

CLAUDE E. SHANNON
Honorary degrees of Doctor of Science, University of Michigan and Princeton University.
Steinmetz Memorial Lecturer at the Steinmetz Memorial Foundation and the Schenectady Section, American Institute of Electrical Engineers.

HERBERT M. TEAGER
Chairman of the *ad hoc* Panel on Non-Numerical Information Processing.

JEROME B. WIESNER
Special Assistant to the President for Science and Technology.

DAVID C. WHITE
Visiting Professor at the University of Wisconsin.
Professor Honorario at the Instituto Politechnico Nacional, Mexico D.F.
Chairman of the Advanced Technology Subcommittee of the Aero-Space Energy Conversion Committee, American Institute of Electrical Engineers.

DAVID R. WHITEHOUSE
Member of the Steering Committee, Symposium on Engineering Aspects of Magnetohydrodynamics.

VICTOR H. YNGVE
Editor of *Mechanical Translation.*

HENRY J. ZIMMERMANN
Member of the Board of Directors, Northeast Electronics Research Engineering Meeting.

DEPARTMENT OF MECHANICAL ENGINEERING

GEORGE A. BROWN
Member of the Steering Committee on Mechanical Engineering Laboratory Education, National Science Foundation.

JACOB P. DEN HARTOG
Honorary degree of Doctor of Engineering, Carnegie Institute of Technology

JAMES A. FAY
Fellow of the American Academy of Arts and Sciences.

GEORGE N. HATSOPOULOS
Golden Plate Award of the Academy of Achievement.

AUGUST L. HESSELSCHWERDT, JR.
President of the Boston Chapter, American Society of Heating, Refrigerating, and Air Conditioning Engineers.

PHILIP G. HILL
Fellowship of the John Simon Guggenheim Memorial Foundation.

WILLIAM M. MURRAY
Honorary President of the Society for Experimental Stress Analysis.

GEORGE S. REICHENBACH
Award for Advancement of Basic and Applied Science of the Yale Engineering Association.

Vice Chairman of the Subcommittee on Rolling Elements, American Society of Mechanical Engineers.
Alfred Noble Prize awarded jointly by five professional societies.

BRANDON G. RIGHTMIRE
Vice Chairman of the Research Committee on Lubrication, American Society of Mechanical Engineers.

WARREN M. ROHSENOW
Chairman of the Heat Transfer Division, American Society of Mechanical Engineers.

ASCHER H. SHAPIRO
Chairman of the National Committee for Fluid Mechanics Films.

J. LOWEN SHEARER
Member of the Executive Committee, Boston Section, American Society of Mechanical Engineers.

H. GUYFORD STEVER
Chairman of the Scientific Advisory Board, U.S. Air Force.

GEORGE W. SUTTON
Chairman of the Symposium on Engineering Aspects of Magnetohydrodynamics.
Member of the Research Advisory Committee on Fluid Mechanics, National Aeronautics and Space Administration.

C. FAYETTE TAYLOR
Lester D. Gardner Lecturer at the Massachusetts Institute of Technology.

TAU-YI TOONG
Outstanding Achievement Award of the Chinese Institute of Engineers.

DEPARTMENT OF METALLURGY

CLYDE M. ADAMS
Adams Memorial Award of the American Welding Society.

JOHN CHIPMAN
Honorary degree of Doctor of Science, University of Pennsylvania.

ROBERT L. COBLE
Member of the Executive Board of the Northeast Section and Program Chairman of the Basic Science Division, American Ceramic Society.

MORRIS COHEN
Zay Jeffries Lecturer and Member of the Board of Trustees, American Society for Metals.
Howe Memorial Lecturer, American Institute of Mining, Metallurgical, and Petroleum Engineers.
Hatfield Memorial Lecturer, British Iron and Steel Institute.

ANTOINE M. GAUDIN
Chairman of the Engineering Foundation.
Chairman of the Committee Surveying Research Activities of the U.S. Bureau of Mines, National Academy of Sciences.

W. DAVID KINGERY
Fellow of the American Ceramic Society.

DAVID A. THOMAS
Program Chairman for the Sixteenth New England Regional Conference, Metal-

lurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers.

