PRESIDENT'S REPORT ISSUE 1963

MASSACHUSETTS
INSTITUTE OF
TECHNOLOGY BULLETIN

VOLUME 99, NUMBER 2, NOVEMBER, 1963

PRESIDENT'S REPORT ISSUE

FOR THE YEAR ENDING JULY 1, 1963

MASSACHUSETTS

INSTITUTE OF

TECHNOLOGY BULLETIN

The list of Publications and Theses, heretofore included in this volume, is published separately this year as Volume 99, Number 3, of the *Massachusetts Institute of Technology Bulletin.* Copies are available without charge from the Office of Publications, Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY BULLETIN

Published by the
Massachusetts Institute of Technology
Cambridge Station, Boston, Massachusetts,
six times yearly in March, June, July, September, November, and December.
Second class postage paid at Boston, Massachusetts.

Issues of the Bulletin include
REPORT OF THE TREASURER
REPORT OF THE PRESIDENT
PUBLICATIONS AND THESES
SUMMER SESSION CATALOGUE
UNDERGRADUATE CATALOGUE
and
GENERAL CATALOGUE

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Cambridge, Massachusetts, 02139

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PRESIDENT

I

In the spring of 1960 M.I.T. announced its Second Century Program with a minimum goal of $66 million. Just three years later, on the seventh of this past May, a Victory Dinner at the Waldorf Astoria in New York marked the formal completion of the campaign. It was a celebration planned particularly for the Honorary Chairman, Alfred P. Sloan, Jr., on the eve of his eighty-eighth birthday, and an occasion to express publicly our grateful thanks to every donor and worker —and to all who by their labor and by their generosity had assured the success of a great undertaking.

That success surpassed all our hopes. Of the $98 million reported by John Wilson, the General Chairman, $77 million in gifts and pledges resulted directly from the organized appeal. An additional $21 million over the three-year period in gifts applicable to the broad objectives of the Program was clearly stimulated by the efforts of the workers. The entire sum came wholly from private philanthropy— from alumni, from a notable number of other friends, from foundations, and from the corporate grants of business and industry.

Those who were present on that memorable evening in May were profoundly stirred by this demonstration of national support. The magnificent outcome of the campaign affords proof of public confidence in our objectives and an understanding of their importance to the country. It now remains for us to give reality to these objectives, and we commit ourselves completely to that task.

The move from Copley Square across the Charles to Cambridge in 1916 marked for M.I.T. the close of one era and the opening of another. No doubt the predominant sentiments of faculty and students at the time were those of thankfulness in the escape from the old, cramped quarters on Boylston Street and of pride in the imposing white buildings on the river. But the larger implications went far beyond the acquisition of more ample space. The stage was set for changes in the academic character of M.I.T.—and for its transition from a rather local to a national institution—that were to influence its course over the next thirty years. Surely it was with a sense of great things to come that President Maclaurin inscribed over the fireplace of his new office in Cambridge the words: *Alia initia e fine*—from every ending another beginning.

M.I.T. has come now to the crossing of another historic threshold. Just as the munificent Eastman and du Pont gifts of some fifty years ago made possible an entire new campus, so will the Second Century Fund provide the means for a major renewal and expansion of the physical space and facilities of the Institute. These additions to laboratories, classrooms, libraries, housing, and a new Student Center have been most sorely needed. Their immediate impact upon the visible form of M.I.T. will be enormous. But there are developments in another domain of even greater significance, and they have been in process for some little time. They reflect changes in intellectual outlook, in basic academic policies, and in our range of interests. Not that the lessons of the past have been ignored or rejected. In our present approach to higher professional education one may easily recognize many of the ideas and much of the philosophy expressed by William Barton Rogers one hundred years ago. Yet these ideas must now be interpreted in the totally different context of the mid-twentieth century, and they are leading us in directions wholly unforeseen by our predecessors.

The intellectual climate of M.I.T. today is one of extraordinary activity, of ferment, and of constructive movement. There are high hopes and aspirations and an abundance of fresh ideas on the position that this institution should occupy in an age of science. The real purpose of the Second Century Fund is to bring the very best of these ideas to fruition.

At the outset of the Program we established certain objectives.

For most of these the funds are now on hand, and our first priority is to carry each through to rapid fulfillment. However, there are some goals remaining, such as the proposed Graduate Center, for which financing is still incomplete. And as the Institute itself has forged ahead since the inception of the plan, new needs have emerged. Several projects that only recently seemed long term—among them additional undergraduate housing—have now assumed a most urgent importance. Far sooner than anyone might have anticipated, M.I.T. has moved to a higher plateau of development.

As the horizons of science and engineering expand, the opportunities that open before us in new fields appear almost limitless. At the close of my report one year ago, I ventured to sound a note of caution. There is at the Institute a readiness to innovate and a flexibility 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. We cannot engage in every project nor climb every mountain without losing something of the power that comes from well-defined objectives. We need to maintain a focus in our efforts 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.

Never within the past half century has the faculty given more thoughtful attention to the academic development of M.I.T. or indicated a clearer awareness of the risks that go with a wealth of opportunities. This past winter and spring the Committee on Educational Policy, under the chairmanship of Professor Harold Mickley, spent countless hours on matters of teaching and research. Their efforts have been supplemented by the work of school and departmental committees on curricula, by various *ad hoc* groups of the faculty, and by any number of informal discussions. Many of our policies and procedures have come under scrutiny. Discussion and criticism have been uniformly constructive and provide the most reassuring evidence of a healthy concern for fundamentals.

In the spirit of these remarks I propose to dispense in this report with much of the annual inventory, leaving the more detailed review of the year's events to the individual reports of the deans and department heads. Instead I shall try briefly to express some thoughts about the present state of the Institute, about guide lines for the future, and about tasks that lie immediately before us. These views are my own, but they have been strongly influenced by the judgment and experience of my colleagues.

President

Any serious assessment of M.I.T. must take account of several observations which constantly recur in discussions with others about our current progress. The first is an expression of respect for the quality of the Institute, for the stature of the faculty, and for the thoroughness and rigor of the curriculum. The second—and this one hears perhaps even more abroad than at home—is an acknowledgment with surprise of the breadth and range of fields that currently engage the interests of our students and faculty. Both in the formal curriculum and in research, M.I.T. has broken out of the rather limited, traditional domain of an institute of technology. Our support and encouragement of the humanities and the substantial development of the social sciences and of management in recent years appear to be highly regarded. The contributions of our faculty in the fields of economics, political science, psychology, and linguistics are internationally known. There is a general impression that we care about these things and that they are much more than mere fringes about our central activity.

Such comments are gratifying, for we are endeavoring to build upon a foundation of quality, breadth, and balance. But it is from adverse criticism that one learns and benefits most. And on the less favorable side, we must recognize that there is often serious questioning of what is taken to be an increasing identification of the Institute with research on a large scale, with major organized projects and big laboratories, with a flow of Federal funds, and a network of communications and ties to Washington.

It is certainly true that some of the praise is unmerited, but it is equally true that some of the conclusions relating to the role of research at M.I.T. are grossly inaccurate.

Whatever one's present estimate of the Institute may be, it is clear that these issues of quality, of the role of research, and of the expansion of our interests are interrelated and of central importance. Considered together, they bring us hard against one of the most difficult problems in this period of our development. That is the task of directing our growth towards clearly defined objectives.

M.I.T. is growing at a tremendous rate—growing in graduate students, in faculty, in resources. These are the products of our success. But in what degree, and in what relation, is quality compatible with an ever expanding size? This is a question that is by no means confined to our institution, for it is of crucial concern to nearly every major American university. Yet the character of the Institute's development has special properties of its own and stems in large degree from the very nature of our undertakings.

To examine these matters in some detail, I shall begin with a review of some of the facts relating to our size and the trends in our affairs. Figure 1(A) shows that for the past eight years, our undergraduate enrollment has remained essentially level at about 3600, reflecting the decision prior to 1955 to limit first-year admissions to a class of 900. This is still our policy. In view of the rising demand for college education and the special need for graduates in the fields represented here, it was not adopted lightly. It was a decision based on a balance of quality and resources. Although I summarized the main points in the argument for stabilization in my report for 1959, I think it important to recall them in the context of the present discussion.

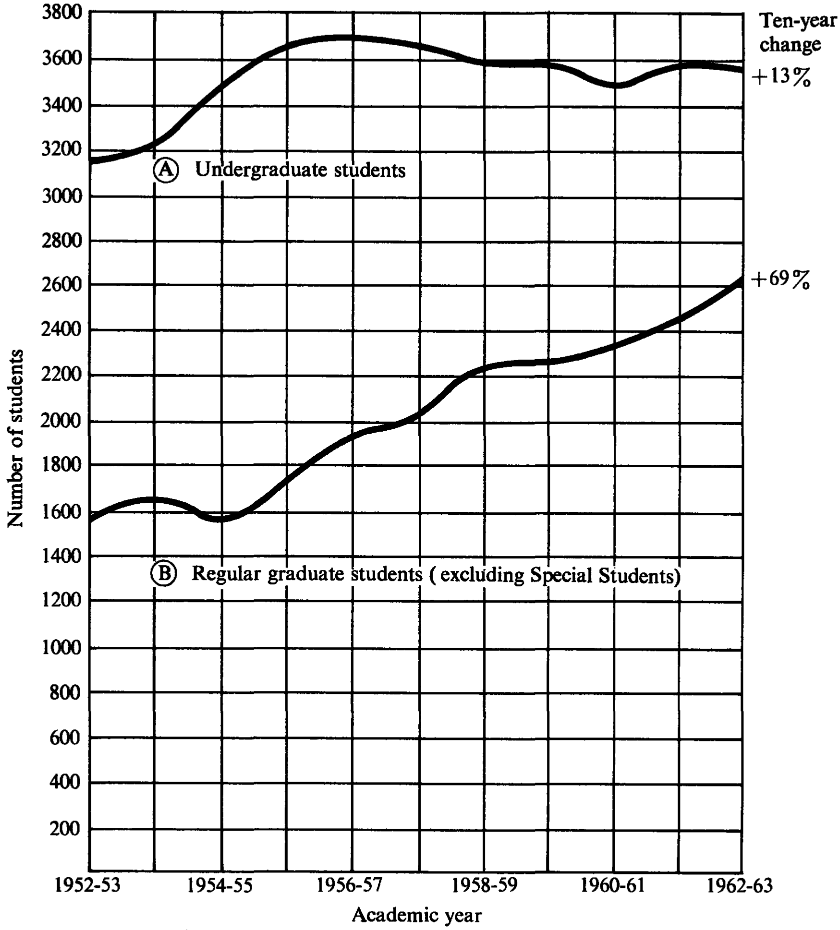
One begins with the premise that M.I.T., of whatever reasonable size, will educate only a small fraction of the country's undergraduate students in science and engineering. What we can at most contribute is a limited number of young men and women of exceptional ability brought to the highest level of professional competence. To stretch our resources to accommodate another one hundred or two hundred students would be to risk the quality of the whole effort. It is in the capability and versatility of our graduates that we will make our contribution to the nation. The freshmen who enter each fall are by every measure among the very ablest of their generation. Our own central purpose, as I have emphasized before, must be to provide them with a program that will set standards and serve as a model of excellence in our fields of education.