HERBERT H. UHLIG
Palladium Medal of the Electrochemical Society.

DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENGINEERING

EDWARD S. ARENTZEN
Joseph H. Linnard Award of the Society of Naval Architects and Marine Engineers (with Professor Philip Mandel).

COMMANDER JOHN R. BAYLIS, U.S.N.
Member of the Legion of Merit.

J. HARVEY EVANS
Chairman of the Hull Structure Committee, Society of Naval Architects and Marine Engineers.
Chairman of the Committee on Design Philosophy and Design Procedure, International Ship Structures Congress.

FRANK M. LEWIS
Davidson Medal of the Society of Naval Architects and Marine Engineers.

PHILIP MANDEL
Joseph H. Linnard Award of the Society of Naval Architects and Marine Engineers (with Professor Edward S. Arentzen).
Chairman of the Flow Studies Panel, Society of Naval Architects and Marine Engineers.

DEPARTMENT OF NUCLEAR ENGINEERING

MANSON BENEDICT
President of the American Nuclear Society.
Chairman of the General Advisory Committee, Atomic Energy Commission.

ELIAS P. GYFTOPOULOS
Technical Program Chairman for the 1962 Annual Meeting, American Nuclear Society.

EDWARD A. MASON
Chairman of the Northeastern Section, American Nuclear Society.

THEOS J. THOMPSON
Member of the Board of Directors, American Nuclear Society.

WILLIAM M. TRENHOLME
General Chairman of the Industrial Electronics Symposium (September, 1961, Boston).
Chairman of the Reactor Instruments Subcommittee, Nuclear Instrumentation Committee, American Institute of Electrical Engineers.

School of Humanities

DEPARTMENT OF ECONOMICS AND SOCIAL SCIENCE

LINCOLN P. BLOOMFIELD
Member of the Board of Directors, Massachusetts World Affairs Council.
Member of the Advisory Committee, Peace Research Institute.

EVSEY D. DOMAR
Fellow of the American Academy of Arts and Sciences.

EVERETT E. HAGEN
Fellowship of the John Simon Guggenheim Memorial Foundation.

DANIEL LERNER
Life Fellow of the International Institute of Arts and Letters.
Presidential Citation of New York University.

CHARLES A. MYERS
McKinsey Prize of the *Harvard Business Review.*
President of the Industrial Relations Research Association.

LUCIAN W. PYE
Fellow of the American Academy of Arts and Sciences.

PAUL N. ROSENSTEIN-RODAN
Fellow of the Academy of Arts and Sciences.

PAUL A. SAMUELSON
Honorary degree of Doctor of Literature, Ripon College.
Hoyt Visiting Fellow at Calhoun College, Yale University.

ROBERT M. SOLOW
John Bates Clark Medal of the American Economic Association.

MICHAEL A. WALLACH
Representative of Division 10 to the Council, American Psychological Association.

DEPARTMENT OF HUMANITIES

ALFRED D. CHANDLER, JR.
Member of the Executive Committee, Association for Higher Education.

CARVEL COLLINS
Stanford University Fellow at the University of Tokyo.

EMMET LARKIN
Treasurer of the American Committee for Irish Studies.

BRUCE MAZLISH
Associate Editor of *History and Theory.*
General editor for the series, Main Themes in the Evolution of Modern European Civilization, The Macmillan Company.

HUSTON C. SMITH
Charles Strong Memorial Lecturer at the universities of Australia.
"Meet the Professor" television production, American Broadcasting Corporation.

ROBERT S. WOODBURY
Treasurer and Editor of the Monograph Series, Society for the History of Technology.
Abbott Payson Usher Prize of the Society for the History of Technology.
John Simon Guggenheim Memorial Foundation Fellowship.

DEPARTMENT OF MODERN LANGUAGES

WILLIAM F. BOTTIGLIA
Secretary of the Eighteenth Century French Literature Group, Modern Language Association.
Member of the Executive Committee, Northeast Conference on the Teaching of Foreign Languages.

CHARLES T. COLE
Third prize, O. Henry Prize Awards, Doubleday and Company.

MORRIS HALLE
Secretary of the Ninth International Congress of Linguists.

School of Industrial Management

SIDNEY S. ALEXANDER
Ford Foundation grant for study at the Institute of the Behavioral Sciences, Stanford, California.

GEOFFREY P. E. CLARKSON
Fellowship of the Social Science Research Council.

BILLY E. GOETZ
Member of the Board of Directors, Boston Chapter, Society for the Advancement of Management.

HERBERT F. GOODWIN
President of the Boston Chapter, Society for the Advancement of Management.

DANIEL M. HOLLAND
Member of the Committee on Statistics, Treasury Department and Internal Revenue Service.

EDWIN KUH
Faculty Research Fellowship in Business Administration of the Ford Foundation.

HARRY LEVINSON
Chairman of the Kansas Advisory Committee, Civil Rights Commission.

DOUGLAS M. MC GREGOR
Publication Award of the Organization Development Council.
James A. Hamilton—Hospital Administrators' Book Award of the American College of Hospital Administrators.

ELTING E. MORISON
Trumbull Lecturer, Yale University.

EDWARD B. ROBERTS
Program Chairman for the Boston Section, Institute of Management Sciences.

EDGAR H. SCHEIN
Chief Staff Member of the Second Internship Program in Applied Social Science and member of the National Board, National Training Laboratories.

ERWIN H. SCHELL
Chancellor of the International Academy of Management.

WILLIAM P. TRAVIS
David A. Wells Prize of the Department of Economics, Harvard University.

CARROLL L. WILSON
United States Representative and Chairman of the Committee on Scientific Research, Organization for Economic Cooperation and Development.
Member of the Advisory Council on International Science Programs, National Science Foundation.
Chairman of the Committee on Continuing Education and Vice President of the M.I.T. Alumni Association.

Principal Professional Honors and Activities of the Staff

School of Science

DEPARTMENT OF BIOLOGY

JOHN M. BUCHANAN
Member of the National Academy of Sciences.

ALEXANDER RICH
Member of the Council, the Biophysical Society.
Member of the Council, Federation of American Scientists.
Member of the Executive Committee, Division of Biological Chemistry, American Chemical Society.

IRWIN W. SIZER
Member of the Corporation, Museum of Science.
Member of the Corporation, Lesley College.

DAVID F. WAUGH
Borden Award of the American Chemical Society.

DEPARTMENT OF CHEMISTRY

AVERY A. ASHDOWN
Honor Scroll of the New England Chapter, American Institute of Chemists.

KLAUS BIEMANN
Gold Medal and honorary membership in the Belgian Chemical Society.

GLENN A. BERCHTOLD
Associate Editor of the *Journal of Organic Chemistry.*

ARTHUR C. COPE
Chairman of the Board of Directors, American Chemical Society.
Member of the American Philosophical Society.

CHARLES D. CORNELL
Fellowship of the John Simon Guggenheim Memorial Foundation.

F. ALBERT COTTON
Texas Instruments Award in Inorganic Chemistry of the American Chemical Society.
Gooch Lecturer at Yale University.
Fellowship of the Alfred P. Sloan Foundation.

CARL W. GARLAND
Scientific Editor of *Optics and Spectroscopy.*

FREDERICK D. GREENE
Editor of the *Journal of Organic Chemistry.*

LAWRENCE J. HEIDT
Visiting Distinguished Professor of Chemistry, Michigan State University.
Fellowship of the John Simon Guggenheim Memorial Foundation.

DAVID N. HUME
Chairman of the Commission on Equilibrium Data, Analytical Section, International Union of Pure and Applied Chemistry.

RICHARD C. LORD
President of the Commission of Molecular Structure and Spectroscopy, International Union of Pure and Applied Chemistry.

GEORGE SCATCHARD
Kendall Company Award in Colloid Chemistry of the American Chemical Society.

DIETMAR SEYFERTH
Fellowship of the Alfred P. Sloan Foundation.

JOHN C. SHEEHAN
Distinguished Lecturer in Science at Providence College.
Visiting Professor at the Imperial College, University of London.
Fellowship of the John Simon Guggenheim Memorial Foundation.

DAVID P. SHOEMAKER
Secretary-Treasurer of the U.S.A. National Committee for Crystallography.