The situation in the Graduate School is quite different, as indicated by Figure 1(B). This curve shows an increase in graduate student enrollment of about 69 per cent. It relates to regular graduate students only, of whom there were some 2,600 last year, and does not include special, part-time students who are not candidates for degrees. Throughout the United States graduate enrollments have been growing at a relatively faster rate than undergraduate, and the demands for further increases are heavy. The two curves in Figure 1 indicate the changing ratio between graduate and undergraduate students at the Institute. The encouragement of graduate study, particularly in science and engineering, has been a national policy since the conclusion of the Second World War. Although the Institute has tried to respond freely to these demands, in recent years we have had to take a series of steps to contain them.

Immediately after the war the principal limitation was the

FIGURE 1

GRADUATE AND UNDERGRADUATE
ENROLLMENT, 1952-1962



availability of space and staff in each of the respective departments. Then in 1959 we adopted a policy that permitted an increase in total graduate student enrollment of 5 per cent a year, with special allowances for larger increases in new areas. As the graduate enrollment has continued to climb, it has become apparent that graduate students and the research associated with them represent one of our most rapidly developing pressures for additional space and facilities. This past year we have felt compelled to impose further restraints, reducing the enrollment growth to about 2½ per cent per year, but again with extra allowances for those new fields we have selected for particular support.

We are keenly aware that it is in the area of graduate study that the greatest demands—and the greatest shortages—will develop in the years directly ahead. Here is a clear case of the need for a policy which balances increase of enrollment against the rate of increase in the financial resources and the physical facilities of the institution.

To the undergraduate and graduate students we should add, although they are not shown in the graphs, still another category—the postdoctoral group. The rapid rise in the numbers in this category has been one of the notable phenomena of recent years at all our major institutions. Until lately there was at M.I.T. only a handful; today, under various guises and classifications, there are several hundred.

In their interests and backgrounds they reveal the utmost diversity. Some come as experienced and senior people with the support of fellowships; others, also with fellowships, have just received the doctorate; still others come simply as visitors and guests, and for varying periods, to work with particular professors. There is no uniformity in the procedures and arrangements for their affiliation and no formal policy governing their admission. That they contribute greatly is manifest, for they are active at the forefront of many fields and are welcome and stimulating associates of the faculty. Yet their presence does represent a new and uncomputed cost, and only a few postdoctoral fellowships provide even a small grant to the host institution.

In the changing pattern of American university life, these postdoctoral members are a new constituency. They bring a greater maturity than the regular students and are motivated in part by different aims and a different outlook. I think it inevitable that, in the major institutions at least, they will begin to take the form of a cohesive division, comparable to the emergence of the graduate school at an earlier period. We have been experimenting for some time at M.I.T. with a School for Advanced Study without as yet having found the right solution. However, there now appears to be progress towards an ultimate plan. The Sloan Fellows and the Senior Executive group in the School of Management afford excellent examples of one approach to postgraduate education. We are now about to take another step in the same direction with the establishment of the first Center for Advanced Engineering Study. Soon we shall need to set more explicit conditions for admission to postdoctoral study and recognize the presence of this rather large group on the campus in a more formal fashion.

Turning from students to the faculty, we see from Figure II how it, too, has grown over the comparable period. I have resisted the temptation to plot student-faculty ratios, for in an institution as complex as M.I.T. this favorite criterion of efficiency has become almost meaningless. However, when one takes account of the variety of demands upon faculty time—teaching, the development of new curricula, the direction of graduate theses, the duties within departments and on committees, the service to professional societies and the Federal government—one can hardly escape the conclusion that not every faculty member enjoys an abundance of leisure for research. Moreover, it is apparent that the increase of the whole faculty over the past ten years has barely kept pace with the total growth of the Institute.

In Figures III, IV, and V the gross changes shown in the preceding graphs are broken down according to schools.

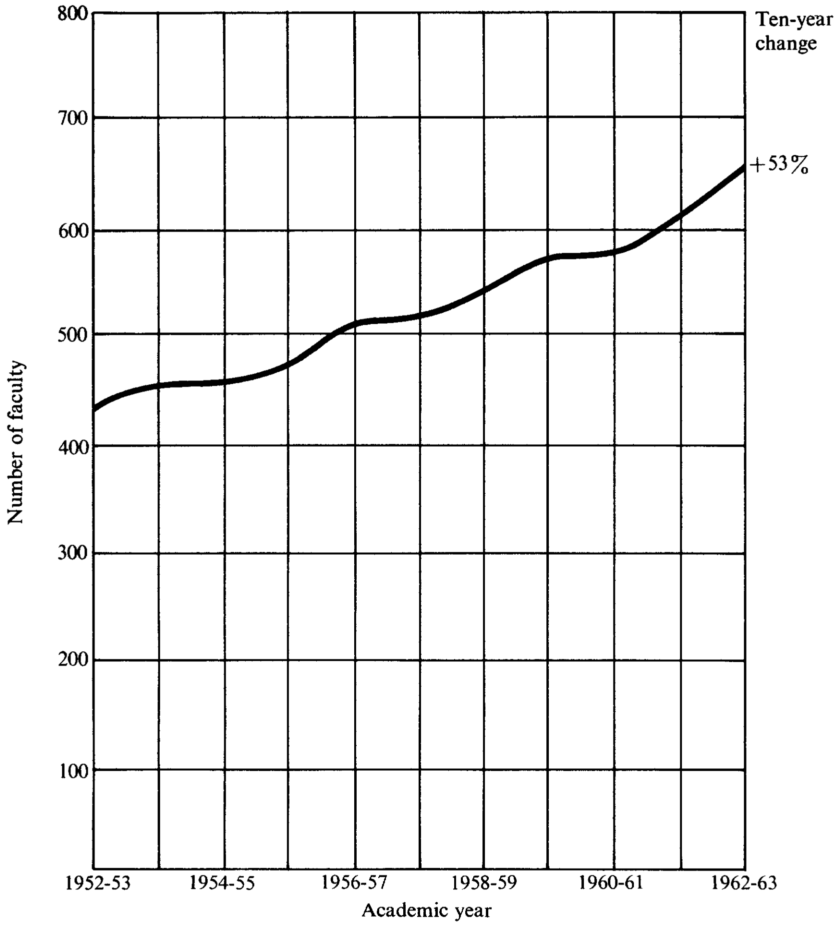
The shift in student interest from engineering to science—another national phenomenon that has been the subject of much discussion—stands out very clearly. Undergraduate enrollment in science at M.I.T. has more than doubled, whereas the number of undergraduate majors in engineering, after reaching a peak in 1955, has fallen off sharply. Graduate engineering enrollment, on the other hand, is steadily rising, and the Institute is by a wide margin the nation's leading source of masters and doctors in engineering. It should be borne in mind that the distribution of undergraduates among the several courses is also affected by the limitation on admission to the freshman class. Since the total number is fixed, an increase of interest in one area is reflected in a decrease elsewhere. Although a quota plan for the individual schools has been proposed from time to time, the idea runs counter to our whole present philosophy of undergraduate education and has, in fact, been rejected by the engineering departments. It is too early to draw firm conclusions, but there are signs that presage a strong renewal of student interest in engineering.

Figures III and IV reveal also the marked shift from under-

FIGURE II

THE FACULTY
1952-1962

This chart includes Institute Professors, Professors, Associate Professors, and Assistant Professors; it does not include members of the Athletic, Medical, and Military Departments, Visiting Professors, Professors Emeriti, and ex-officio members of the faculty.

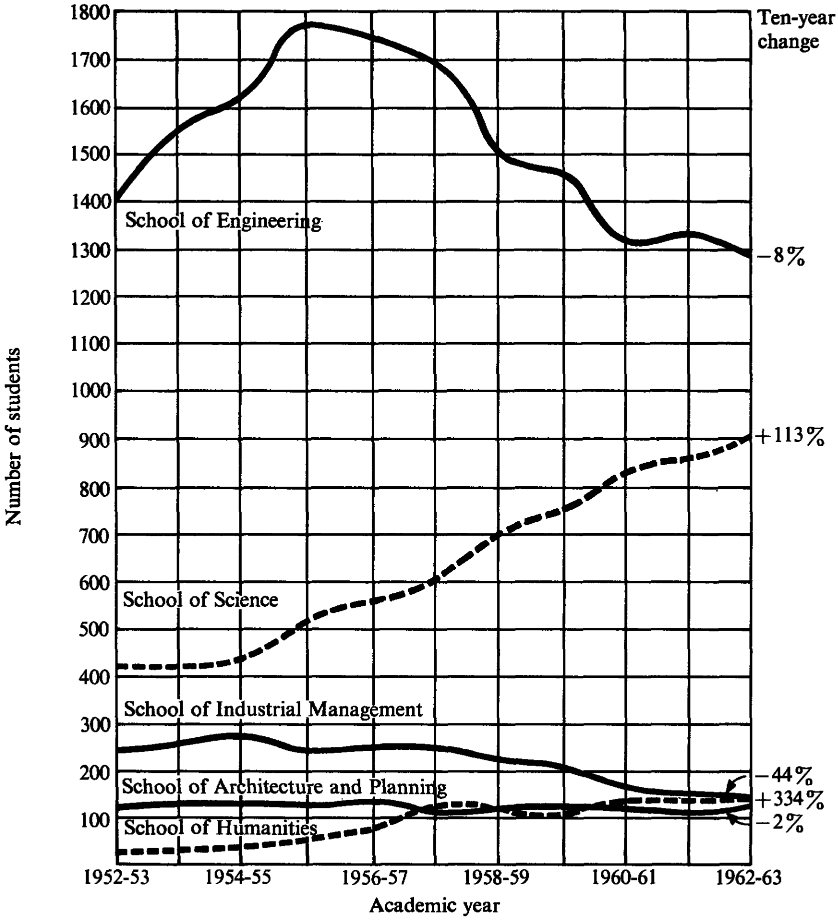


graduate to graduate emphasis in the School of Management. The increase in undergraduate majors in the School of Humanities and Social Science reflects the interest in Course XXI—Humanities and

FIGURE III

UNDERGRADUATE ENROLLMENT
BY SCHOOLS, 1952-1962

This chart excludes first-year students and those second-year students who had not designated a major field of study.

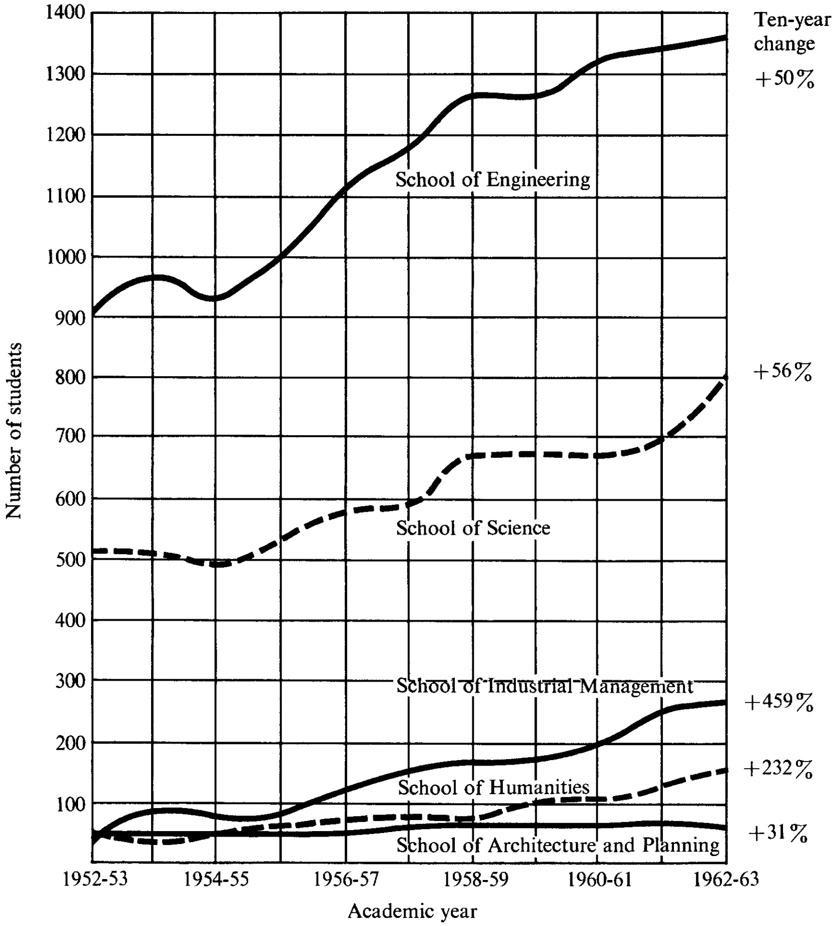


Engineering or Humanities and Science—while the rise of graduate enrollment in this same School is evidence of the important new role of economics, political science, psychology, and linguistics at M.I.T.

FIGURE IV

GRADUATE ENROLLMENT BY SCHOOLS, 1952-1962

This chart excludes Special Students.

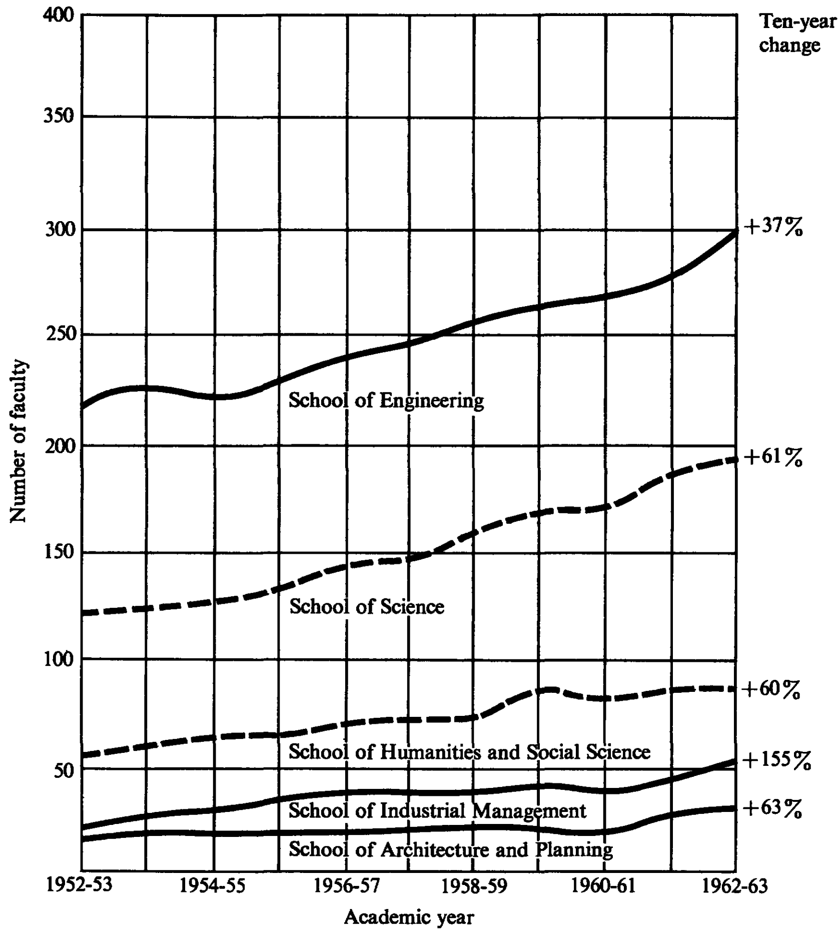


Yet another quantitative measure of our recent development is shown by the changes in educational and research expense exhibited in Figure VI. These curves are compatible with those published in

FIGURE V

THE FACULTY BY SCHOOLS
1952-1962

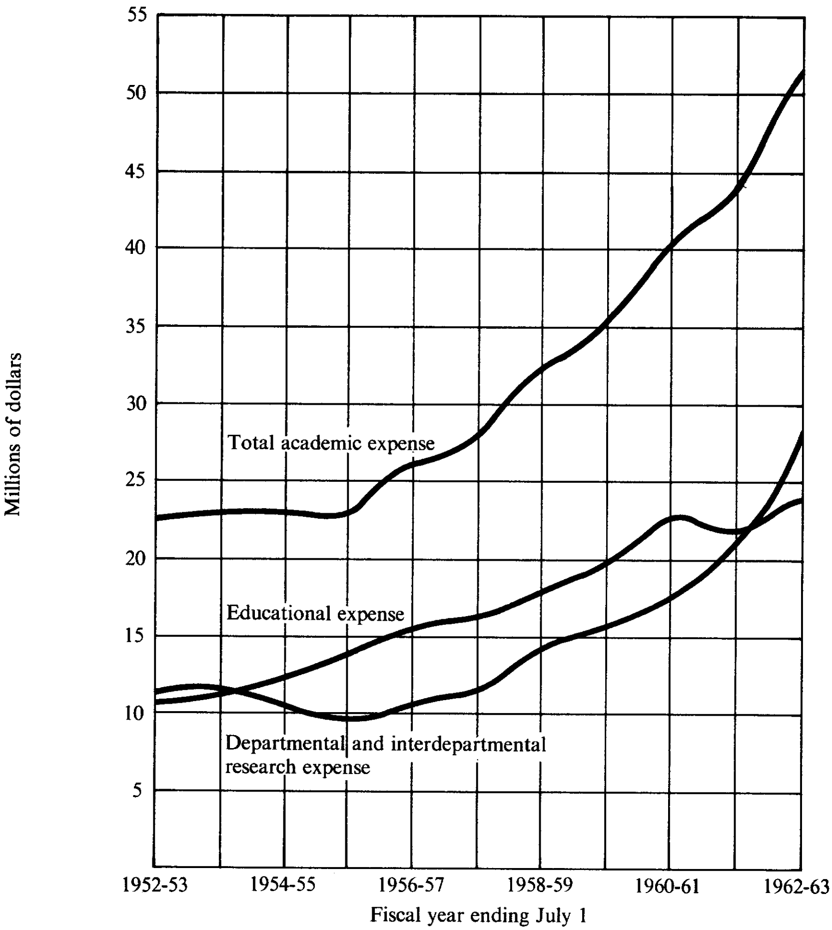
This chart includes all the faculty of Figure II
with the exception of Institute Professors.



my report for 1961. As in that earlier discussion, the Lincoln and Instrumentation Laboratories are excluded, and each curve has been adjusted to reflect its appropriate share of general and administrative

FIGURE VI

ACADEMIC EXPENSE
1953-1963



expense and of the costs of plant operation. It should also be noted that certain expenses attributable to grants-in-aid which were reported prior to 1962 as educational expense are now reflected, due to administrative changes, in the departmental and interdepartmental research expense.

It is apparent from Figure VI that expenditures for research at M.I.T. not only are continuing to rise, but in fact are increasing more rapidly than educational expenses. This chart also shows that these expenditures are now slightly more than half our total academic expense, which is the sum of the educational expense and of the departmental and interdepartmental research expense. Although the ratio of 50 per cent for research to the total does not seem alarming for an institution of the character of M.I.T., nevertheless the trend should be cause for thoughtful concern. The Visiting Committee for Sponsored Research has given particular attention to these mounting figures and in its report of last June urged a high order of selectivity in accepting new programs and continuing vigilance "to ensure that the further growth of campus research makes not only its well-recognized contributions to graduate education, but also strengthens undergraduate instruction, providing the undergraduate with opportunities for participation which enrich his total educational experience."

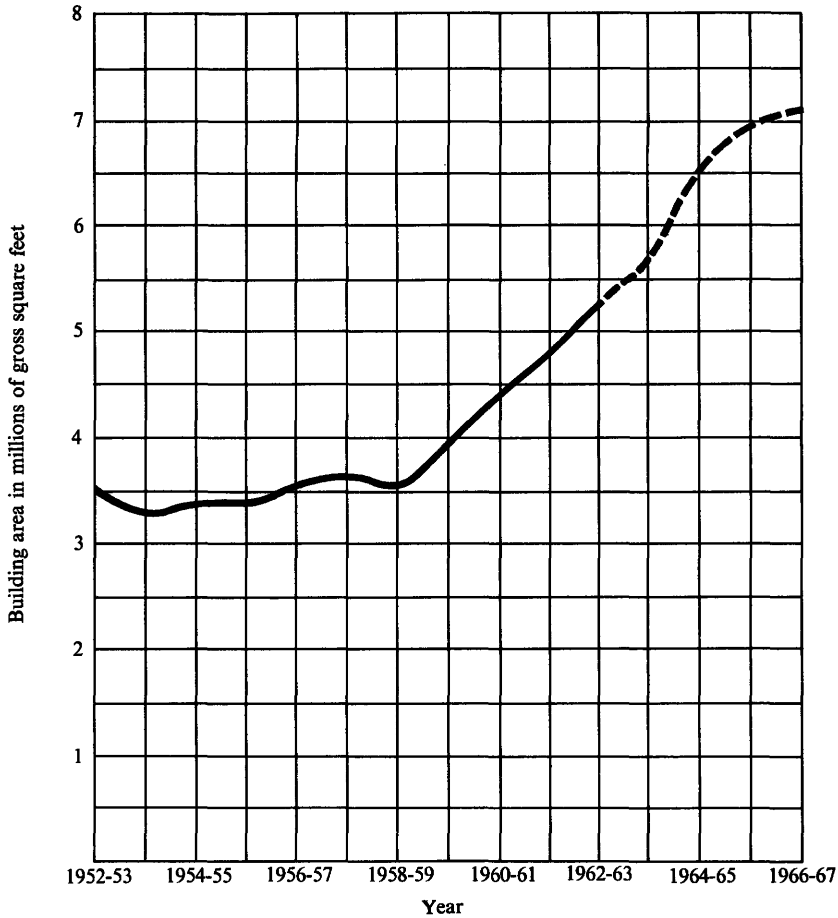
Finally, as one further measure of the current rate of expansion, Figure VII shows the increase in gross square feet of floor space, reflecting graphically the pressures of new fields, more graduate students, and a growing body of research. The curve is extended to include new buildings that have been projected. When they are completed, our total floor area will have been doubled.

In focusing our attention through these growth figures upon the desirability of control and restraint, we must not overlook the highly positive aspects of this same development. Research in a university serves two purposes: to expand the frontiers of knowledge and to advance the education of students. Currently, the volume and patterns of research support by the Federal government are under attack from several quarters. It is asked whether the strong emphasis upon science and engineering may not be diverting students from other important fields of scholarship, whether the emphasis on research for its own sake may not be undermining the concern for good teaching. Lately the interesting suggestion has also been made that research grants to universities may actually be reducing the number of new doctorates available to government and industry—that universities, because of expanding laboratories and research projects, may in fact be absorbing more Ph.D.'s than they are producing.