WALTER H. STOCKMAYER
Class of 1925 Professorship at Dartmouth College.

JOHN S. WAUGH
Fellow of the American Physical Society.

DEPARTMENT OF GEOLOGY AND GEOPHYSICS

RAYMOND HIDE
Fellowship of the Institute of Physics.

ELY MENCHER
Director of the American Geological Institute.

WILLIAM S. VON ARX
Fellow of the American Academy of Arts and Sciences.

DEPARTMENT OF MATHEMATICS

LOUIS N. HOWARD
Fellowship of the John Simon Guggenheim Memorial Foundation.

KENKICHI IWASAWA
Frank Nelson Cole Prize of the American Mathematical Society.
Award of the Japan Academy of Science.

EKKEHART KRONER
Physics Prize of the German Physical Society.
Member of the Advisory Board of the *International Journal of Engineering Science.*
Member of the Advisory Board of *Physica Status Solidi.*

CHI-CHIAO LIN
Member of the National Academy of Sciences.

FRANKLIN P. PETERSON
Fellowship of the Alfred P. Sloan Foundation.

ERIC REISSNER
Fellowship of the John Simon Guggenheim Memorial Foundation.
Chairman of the Applied Mechanics Division, American Society of Mechanical Engineers.

HARTLEY ROGERS
Editor of the *Journal of Symbolic Logic.*

GIAN-CARLO ROTA
Fellowship of the Alfred P. Sloan Foundation.

NORTON L. STARR
Goodwin Medal of the Massachusetts Institute of Technology.

DIRK J. STRUIK
Visiting Professor of Mathematics, University of Puerto Rico.

DEPARTMENT OF METEOROLOGY

HENRY G. HOUGHTON
Member of the Council, American Meteorological Society.
Vice President of the Meteorology Section, American Geophysical Union.
Chairman of the Board, University Corporation for Atmospheric Research.

DEPARTMENT OF NUTRITION, FOOD SCIENCE AND TECHNOLOGY

SAMUEL A. GOLDBLITH
Member of the Special White House Mission to Argentina on Foot and Mouth Disease.
Member of the Committee on Radiation Preservation of Food, National Research Council—National Academy of Sciences.
Member of the *ad hoc* Committee on Environmental Health Problems, U.S. Public Health Service.
Member of the Advisory Committee on Radiation-Pasteurized Foods, American Institute of Biological Sciences—Atomic Energy Commission.
Atomic Energy Commission Delegate to the Fourth Japan Conference on Radioisotopes.
Vice President of the New Century Club of Boston.
Honorary Citizen of Texas.

NEVIN S. SCRIMSHAW
Vice Chairman of the Food and Nutrition Section, American Public Health Association.
Order of Rodolfo Robles of Guatemala.
Fellow of the Massachusetts Medical Society.
Member of the Scientific Advisory Committee, Williams-Waterman Fund.
Member of the Nutrition Study Section, National Institute of Health.
Member of the Committee on Protein Malnutrition, Food and Nutrition Board, National Research Council—National Academy of Sciences.
Member of the Scientific Advisory Committee, Nutrition Foundation.

JOHN W. ZAHRADNIK
Member of the Council, Northeastern Section, Institute of Food Technologists.

DEPARTMENT OF PHYSICS

WILLIAM P. ALLIS
Vice President of the American Academy of Arts and Sciences.

SANBORN C. BROWN
President of the International Commission on Physics Education, International Union of Pure and Applied Physics.
Citation for Distinguished Service to the American Association of Physics Teachers.
Member of the Commission on College Physics, American Association of Physics Teachers.

WILLIAM W. BUECHNER
Member of the International Commission on Nuclidic Masses and Atomic Constants, International Union of Pure and Applied Physics.

DAVID O. CALDWELL
Fellowship of the Ford Foundation.

ROBLEY D. EVANS
Councilor of the Radiation Research Society.

PHILIP M. MORSE
Avalon Foundation Lecturer, Mexico City.
Executive Secretary of the International Federation of Operational Research Societies.
Member of the Committee on Natural Resources, National Academy of Sciences—National Research Council.

HANS MUELLER
Fellow of the American Optical Society.