One cannot respond to such questions with simple generalities. I do believe that the record of contributions to the advancement of

FIGURE VII

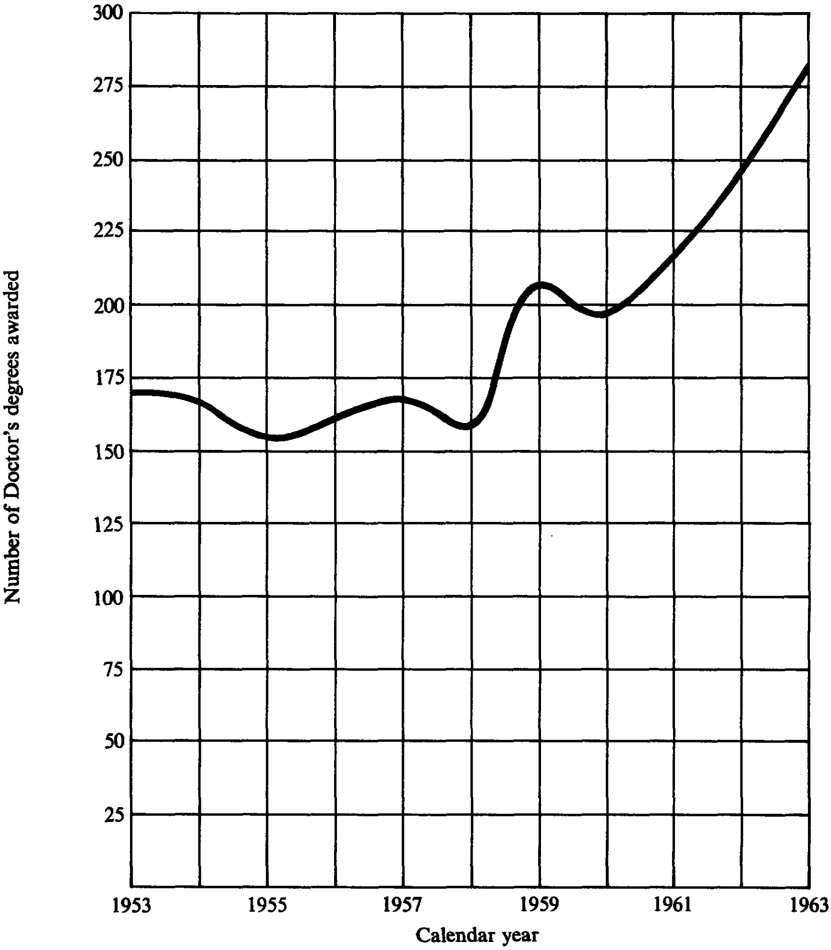
GROWTH AND PROJECTED
GROWTH OF PHYSICAL PLANT
1952-1967



science and engineering emanating from M.I.T. over the past decade speaks for itself. It is my impression that the quality of education, undergraduate as well as graduate, measured by the command of

FIGURE VIII

DOCTORATES AWARDED
1953-1963



knowledge, method, and understanding within the grasp of every student at the moment of graduation, has never stood so high. I am convinced that the character of this education reflects in substantial degree the research environment of the Institute. And as to our net productivity in doctorates, the record is clear. Figure VIII shows the number of doctorates awarded annually since 1953. The total amounts to 2,130, and the curve is rising steeply. Over the same period there have been, of course, additions to the faculty. The net increase in the number who hold doctoral degrees is 313. This includes instructors and lecturers as well as the three professorial grades. Among the research associates, there has been a corresponding net increase of some 85, and approximately 45 more have come to the Division of Sponsored Research. Thus, throughout the past decade of expansion, we have added about 443 holders of doctorates to our ranks, and graduated 2,130. The positive balance, the yield at this highest degree level alone, is represented by the approximately 1,700 men and women who have gone out to schools, to industry, and to government, here at home and in countries in every part of the world.

When one undertakes to analyze the forces which underlie the major developments at the Institute in recent years, it is often difficult to identify cause and effect. Thus we have shown a strong predisposition for large enterprises; but whether this arises from some special mode of thinking on our particular campus, or whether it simply reflects the main trends in contemporary science and engineering, is by no means easy to say.

As a significant example, we may take the evolvement of large interdepartmental laboratories and centers. They represent in many respects an innovation in academic organization. I have commented in previous reports on various aspects of their plan and structure.

Basically each center consists of a group of the faculty representing many disciplines focused upon a common broad field or problem rather than a conventional branch of engineering or science. These new associations reflect the closer interlocking of the sciences and of science and engineering. Each center undertakes to furnish special facilities and to provide for common shops, reading and seminar rooms, and supporting services. Each center also has an administrative staff to relieve the faculty of business details and to conduct the negotiations for grants and financial support.

A center is a well-adapted medium for broad attacks upon large problems of research. Under ideal conditions these need not be highly organized team efforts, but rather a free cooperation among faculty with mutual interests. It should afford wider opportunities for the exchange of ideas and for close collaboration. In our experience at M.I.T. the centers have been extraordinarily effective in drawing in students at the undergraduate as well as at the graduate and postdoctorate levels. Nevertheless, their size and rate of growth must be examined in the light of the possible ultimate effect upon the position of the individual faculty member and student and upon the character of the institution as a whole. This is a fundamental concern and a matter to which I shall return later.

The emergence of these highly important and influential interdepartmental groups in our midst must have an impact upon the organizational structure of the Institute. However, they are in fact only part of a larger, national movement. There are other developments here and at many universities about the country to demonstrate that a well-organized, major collaborative effort can be essential for the progress of *basic* research in certain fields of science and engineering.

One such example is provided by the National Magnet Laboratory, which was dedicated last April. Designed to generate and make available to the whole scientific community the strongest magnetic fields ever produced, it is a large establishment unique in its facilities for research in physics, materials, and the magnet art itself. While the work of the Laboratory will obviously interact with many fields of research in progress at M.I.T., its resources and facilities will draw scientists from other institutions here and abroad. The magnitude of the undertaking is indicated by a research budget that this year will exceed $2 million.

Project MAC, initiated this past spring, is a research program of a totally different character, but it provides another illustration of the essential need for expensive, complex equipment and a group effort to carry out an effective attack on certain technical problems. MAC stands for both "machine-aided cognition," which describes the broad objective of the research, and "multiple-access computer," which is the system to be developed. Thus the project is focused upon basic investigations of the theoretical, logical, and engineering problems that underlie the future development of a powerful new time-sharing system for computers. A budget of $2,220,000 has been funded for the first eighteen months.

As in the case of the large interdepartmental laboratories, the objectives of these projects, and of others like them, are directly related to the interests of many members of our faculty. In the judgment of those who take part, they will thrive best—and perhaps only—in an academic environment. This view is clearly shared by the sponsors.

Nevertheless, because of the scale of such ventures into research, the expense of apparatus, the intrinsic nature of the problems, and the budgetary implications for the Institute as a whole, they constitute an innovation in the academic community, to say the very least. Our common task now—to be shared by the faculty and administration together—is to learn how to promote and maintain under these new conditions the absolutely essential academic purpose and quality of our environment.

Whatever the solutions may be for special cases, the root of the problem of growth lies in the flourishing development of science itself. One can impose quotas for enrollment. One can lay down limits upon the increase in the size of the faculty. But in the meantime science and engineering push on toward new frontiers and burgeon into a multitude of new fields. Nothing has been more characteristic of the past decade or two than the quickening pace of scientific and technological progress. No institution such as M.I.T. can ignore these advances and remain in a healthy state of development. Let me recall a few of these emerging areas of interest and importance.

Biology has been moving so swiftly that much of today's most promising research is directed towards problems and objectives that have been formulated only within the past few years. Plasma dynamics was until recently of moment only to a few physicists studying ionized gases. Now it is a major interest not only of several sciences, but also of engineering, because of the potential application of plasmas to the generation of thermonuclear power, for ion propulsion, and in the conversion of magnetohydrodynamic energy. Other new energy conversion techniques, such as thermionic and thermoelectric converters and fuel cells, have also appeared. The modern communication sciences, though stemming from earlier work in information theory, now span a range of research that extends from computers and controls to studies in neurophysiology and other life sciences. Solid-state physics and molecular engineering are of older origin but are today caught up in a surge of development, with an enormous impact on the whole field of materials. In our Department of Electrical Engineering the principal subjects of teaching and research today are materials and devices, magnetohydrodynamics and energy conversion, the communication sciences, digital computers and programming languages, and automatic control. Each has roots that go back in time, but not one was a major activity here until 1950 or thereafter. Similar changes mark every area of science and engineering, and there are comparable developments at M.I.T. in management and the social sciences. In linguistics, psychology, political science—as well as in management—we have added doctoral programs during the past few years.

Thus the most insistent pressures for growth are in large measure the product of new advances. It would seem reasonable to offset them at least in part by abandoning older courses. In fact, we are constantly subjecting our activities to review, searching for areas from which we might appropriately withdraw. Yet it is characteristic of the problem that a domain of science or engineering, once mastered, rarely seems to lose its importance. Methods, techniques, and interpretations evolve and change. A whole field may lie fallow for a period, only to awaken and to reassert its usefulness in a new context.

The recent history of civil engineering at M.I.T. is a splendid demonstration of a renewal, of fresh life being infused into an old and honored branch of engineering, so that the work in this Department today is to be counted among the most interesting, stimulating, and important of all our efforts. Of the eighty-four subjects offered by the Department two years ago, forty-one have been dropped. Twenty-nine new ones have been added. Such rapid change has given civil engineering at M.I.T. all the characteristics of a new field itself. Newly defined groupings of faculty and students, new subjects, new research directions and laboratory facilities have created a new program focused on a few basic disciplines, and added strength in the applied earth sciences, structures, and systems. A strong and expanding teaching program is fully integrated with faculty research. Much of this research, and of the teaching also, is of interdisciplinary character; and advanced degrees in such fields as geology, physical chemistry, operations research, materials science, chemical engineering, and mechanical engineering, as well as from the more traditional areas of civil engineering, are now represented on the faculty. Largely as a result of this spectrum of interests, the Department is now engaged in joint studies with twelve other departments as well as with the major interdepartmental centers. The very breadth of these activities reflects the changing character of civil engineering and the nature of some of the new problems that now engage the interest of the profession.

In sum, I believe it apparent that the great changes that have come to M.I.T. within the past decade stem from the phenomenal development of science and engineering. The forces for expansion upon this campus are in fact inherent in modern society. So long as we choose to remain in the main stream of advance, we shall have to yield to them to a greater or lesser degree. But we should do so with restraint and with a clear view of purpose and priorities.

Before all else we must preserve our central, overriding concern for education and hold fast to the highest ideals of the academic tradition. We must never forget that the unique product of a university—the basic reason for its being—is the student.

The commitment to teach is by no means necessarily in conflict with a commitment to research. Indeed, the special quality that should distinguish the modern scientific university and set it apart from the laboratories of industry and research institutes is a total involvement in *both* the teaching and learning process. The suggestion is sometimes made that M.I.T. should establish a division of the faculty charged solely with the instruction of undergraduates. We have resisted this superficially appealing proposal as contrary to the spirit of the institution. We have set great store on the unity of our faculty and the development of outstanding scholarly distinction. We expect each senior as well as each junior member to share in the guidance of both undergraduates and graduates, to feel a personal concern for all students, to teach them by example as well as by formal instruction, and to draw them little by little into the more advanced and sophisticated work of the Institute. Of all the developments at M.I.T. within the past few years, none is more reassuring than the increase in precisely this kind of involvement on the part of our faculty and the widespread concern for improvement in the quality of teaching and the content of the curriculum. This judgment could be supported by a vast number of specific examples. The movement is apparent in the growing number of project laboratories, described in earlier reports, and in the work of the Committee on Curriculum Content, upon which I shall comment later.