CLIFFORD G. SHULL
Chairman of the Solid State Physics Division, American Physical Society.
Chairman of the Visiting Committee to the Physics Department, Brookhaven National Laboratory.

MALCOLM W. P. STRANDBERG
Fulbright Lecturer to the University of Grenoble.

LASZLO TISZA
Fellowship of the John Simon Guggenheim Memorial Foundation.

Other Offices and Departments

LINCOLN LABORATORY

CHARLES E. CHASE
Fulbright Award for research at the University of Leiden.

WESLEY A. CLARK
Member of the Committee on the Use of Electronic Computers in the Life Sciences, National Research Council—National Academy of Sciences.

RONALD G. ENTICKNAP
U.S. Delegate to Committee A, Comité Consultatif International Télégraphique et Téléphonique.

HARRY C. GATOS
Vice Chairman of the Committee on Electronic Materials, American Institute of Mining, Metallurgical, and Petroleum Engineers.
Vice Chairman of the Corrosion Division and Interdivisional Editor (Corrosion-Electronics) of the *Journal*, Electrochemical Society.

PAUL E. GREEN, JR.
Fellow of the Institute of Radio Engineers.

DAVID S. GREY
President of the New England Section, Optical Society of America.

WALTER W. HARVEY
Treasurer of the Boston Section, Electrochemical Society.

FRANK E. HEART
Treasurer and Member of the Board of Governors, American Federation of Information Processing Societies.

CHARLES F. KAYE
Member of the Massachusetts Bar Association and American Bar Association.

CHARLES S. KEEVIL, JR.
Diplomate of the American Board of Internal Medicine.

ROBERT KRAMER
Chairman of the Subcommittee on Symbols and Terminology for Feedback Control Systems, Institute of Radio Engineers.

BENJAMIN LAX
Fellow of the American Academy of Arts and Sciences.

JOHN J. G. MC CUE
Member of the Administrative Committee, Professional Group on Ultrasonics Engineering, Institute of Radio Engineers.

GORDON H. PETTENGILL
Member of Commission II (Propagation in Non-ionized Media), U.R.S.I.
Member of Subcommission 16 (Physical Studies of the Planets and Satellites), International Astronautical Union.

ROBERT PRICE
Fellow of the Institute of Radio Engineers.

ROBERT H. REDIKER
Chairman of the Committee on Solid State Devices and Member of the Administrative Committee, Professional Group on Electron Devices, Institute of Radio Engineers.

LEON J. RICARDI
Chairman of the Boston Section, Professional Group on Antennas and Propagation, Institute of Radio Engineers.

LAURA M. ROTH
Medal for Distinguished Achievement, Graduate Chapter, Radcliffe Alumnae Association.
Merit Award of *Mademoiselle* Magazine.

HERBERT SHERMAN
Secretary of the Committee on Communication Theory, American Institute of Electrical Engineers.
Member of the Review Committee for *Radio Engineering and Electronic Physics*.

CHARLES H. STEVENS
Chairman of the Recruiting Committee, Boston Chapter, Special Libraries Association.

WARREN S. TORGERSON
Member of the Council of Directors of the Psychometric Society.

THOMAS P. TURNBULL
Honorable Mention and Medal at the 16th Metallographic Exhibit, American Society for Metals.

ALEXANDER VANDERBURGH, JR.
Vice-Chairman of the Professional Group on Electronic Computers and Chairman of the Program Committee, Institute of Radio Engineers.

EDWARD P. WAREKOIS
Member of the Executive Committee, Boston Section, American Institute of Mining, Metallurgical, and Petroleum Engineers.

OPERATIONS EVALUATION GROUP

HUGH J. MISER
President of the Operations Research Society of America.

OPERATIONS RESEARCH CENTER

HERBERT P. GALLIHER, JR.
Editor of *International Abstracts in Operations Research.*

LIBRARIES

WILLIAM N. LOCKE
Chairman of the Local Committee, 1961 Annual Meeting, American Documentation Institute.

NATALIE N. NICHOLSON
Chairman of the Committee on Committees, Special Libraries Association.