As we examine further into the factors that affect the character of M.I.T., we must consider the growing demands upon us for public service. Institutionally, M.I.T. has a fundamental obligation to assist the city, the state, and the nation. There are also many calls made upon individual members of our faculty. They feel bound to respond to some of these requests, and they quite properly look to the Institute for support. The question is not simply one of public responsibility but also one of degree and the apportioning of duties. The sum of all these demands is steadily growing, and inescapably they compete for time otherwise devoted to teaching and research. As in most matters of this kind, there are few clear-cut rules of action; but as the number of such diversions increases, I anticipate that the faculty and the Corporation together will have to establish priorities more carefully and formulate in more detail the conditions under which we assume outside commitments.

When a university expands very rapidly, it may develop symptoms that are at first no more serious than growing pains but which, if ignored, may deepen into a chronic condition. One such symptom is the prevalent feeling on the part of individual students and faculty of isolation or personal separation from the main stream of institutional policies and decisions. An academic community thus begins to lose its cohesive unity. For the faculty the constant flow in and out of younger members is a stimulating influence, but the shortness of their stay and the intensity of their preoccupation with teaching and research make it difficult for them to absorb the traditions or the deep feelings of attachment that once went commonly with academic life.

These observations are not characteristic solely of M.I.T.; they apply to a substantial number of the major American universities. One of the principal factors contributing to a weakening of institutional ties has been the emphasis placed upon research and the large availability of Federal funds for support. The comment has frequently been made that it is in fact good that the principal allegiance of a professor should be to his field of scholarship rather than to the particular institution that happens to house him at the moment. Certainly a profound attachment to one's scholarly field is an admirable thing. But if we in the United States develop a population of roving research workers, who move from one institution to another following the vagaries of support without ever putting down roots, we shall lose much of the tranquility and quiet sense of security which are essential for fine scholarship.

M.I.T. today offers not only extraordinary advantages for research but also a multitude of diversions from quiet work. It has been blessed by a minimal amount of factionalism, and over a very long period there has prevailed a remarkably harmonious spirit. Yet in these time of great progress and development, I think it incumbent upon the senior faculty and the administration to assume a responsibility for helping the newcomers to our community to develop a sense of belonging, of pride in the institution, of sharing in its plans and its future. In short, we must encourage, on the part of faculty as well as students, a personal identification with the Institute, with its interests, and with its purpose.

These thoughts lead me to comment on the particular character of our faculty government. By and large, members of our faculty appear to participate less in major policy decisions than is the case at a number of other universities in this country, although, as I noted earlier, they have become deeply preoccupied with matters of educational development. This tendency towards disengagement may be partly an inheritance from the past, but principally I think it is again the result of intense dedication to work and of the pace of research and teaching activity. Now it is true that this condition may simplify the tasks of academic administration, but I doubt whether in the long term it is conducive to the best possible academic environment. There should be a balance between a happy *laissez-faire* attitude towards the responsibilities of self-government and the state of affairs which exists at some institutions, where a large segment of the faculty is completely preoccupied a good part of the time by committee work. If, as I hope, the younger members of our faculty are to be drawn quickly into the life of the Institute and are to identify themselves with its aims, to take pride in its successes, and to share responsibility for its shortcomings, then it is essential that they participate to some extent in the formation of academic policy.

In the course of recent developments each department, each school, each individual group of the faculty has enjoyed a very large degree of freedom to take advantage of new opportunities without great concern for their impact upon other parts of the institution. It is essential that we retain freedom of movement and the kind of flexibility which is the particular privilege of the private institution. However, we must recognize more than we have in the past that we cannot always act as a lot of independent units, that actions in one area do affect the interests of all the others and of the whole. The preservation of balance, adherence to plan and policy, the husbanding of resources, the shaping of our goals, are not simply matters for the administration or the Corporation; they are a responsibility of the faculty as well— a responsibility that must be met with resolution and understanding. We need to give serious attention especially to the process through which our basic resources —funds and space—are allocated to our diverse activities.

Closely related to the foregoing is another problem to which we must address ourselves. As science and engineering grow more complex, as the amount of necessary apparatus and the costs increase, the incentives to team work, to group projects, and to large laboratories grow in proportion. One of the distinctive qualities of M.I.T. in recent years—upon which I have commented earlier in this report —has been the facility with which such groups have formed, the harmony which has marked their efforts, and the general ease with which both students and faculty have been able to move from one field or department to another. By and large, the productivity of these large laboratories has been impressive. Yet I think it of the utmost importance—and this admonition applies not only to this institution but also to the whole of science, and indeed to much of modern scholarship—that in our cultivation of group activities we do not neglect the individual. This past August, in a tribute to Professor Arthur von Hippel at the opening of his symposium on Molecular Designing of Materials and Devices, I made the following comment:

"I most certainly do believe that the interdepartmental laboratories and their newer versions, the research centers, have an essential part to play at M.I.T. and at other institutions about the country. The scale of the modern university, the cost and complexity of modern scientific research, are such as to make this conclusion simply inescapable.

"But if universities are to preserve in this brave, new technological world the special quality that sets them apart from all other forms of social institutions, then they must continue to offer a haven and an intellectual climate in which the highly creative, highly individualistic worker can also pursue harmoniously and fruitfully his own course in his own way.

"I do believe it possible to reconcile both objectives. I believe that the Research Laboratory of Electronics, for example, *has* demonstrated over the past fifteen years that it *is* possible to encourage and protect the imaginative, creative student in the environment of a large laboratory. But now, of all times, when science and the universities are being transformed almost overnight, we need constantly to be reminded of the true ideals of academic effort."

The nature of Federal funding of academic research contributes to the complexities of this problem. There has been a laudable desire on the part of a number of public and private sponsors of research to support individuals rather than projects. As a consequence, however, the individual professor is placed in the position of having constantly to cultivate the sources of future funds and is burdened with the preparation of proposals and progress reports. Although the objective of supporting individual scholars is motivated by the highest ideals, in practice it is just this procedure that has contributed most to the charges of opportunism, to the directing of proposals toward popular fields, and to the rise of a new class of "scientific entrepreneurs." An alternative solution to counter some of these criticisms is the procedure of block grants. These are not necessarily "projects" in the pejorative sense of that term, but grants made to a department or a laboratory of a university for research in some specified area of science or engineering. Thus the university itself, through the department or laboratory, is entrusted with the responsibility of administering the funds. The grant is made according to the institution's record of total productivity and quality. In sum, it represents a judgment of the stature of an institution in the given field, and the individual faculty member is relieved of much of the burden of contract negotiations and administration.

The block-grant idea as it has been effectively developed in several areas at M.I.T. over the past ten years or so has certain great advantages; yet I think we must recognize that as our research units grow larger and the numbers of students and faculty involved increase, there may develop a subtle but almost irresistible pressure towards an undue amount of organization and of group operations. Without wishing to exaggerate the dangers, I do feel the need for thoughtful surveillance. It seems to me that there is a place for both plans of funding research. Our principal care must be to insure that each individual faculty member is afforded the maximum support to develop in an intellectual and organizational environment best adapted to his own interests and gifts.

Finally, I think the time has come to give serious thought to the desirability of changes in the formal administrative structure of the Institute in keeping with the vastly extended range of its interests and obligations. In many respects, M.I.T. operates as a highly centralized organization. Our procedures are inherited from the time when we were a great deal smaller—when this was in fact, as well as in name, an "institute." The departments today are indeed grouped into five schools, each under an academic dean, and in recent years there has been a conscious endeavor to allot an increasing degree of responsibility and authority to these deans. Nonetheless, the school autonomy is far less than is generally the case for professional schools of most universities.

Unified central action has many advantages. Yet as the Institute increases in size and complexity, these procedures may become an impediment rather than an aid to rapid and wise decisions.

There are aspects of the present administrative plan that I believe we should always endeavor to retain. Among these is the joint participation of the deans in the appointment procedure, which leads to a uniformity in quality of appointment and scale of salaries. We need clearly established basic policies and goals arrived at by common consent. But there are many budgetary matters and space allocations that I believe now could be delegated to the schools for independent administration. With our total budget rising year by year, reflecting an extraordinary variety of interests, it would seem wise to examine whether we now have the optimum balance between centralized authority and decentralized responsibility.

II

Although I have omitted most of the usual review of the year, there are a few special developments that I think it important to summarize.

I referred earlier to the deep concern throughout the Institute for undergraduate education and for our obligation to maintain M.I.T. as a superb teaching institution. In my recent reports I have described in some detail the unremitting efforts of the faculty to keep our curriculum relevant, fundamental, and strong. These efforts have continued over the past year, and I want to cite a few to convey an impression of the whole.

In the School of Engineering there has been continued development of the idea of projects laboratories. In several departments instruction by means of realistic design studies has been extended. We are seeking better ways to introduce the student to the problems of systems engineering, and throughout the School there has been renewed emphasis on experimental problem solving.

In the School of Science, the Department of Biology has developed an entirely new introductory subject. Unlike traditional elementary biology, it will be presented from the molecular point of view and will take special advantage of the strong background of all our students in mathematics and physics. In the Department of Nutrition and Food Science there has been a growing teaching involvement at the graduate level with various aspects of medicine and medical science. During the past year we instituted graduate programs for physicians in clinical nutrition and metabolism, for dentists in oral science, and for veterinary pathologists in physiological chemistry.

M.I.T.'s extensive work in applied mathematics has been brought into sharper focus and given greater coherence with the establishment of a Committee on Applied Mathematics and the appointment of Professor Chia-Chiao Lin as the first chairman. A sequence of elective subjects at both the undergraduate and graduate levels has been developed to guide and encourage students with special interests in the field. The Committee also conducts a series of weekly colloquia which, while centered in the Department of Mathematics, provide a second focus of attention for students and staff in geophysics, meteorology, physics, aeronautical engineering, mechanical engineering, and other areas with interests in applied mathematics.

The School of Management will offer for the first time in the fall of 1963 a two-year sequence for undergraduates in the new field of industrial dynamics. This work, which will be available to a limited and selected number of juniors, will consist of a program of research and guided study in management for a systems point of view. In the Humanities we have continued to strengthen the double-major Course XXI, and some eighty-five students, the largest number yet, were enrolled this past year. We have added further subjects in psychology, linguistics, and political science.

The work of the Science Teaching Center has progressed to the point where the new treatment of introductory physics, giving added emphasis to relativity and quantum physics, will now be offered in the regular curriculum. Last year Professors Nathaniel H. Frank and Anthony P. French explored in a freshman seminar the feasibility of an approach to the teaching of special relativity based on dynamics. A substantial amount of new material has been developed for an introductory course which will be taught to two sections of freshmen during the coming year.

The general freshman seminars were offered for a second year with even greater success. These seminars for small groups of freshmen are designed to promote a close association between faculty and student. The individual subjects span the whole spectrum of faculty interests and provide exceptional opportunities for serious study with a great deal of individual responsibility. The effectiveness of the seminars now needs to be evaluated further prior to our seeking the means to finance them on a permanent basis.

The catalogue of such developments and improvements in education at the Institute is long. They have taken place in every area and at every level. But there is one of such overriding importance for the whole of M.I.T. and for the future of our educational plan that I wish to review it in some detail.

A year ago I reported on the establishment of a special faculty committee under the chairmanship of Professor Jerrold R. Zacharias to undertake a review of the core curriculum. Throughout the past year the Committee on Curriculum Content has addressed itself to this difficult task with the greatest energy and has, in my judgment, produced the most penetrating study in our history of undergraduate education at the Institute.

They have examined in detail the core subjects in each of the basic disciplines—engineering, physics, chemistry, mathematics, the humanities—and in biology as well. They have read the primary texts used by undergraduates and much of the reference material. They have studied the form of the curriculum as well as its content. They invited expert testimony from our ablest teachers, from faculty at other universities, and from leading industrialists. In short, their review has been broad and sweeping.

During the year a widening circle of the senior faculty was involved in the discussions and deliberations. In the spring the Curriculum Committee met first with the Committee on Educational Policy and later with the Faculty Council. After discussions with these groups, an interim report was issued to all the faculty in June. I shall not summarize this report in detail but wish to indicate the nature of the issues and the character of the recommendations.

While the Committee viewed the undergraduate experience as a whole, it concentrated especially on the first two years. Its major recommendations are based on the premise that many M.I.T. students are capable of a far more mature approach to education than the traditional system affords. The Committee feels that our undergraduates, particularly during their freshman and sophomore years, need more opportunity to exercise initiative and to accept responsibility and that some checks should be imposed to prevent excessive preoccupation with grades and credits. The Committee believes that the fault lies in the organization of the curriculum which currently, in their view, gives too much emphasis to immediate tasks rather than to the education of students as individuals capable of different achievements. One of its chief concerns has been the excessive fragmentation of time which, they believe, more than any other single factor inhibits a sustained inquiry in a subject or project that might engage a student's special interest and prevents an early worth-while experience of a professional kind.

The Committee has urged a series of measures to reduce the pace and competitiveness of education at M.I.T. and proposed a program which provides greater flexibility and increased choice of electives. There is, of course, inherent in the nature of a scientific curriculum the need for prescribed requirements, and the Committee in all its deliberations was conscious of this conflict between flexibility and specified pattern. Nonetheless, the weight of their analysis favors greater freedom. Accordingly, they have made recommendations to provide for individual variations and yet assure some balance between professional and more general needs.

One major proposal is that the number of subjects now specified in the common core of science and mathematics be reduced and that special elective subjects in other science areas be added as part of the core requirements. The Committee, which was drawn from several departments and schools, also believes that ways must be found to acquaint the student with the creative, professional aspects of engineering while he is studying the basic scientific subjects, and they recommend that he be given an early opportunity, perhaps even in the freshman year, to elect engineering subjects.

The Committee has also proposed that the Institute change from its present semester system to a quarter system, with three quarters as the normal academic year and three subjects per quarter as the normal student load, instead of the five or six and frequently even seven that some students now carry in a semester. The Committee was unanimous in its view that all subjects be presented in depth. The course content could be limited, they felt, but the questions raised must be serious and precise. They have recommended also that the freshman curriculum be made sufficiently flexible so that students in the transition from secondary school can advance at varying rates and more in accord with individual aptitudes or academic backgrounds. They have strongly urged more freedom for experimentation and innovation in the freshman subjects.

The Committee re-examined the present laboratory subjects and discussed ways in which their significance could be increased. From this have come recommendations to improve the nature of the undergraduate laboratories in core subjects and to use the laboratory to introduce the student earlier and more effectively to the basic nature of science and engineering. The Committee has set forth the radical view that laboratories should be decoupled from the subject and that each student be required to take two one-term laboratory subjects during his first two years at the Institute.

Each of these new subjects would be scheduled at least two afternoons a week. They would have "project" rather than "exercise" emphasis; and each experimental problem to be solved, or device to be built, would require less than a term but more than a single session for its completion. The traditional set experiments would be eliminated, and the chief purpose of the laboratory would become that of providing a means by which the student may learn the essential nature of the experimental approach.

All these various proposals and recommendations are still in the stage of ideas. The faculty is now actively examining their feasibility. Their ultimate merit must, of course, stand the test of experience and practicality. Yet the work of the Committee has already had an impact on a number of specific developments and is creating a new mood of educational experimentation.

Within the past decade the interest at M.I.T. among both faculty and students in space science and engineering has mounted steadily. The Institute has made outstanding contributions, especially in guidance and communications, to the national space program. Last year I reported on the formation of a Committee on Planetary and Space Science to encourage interdepartmental study and research in these areas.

The total program of space research at M.I.T. is now extensive. In the physical sciences and in engineering it includes studies in space physics, mathematics, information and computer technology, geophysics, chemistry, meteorology, space propulsion, navigation components and technology, energy conversion, and materials. And it includes also space-related fields that touch upon biology, nutrition, the social sciences, and management. Presently more than 150 members of our faculty, representing fourteen departments and four schools, are engaged in these studies.

To strengthen this broad program the faculty, under the leadership of Dr. Charles H. Townes, Provost, established this spring a Center for Space Research. A grant from the National Aeronautics and Space Administration of $3 million has been augmented with funds from the Second Century Fund to construct a building for this Center. Preliminary plans provide for a five-story structure containing 100,000 square feet of laboratory, classroom, and office space. To be located on Vassar Street adjacent to the Metals Processing Laboratory, the structure will be another step in the development of our

North Campus. It is expected that final plans will be ready for bidding next spring.

Dr. John V. Harrington, former head of the Radio Physics Division at Lincoln Laboratory, has been appointed Director, and advisory and technical committees have been formed. In support of the research program and supplementing the funds for the building, N.A.S.A. has made a grant of $2 million.

The establishment of the Center for Space Research provides another illustration of the interdepartmental center at M.I.T., which will draw in this case not only upon engineering and the physical sciences, but upon the life and social sciences and upon the School of Management as well. The sponsor of the program has expressed the hope that M.I.T. will examine aspects of the economic and social impact of our national involvement in space exploration.

The Center will also undertake experiments directly in space, using either space vehicles or ground-based equipment. These may include, for example, plasma and cosmic ray probes, exploration of the solar corona, and experiments in boiling and heat transfer under conditions of zero gravity. The instrumentation for several in-space experiments has been completed with great success, and other experiments are now being planned. There are plans also for the development of small space probes which would widen the participation of faculty and graduate students in flight experiments.

Earlier in this report I commented on the increase in recent years in postdoctoral and other postgraduate study at the Institute and noted that we are now to add at this level a Center for Advanced Engineering Study. Designed to provide a substantial new curriculum of postgraduate work for both practicing engineers and for professors of engineering, the Center was established this spring with a grant of $5 million from the Alfred P. Sloan Foundation. It promises to give form to an altogether new component of engineering education and to contribute significantly to the effort we have undertaken through the Second Century Program to strengthen engineering education on all levels.

Basically the purpose is to meet the rising need for more engineers with the capacity to turn the discoveries of modern science to useful ends. It will endeavor to enlarge the potential of mature engineers and engineering managers now in the profession and help them to cope with the advancing technology of our time.

With this same end in view, a number of industrial concerns have inaugurated first-rate short courses, both in-plant and in association with special university programs. M.I.T., through its Summer Session, has offered similar programs over the past decade or so. Last year, for example, we provided nineteen short summer programs in advanced engineering subjects. These subjects—in such fields as optical masers, heat transfer, structure of materials—enrolled about 1,000 engineers from industry and government and some 140 faculty members from the other educational institutions. It is our hope that the new M.I.T. Center will add another dimension to all such post-graduate education in engineering.

Professor Harold S. Mickley, Ford Professor of Engineering, has been appointed Director. A new building, of some 55,000 square feet, will be constructed along Massachusetts Avenue between the School of Architecture and the Guggenheim Aeronautical Laboratory. While integrated with the whole range of our activities, the Center will draw fully upon all the resources of the Institute. We expect to admit a limited number of engineers and teachers of engineering in the fall of 1964, and plans are developing for the curriculum. Besides special one- to two-week courses on the model of our established summer studies, we are currently contemplating three types of programs:

1. Eight- to ten-week programs designed to provide a quantitative working familiarity in new areas of importance and to help the participants to increase substantially their capacity to exploit such fields for useful ends.
2. Other eight- to ten-week programs designed to cover broad areas of science and technology for senior engineers concerned with the initiation and direction of comprehensive projects in government and industry. The objective will be to review the directions of recent advances and to aid the participants in relating these developments to the context of their own organizations.
3. Twelve-month courses that in most instances will be broadly adapted to individual goals. While some participants may follow a somewhat formal program, all will be able to some extent to pursue freely studies related to their particular needs.

The Center represents in every respect a major addition to our School of Engineering, and we hope, of course, that it may become the prototype of a valuable new resource for the profession. That it should also forge another bond between the Institute and industry seems clear, and we have begun discussions with industrial groups to identify the types of engineers who might participate and to determine in detail how to serve them most effectively. The response has been wholly enthusiastic. A press commentary has called the Center "significant far beyond the frontiers of one campus . . . a hint of the future pattern of education and manpower." This is our goal as we now undertake its development.

The extraordinary increase in the variety and complexity of the outside professional activities of our faculty in recent years has generated a number of problems to which we must give the most serious consideration.

More than a year ago, an *ad hoc* committee under the chairmanship of Professor Frank undertook this very difficult assignment. The problems of conflict of interest, the balance of outside and internal obligations, and of establishing a basic code of ethics by which we should govern ourselves are exceedingly complex but of enormous importance for the development and good name of the Institute.

Within the past twelve months, the Committee has submitted a report which constitutes a most statesmanlike treatment of the whole subject, marked by a clear analysis and sound recommendations. The Committee faced up to the thorny problems and found here a good balance between academic freedom and academic responsibility.

Although I commented orally last March to the Corporation on the recommendations of the Frank Committee, I think it appropriate to record here the main conclusions drawn from the report itself.

The Committee notes that by far the most sensitive, subtle, and complex ingredient in this whole area is the widespread close interaction with government, owing both to the large Federal support of research at M.I.T. and correspondingly large Federal expenditures in industry. Thus the sensitivity of our situation with regard to possible conflicts of interest, both legal and ethical, has grown not only with respect to normal technical consulting for industry and service on government advisory boards and panels, but especially with regard to the launching of new business enterprises and to service as officers of existing companies. Equally important, if not more so, it is incumbent on the Institute to provide continuing leadership in the evolution and establishment of new requirements as will constantly appear as the coupling between educational institutions, industry, and government grows more intricate and involved.

The report reaffirms the fundamental principle that there can be no compromise with the position that the primary and overriding loyalty of a full-time staff member is to the Institute, no matter what the spectrum of his activities. Any useful statement of procedures and regulations must be predicated on this principle as it applies both in fact and appearance.

The Committee recognized that appointment to the faculty of an academic institution involves a relationship which differs in many ways from employment by other organizations. Duties and responsibilities are less clearly defined, there are fewer rules governing the behavior of the members of the organization, the hierarchical structure is less formal, and the individual has greater autonomy. The independence of the faculty is substantially greater, and the influence of the administration upon the affairs of individual faculty members is substantially less than in the case, for example, of an industrial organization or a governmental agency.

As a consequence, the successful functioning of an academic institution depends heavily on the acceptance by each faculty member of a high degree of personal responsibility for his contribution to the goals of the institution, for integrity, and for the exercise of thoughtful judgment in any of his activities which may affect negatively the welfare or reputation of the institution. The "price" of academic freedom, and of the other freedoms associated with membership on the faculty, is personal responsibility. Moreover, the necessary degree of personal responsibility cannot be defined by specific rules and regulations; the relationship must rest on mutual trust and understanding.

The Committee agrees that the primary function of an institution such as M.I.T. is education. To provide educational opportunity of the highest quality, the faculty must possess outstanding competence and maintain it by furthering the growth and the use of knowledge. This requires strong and continuing research activities. The institutional purposes are also served, and the competence of the faculty generally increased, by various forms of public service. Because M.I.T. is a technical and scientific institution, the relationships of its faculty with industry and government are somewhat closer and more complex than is true of many other academic institutions. Thus service in a variety of forms—in addition to teaching and research—is recognized within moderate limits as part of the normal responsibilities of the faculty.