PETER SCOTT
Associate Editor of *American Documentation.*

MEDICAL DEPARTMENT

HARRIET L. HARDY
Fellow of the Industrial Medical Association.
William S. Knudsen Award of The Industrial Medical Association.

MELVIN H. RODMAN
Member of the Executive Council, Massachusetts Thoracic Society.
Fellow of the American College of Physicians.

BENSON R. SNYDER
Member of the Board of Trustees, Group for the Advancement of Psychiatry.

ROBERT F. TILLEY
Secretary of the New England Dermatologists Society.
Chairman of the Section of Dermatology, Massachusetts Medical Society.

ADMINISTRATION

GORDON S. BROWN
Member of the President's Committee on the Medal of Science.
Member of the Engineering Education Commission.
Member of the Committee on Scientific Personnel and Education, Division of Engineering Sciences, National Science Foundation.

VANNEVAR BUSH
Charles F. Kettering Award of the Patent, Trademark, and Copyright Foundation, George Washington University.

EUGENE R. CHAMBERLAIN
Chairman of the Committee on Admissions and Placement and Director, National Association of Foreign Student Advisers.

THOMAS W. HARRINGTON, JR.
Second Vice President of the Eastern College Personnel Officers Association.

ROBERT E. HEWES
Vice President (professional activities) of the American Association of Collegiate Registrars and Admissions Officers.

WOLCOTT A. HOKANSON
Certificate of Appreciation for services as Assistant Treasurer, American Academy of Arts and Sciences.

HOWARD W. JOHNSON
Member of the Visiting Committee, Systems Command, U.S. Air Force.

Principal Professional Honors and Activities of the Staff

JAMES R. KILLIAN, JR.
Honorary degree of Doctor of Laws, Meadville Theological School.
Honorary degree of Doctor of Education, Rhode Island College.

MALCOLM G. KISPERT
Honorary degree of Doctor of Science, Bradford Durfee College of Technology.

JULIUS A. STRATTON
Honorary degree of Doctor of Humanities, Hebrew Union College—Jewish Institute of Religion.
Honorary degree of Doctor of Laws, the Johns Hopkins University.
Officer of the French Legion of Honor.

B. ALDEN THRESHER
Honorary Life Member of the College Entrance Examination Board.
Trustee of Thayer Academy.
Member of the Advisory Committee on the Guidance Training Institutes Program, U.S. Office of Education.

CHARLES H. TOWNES
Arnold O. Beckman Award of the Instrument Society of America.
David Sarnoff Award in Electronics of the American Institute of Electrical Engineers.
John J. Carty Medal of the National Academy of Sciences.

Publications from the Institute

PERIODICAL PUBLICATIONS, BOOKS, AND REVIEWS BY THE STAFF, JULY 1, 1961, TO JUNE 30, 1962[1,2]

School for Advanced Study

BUERGER, MARTIN J., and C. W. BURNHAM. Refinement of the crystal structure of andalusite. *Zeit. f. Kristallographie* 115, pp. 269-290, August, 1961.

BUERGER, MARTIN J., and C. T. PREWITT. The crystal structure of cahnite, $Ca_2BAsO_4(OH)_4$. *Am. Mineralogist* 46, pp. 1077-1085, September-October, 1961.

BUERGER, MARTIN J., and C. T. PREWITT. The crystal structures of wollastonite and pectolite. *National Acad. Sci. Proc.* 47, pp. 1884-1888, December, 1961.

BUERGER, MARTIN J. Image sets. *Zeit. f. Kristallographie* 116, pp. 431-467, December, 1961.

BUERGER, MARTIN J. A review of *Fourier transforms and convolutions for the experimentalist,* by R. C. Jennison (N.Y., Pergamon, 1961). *Science* 134, pp. 2093-2094, December 29, 1961.

BUERGER, MARTIN J. The algebra and geometry of convolutions. *Accademia Nazionale dei Lincei Atti* 6, pp. 83-95, 1962.

BUERGER, MARTIN J. An algebraic representation of the images of sets of points. *Accademia delle Scienze de Torino Atti* 96, pp. 175-192, February 6, 1962.

BUERGER, MARTIN J. A review of *Organic chemical crystallography,* by A. I. Kitaigorodskii (N.Y., Consultants Bureau, 1961). *Science* 135, p. 912, March 16, 1962.