Finally, the Committee stresses the importance of advice and disclosure, of continuous and open communication about outside activities between individual faculty members and their department heads. The purposes of such communication are to provide for full discussion, awareness of possible problems and difficulties, recognition of the rationale behind Institute philosophy, and guidance to the faculty members.

In accepting the report, the faculty recognized the continuing nature of the problem and voted to establish a Standing Committee on Outside Professional Activities. It will be the responsibility of this permanent committee to be informed, to examine cases of potential conflicts of interest, and to insure that our policies and procedures are in harmony with the conditions of our rapidly changing technological society.

I have spoken of the importance of faculty participation in the formation of academic policy. The work of the Frank Committee is a splendid example of a faculty assuming responsibility for its own affairs.

This report has departed radically from the conventional format. Many important events of the year have been passed over without comment, but I have endeavored in these pages to identify the main lines of progress and to define the large tasks that lie ahead. There are vital issues of academic and administrative policy to be clarified and resolved. They present to us an enormous challenge, and opportunity, for the steps we take now will determine the character of M.I.T. for a long time to come. Moreover, the developments that I have examined here reflect in great measure the forces of change that are affecting our society as a whole.

Indeed this involvement in contemporary affairs, this deep engagement in the major movements of the day, is entirely in keeping with our tradition. And as one looks about at the most vigorous modern institutions—whether in industry, in government, or in education—one comes upon the same problems of expanding scale, of the impact of research, of the breakdown of timeworn patterns of organization and channels of communication. These all are products of the scientific revolution. It is in this larger context that we should view the current changes and developments that are taking place at M.I.T.

J. A. STRATTON

III

STATISTICS OF THE YEAR

The following paragraphs report briefly on various aspects of the Institute's activities and operations during the 1962-63 year.

REGISTRATION

In 1962-63 student enrollment was 6,695 as compared with 6,454 in 1961-62. We estimate that enrollment this fall will be about 6,900. Married students in 1962-63 accounted for about 23 per cent of the enrollment. There were 208 women enrolled, 110 of whom were graduate students.

Enrollment in the Graduate School was 3,142, including 122 officers from the United States armed services.

Students who entered M.I.T. last year held degrees from 308 other colleges and universities, 175 American and 133 foreign. The foreign student population was 814, representing some 12 per cent of the total student body. These students were citizens of 75 different countries.

Degrees awarded by the Institute in 1962-63, in the various categories, were as follows: 834 Bachelor's degrees, 692 Master's degrees, 83 Engineer degrees, and 274 Doctoral degrees—a total for all categories of 1,883.

STUDENT AID

This year 1,799 undergraduates, or about 50 per cent of those enrolled, received $1,536,546 in scholarship aid and $639,374 in loans. These two categories of direct aid totaled $2,175,920, a gain of 10 per cent over the year before.

Undergraduate earnings in term-time jobs this year amounted to $938,126. Thus, through scholarships, loans, and campus employment, $3,114,046 was made available to undergraduates during 1962-63.

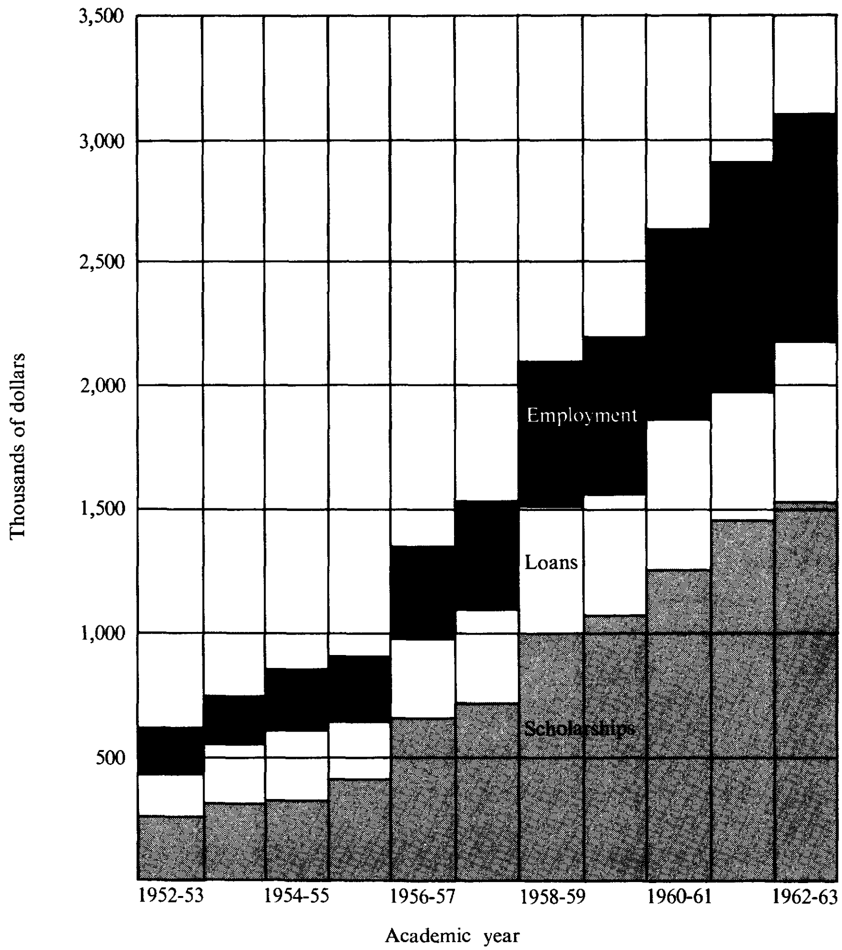
Sixty-five students also received $34,315 under the Institute's Installment Credit Plan, which permits a portion of the tuition fee to be paid over a ten-year period.

The balance of funds for student loans increased by almost $1,000,000 during the year. Scholarship endowment also increased, and the total of this endowment is now $10,479,000.

To graduate students, the Institute awarded $977,174 in fellowships and scholarships, $422,801 in staff tuition grants, and $305,789

FIGURE IX

FINANCIAL AID TO
UNDERGRADUATE STUDENTS
FROM ALL SOURCES
1953-1963

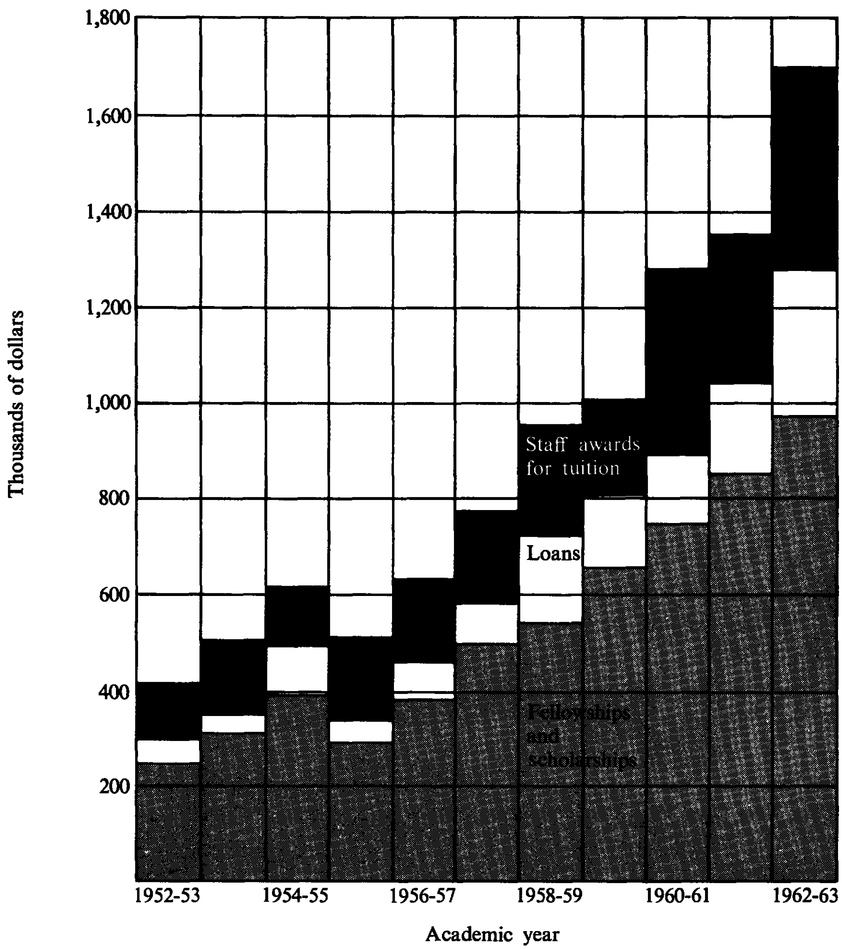


in loans, for a total of $1,705,764. The corresponding figures for last year were $856,930, $309,474, and $182,725 respectively, for a total of $1,349,129.

FIGURE X

FINANCIAL AID TO GRADUATE STUDENTS
AWARDED BY M.I.T.
1953-1963

Staff wages are not included



In addition, 291 graduate students held fellowships awarded by Federal agencies, and the Institute paid $4,089,267 in staff wages. Figures IX and X show the history of recent increases in financial aid to undergraduate and graduate students at the Institute.

PLACEMENT

About 450 employers, essentially the same number as a year ago, visited the Placement Bureau during the period between October, 1962, and April, 1963; and some 1,243 students met employers' representatives in 7,120 interviews. The average offer to this year's graduating seniors was $606 per month; to Master's candidates, $725; and to Doctor's candidates, $990. The corresponding averages last year were $582, $690, and $925 per month.

Slightly more than 60 per cent of the seniors who took their degrees in June were going on to graduate work. This compares to 58 per cent of the comparable group last year and to 33 per cent just five years ago.

FINANCES

During the year 1962-63 the Institute's educational and general expenses—excluding the direct expenses of departmental and interdepartmental research and of the Lincoln Laboratory, Instrumentation Laboratory, and Operations Evaluation Group—amounted to $33,757,000. This compares to educational and general expenses of $31,033,000 in the preceding year.

The direct expenses of the departmental and interdepartmental research increased from $19,440,000 to $25,014,000; and the direct expenses of the combined operations of the Lincoln Laboratory, the Instrumentation Laboratory, and the Operations Evaluation Group increased from $57,480,000 to $72,558,000. Responsibility for the Operations Evaluation Group was transferred two years ago to another institution, and this account is now all but terminated.

The Institute's investments, excluding retirement funds, had a book value at the end of the fiscal year of $146,119,000 and a market value of $228,976,000. This compares to book and market totals of $132,719,000 and $186,721,000 last year. Endowment and other funds increased this year from $134,875,000 to $150,008,000, and the educational plant assets from $51,856,000 to $59,334,000.