[1] For reprints of periodical publications and reviews, consult the author. For copies of books, consult the publishers or a retail bookseller.

[2] This list has been compiled under the direction of Eleanor L. Bartlett, Archives and Gifts Librarian.

BUERGER, MARTIN J. A review of *Crystallization, theory and practice,* by A. van Hook. (N. Y., Reinhold, 1961.) *Science* 136, pp. 518-519, May 11, 1962.

BUERGER, MARTIN J., and D. R. PEACOR. The determination and refinement of the structure of narsarsukite, $Na_2TiOSi_4O_{10}$. *Am. Mineralogist* 4, pp. 529-556, May-June, 1962.

BUERGER, MARTIN J., C. W. BURNHAM, and D. R. PEACOR. Assessment of the several structures proposed for tourmaline. *Acta Crystallographica* 15, pp. 583-590, June 1962.

HYODO, TOMONORI. Backscattering of gamma rays. *Nuclear Sci. & Eng.* 12, pp. 178-184, February, 1962.

JAKOBSON, ROMAN, C. G. M. FANT, and M. HALLE. *Preliminaries to speech analysis.* Cambridge, Mass., M.I.T. Press, 1961.

JAKOBSON, ROMAN. Aphasia as a linguistic problem. (A chapter in *Psycholinguistics,* edited by S. Saporta and J. R. Bastian. N.Y., Holt, Rinehart & Winston, 1961.)

JAKOBSON, ROMAN. Phonemic patterning. (A chapter in *Psycholinguistics,* edited by S. Saporta and J. R. Bastian. N.Y., Holt, Rinehart & Winston, 1961.)

JAKOBSON, ROMAN, and E. M. VAN SCHOONEVELD. *Tonnies Fenne's low German manual of spoken Russian, Pskov 1607.* Copenhagen, Royal Danish Academy of Sciences, 1961.

JAKOBSON, ROMAN. Strukturata na poslednoto Botevo stihotvorenie. *Ezik i literatura* 16, pp. 1-14, 1961.

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The Detection and Identification of Underground Nuclear Explosions: a Study, G. L. TURIN, 34G-2, March 2, 1962.

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Instantaneous Spectra and Ambiguity Functions, M. J. LEVIN, 34G-5, March 2, 1962.

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Free Carrier Faraday and Voight Effects for a Cubic Crystal with a Pb-Te-Like Band Structure, J. HALPERN, 85G-0011, August 25, 1961.

NATIONAL MAGNET LABORATORY

Some Useful Information for the Design of Air-Core Solenoids, D. BRUCE MONTGOMERY and J. TERRELL, AFOSR-1525, November, 1961.

Some Useful Information for the Design of Iron Magnets, D. BRUCE MONTGOMERY, AFOSR-1526, November, 1961.

Theses Submitted for Advanced Degrees[1, 2]

School of Architecture and Planning

DEPARTMENT OF ARCHITECTURE

Master in Architecture

JOSEPH RAYMOND BLAIR, *Fine Arts Complex for Macalester College* (September, 1961).

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DON ALAN ELLIS, *Housing for the University of Cincinnati* (September, 1961).

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WILLIAM LESTER KITE, JR., *Government Center for Providence, R.I.* (September, 1961).

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Doctoral Degrees—Sanitary Engineering

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Building Engineer

SIAVASH ADIBZADEH, *Shelters* (January, 1962).

Civil Engineer

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Sanitary Engineer

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Master of Science—Building Engineering and Construction

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Theses Submitted for Advanced Degrees

Master of Science—Civil Engineering

MARCELO DARWIN ARCOS EGRED, *Investigation of the Optimum Design of Columns from the Weight-Strength Point of View* (June, 1962).

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MIGUEL VICENTE BOCCO, *Effect of Gradual Change of Depth on a Train of Surface Waves* (with J. L. M. Gagnon, June, 1962).

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Master of Science—Sanitary Engineering

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DEPARTMENT OF ELECTRICAL ENGINEERING

Doctoral Degrees

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Theses Submitted for Advanced Degrees

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Master of Science

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Theses Submitted for Advanced Degrees

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