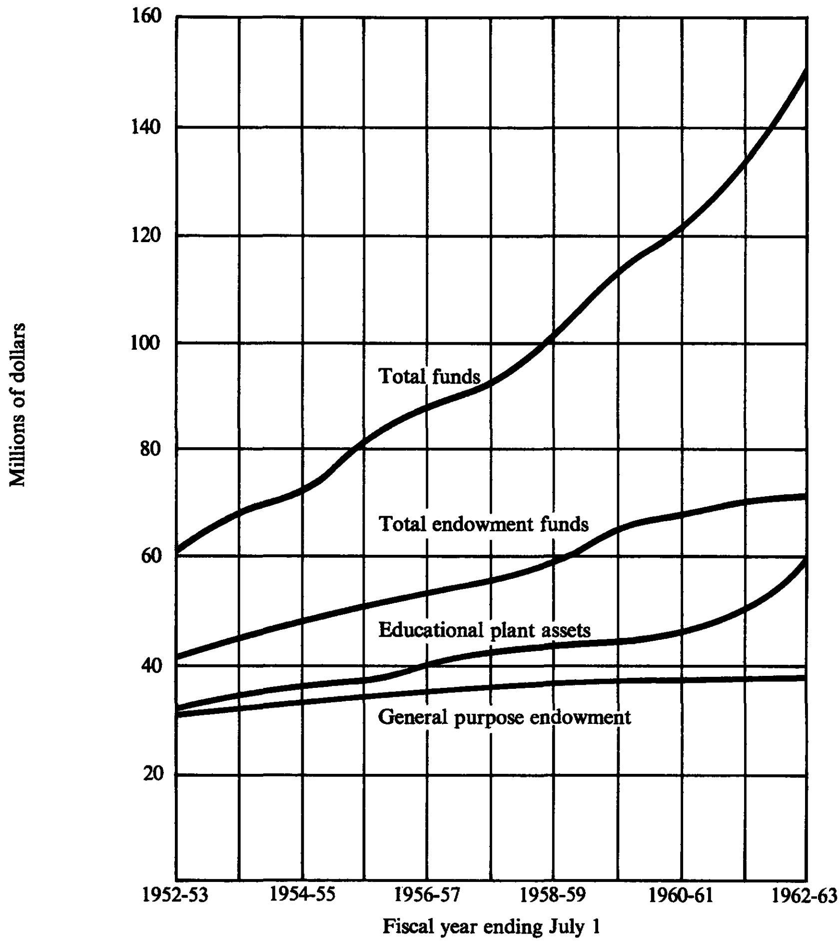
The rate of income earned last year on the funds sharing in the general investments was 6.51 per cent on the average book value, compared to 6.44 per cent in 1961-62. The total income on the general and special investments was $7,245,000 compared to $6,581,000 in the previous year.

Figure XI shows the recent growth of M.I.T.'s funds and plant.

FIGURE XI

THE GROWTH OF M.I.T.'S
FUNDS AND PLANT ASSETS

1953-1963



GIFTS

Gifts in 1962-63 amounted to $17,479,000 as compared to the very similar amount of $17,691,000 the year before. As reported separately by the Treasurer, this total includes major gifts for part of the cost of a building for chemistry, for the women's residence, and for a new library and research center for management and the social sciences. It also includes $429,000 reported by the Alumni Fund, but it does not include Second Century Fund pledges payable over a period of years.

Of the gifts received, 29 per cent came from foundations; 23 per cent from corporations; 19 per cent from alumni; 20 per cent from other friends; and the remainder from bequests and other sources. The Treasurer has also reported that over two-thirds of the gifts related to the Second Century Fund have now been received.

IV

PERSONNEL CHANGES AS OF OCTOBER 1, 1963

CORPORATION

DEATHS

GODFREY L. CABOT
Life Member

FRANCIS J. CHESTERMAN
Life Member

WILLIAM L. STEWART, JR.
Life Member

TERM EXPIRATIONS

CLARENCE H. LINDER
Special Term Member

DONALD W. DOUGLAS
Alumni Term Member

ROBERT C. GUNNESS
Alumni Term Member

WILLIAM L. TAGGART, JR.
President of Alumni Association

GOVERNOR JOHN A. VOLPE
Ex-officio Member

CHANGES

JAMES B. FISK
Life Member

GEORGE P. GARDNER, JR.
Life Member

GILBERT M. RODDY
Life Member

ELECTIONS

LOUIS W. CABOT
Special Term Member

IRENEE DU PONT, JR.
Special Term Member

EUGENE MCDERMOTT
Special Term Member

IVAN A. GETTING
Alumni Term Member

ELISHA GRAY, II
Alumni Term Member

THOMAS F. MORROW
Alumni Term Member

WILLIAM L. TAGGART, JR.
Alumni Term Member

ROBERT H. WINTERS
President of Alumni Association

APPOINTMENT

GOVERNOR ENDICOTT PEABODY
Ex-officio Member

FACULTY

DEATHS

FREDERICK K. MORRIS
Emeritus Professor in Geology

CHARLES H. PORTER
Emeritus Professor in Industrial Management

CHARLES M. SPOFFORD
Emeritus Professor in Civil Engineering

WALTER H. JAMES
Emeritus Associate Professor in Mechanical Engineering

ALPHEUS G. WOODMAN
Emeritus Associate Professor in Chemistry

HOULDER HUDGINS
Professor in Industrial Management

RETIREMENTS

EDWARD L. BOWLES
Consulting Professor in Industrial Management

MURRAY F. GARDNER
Professor in Electrical Engineering

ERNST A. GUILLEMIN
Professor in Electrical Engineering

MARCY EAGER
Associate Professor in Electrical Engineering

ERNEST N. GELOTTE
Associate Professor in Architecture

LOUIS HARRIS
Associate Professor in Chemistry

PARRY MOON
Associate Professor in Electrical Engineering

RESIGNATIONS OF PROFESSORS

COLONEL IRVING W. FINBERG
Head of the Department of Military Science

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

ALFRED D. CHANDLER
Humanities

RESIGNATIONS OF ASSOCIATE PROFESSORS

LIEUTENANT COLONEL ALBERT E. ANDREWS
Military Science

MICHAEL P. BARNETT
Physics

FRANCIS M. BATOR
Economics and Social Science

COMMANDER JOHN R. BAYLIS
Naval Architecture and Marine Engineering

GEORGE T. BRYANT
Civil Engineering

DAVID O. CALDWELL
Physics

PIERRE E. CONNER, JR.
Mathematics

COMMANDER ROBERT B. GIBLIN
Naval Science

DAVID M. GREEN
Economics and Social Science

EDWARD HERBERT
Biology

DAVIS H. HOWES, 3D
Economics and Social Science

ARTHUR L. LOEB
Electrical Engineering

RONALD MELZACK
Economics and Social Science

CAPTAIN JAMES M. NORTON
Military Science

MAJOR MAX B. SCHEIDER
Military Science

J. LOWEN SHEARER
Mechanical Engineering

JOHN A. SWETS
Economics and Social Science

DAVID A. THOMAS
Metallurgy

RESIGNATIONS OF ASSISTANT PROFESSORS

EDWARD A. ARTHURS
Electrical Engineering

HENRY A. BECKER
Chemical Engineering

JOHN D. BOSSONS
Industrial Management

JERE H. BROPHY
Metallurgy and Food Science

STANLEY E. CHARM
Nutrition and Food Science

LIEUTENANT JERRY B. CHICHESTER
Naval Science

LIEUTENANT WILLIAM H. CURRY, JR.
Naval Science

MYLES M. DRYDEN
Industrial Management

FRANK J. HEGER
Civil Engineering

EDWARD M. HOFSTETTER
Electrical Engineering

William F. Hosford, Jr.
Metallurgy
C. Judson King
Chemical Engineering
Marc A. Kolpin
Aeronautics and Astronautics
James A. Larrimore
Nuclear Engineering
Daniel H. Marcus
Mechanical Engineering
Raphael Moissis
Mechanical Engineering
Charles C. Robinson
Electrical Engineering
Ralph R. Rumer, Jr.
Civil Engineering
David J. Sakrison
Electrical Engineering
Bradbury Seasholes
Economics and Social Science
James L. Stockard
Aeronautics and Astronautics
William M. Whitney
Physics

CHANGES OF APPOINTMENT

Howard R. Bartlett
Professor of Humanities
Lan J. Chu
Edwin Sibley Webster Professor in Electrical Engineering
Moise H. Goldstein, Jr.
Lecturer in Electrical Engineering
Harold C. Kirker
Lecturer in Humanities

PROMOTIONS TO PROFESSOR

Clyde M. Adams, Jr.
Metallurgy
Walter A. Backofen
Metallurgy
Raymond F. Baddour
Chemical Engineering
Warren G. Bennis
Industrial Management
Klaus Biemann
Chemistry
John M. Biggs
Civil Engineering
Lincoln P. Bloomfield
Economics and Social Science
Harald A. Enge
Physics
Morton Finston
Aeronautics and Astronautics
Donald R. F. Harleman
Civil Engineering
John B. Hersey
Geology and Geophysics
Thomas M. Hill
Industrial Management
Daniel M. Kan
Mathematics
William L. Kraushaar
Physics
Marten T. Landahl
Aeronautics and Astronautics
Kevin A. Lynch
City Planning
Philip Mandel
Naval Architecture
Robert W. Mann
Mechanical Engineering
Edward A. Mason
Nuclear Engineering
Henry P. McKean, Jr.
Mathematics
William M. Siebert
Electrical Engineering
Kenneth N. Stevens
Electrical Engineering
Tau-Yi Toong
Mechanical Engineering
Robert V. Whitman
Civil Engineering
Robert S. Woodbury
Humanities
Herbert H. Woodson
Electrical Engineering

PROMOTIONS TO ASSOCIATE PROFESSOR

Albert K. Ando
Economics and Social Science
David J. Benny
Mathematics
Abraham Bers
Electrical Engineering
John Blair
Electrical Engineering

Joseph D. Everingham
Humanities

Henri Fenech
Nuclear Engineering

Frederick W. Frey
Economics and Social Science

James G. Glimm
Mathematics

Marvin E. Goody
Architecture

David M. Green
Economics and Social Science (resigned August 31)

Henry W. Kendall
Physics

Deane Lent
Mechanical Engineering

G. Hubert Matthews
Modern Languages

James R. Munkres
Mathematics

Robert E. Newnham
Electrical Engineering

Herbert H. Richardson
Mechanical Engineering

Abner E. Shimony
Humanities

Arthur C. Smith
Electrical Engineering

Joseph L. Smith, Jr.
Mechanical Engineering

Herbert M. Teager
Electrical Engineering

David R. Whitehouse
Electrical Engineering

Emily L. Wick
Nutrition and Food Science

John W. Winchester
Geology and Geophysics

PROMOTIONS TO ASSISTANT PROFESSOR

Raymond A. Alvarez, Jr.
Physics

Hale V. Bradt
Physics

Charles K. Crawford
Electrical Engineering

Hubert L. Dreyfus
Humanities

Ira A. Glazier
Humanities

Albert R. Gurney, Jr.
Humanities

Walter M. Hollister
Aeronautics and Astronautics

Charles E. Holt III
Biology

Phillip Issenberg
Nutrition and Food Science

Robert S. Kennedy
Electrical Engineering

Ulrich Luscher
Civil Engineering

Benjamin R. Martin, Jr.
Athletics

David E. Newland
Mechanical Engineering

John W. Poduska
Electrical Engineering

Samuel J. Todes
Humanities

William B. Watson
Humanities

APPOINTMENTS AS PROFESSOR

Lieutenant Colonel James W. Gilland
Head of the Department of Military Science

John V. Harrington
Aeronautics and Astronautics, and Electrical Engineering; Director of the Center for Space Research

Richard M. Held
Economics and Social Science

Captain Harry M. Pugh
Head of the Department of Naval Science

Jack P. Ruina
Electrical Engineering; Assistant to the Vice President

Henry M. Stommel
Meteorology

James F. Thomson
Humanities

APPOINTMENTS AS VISITING PROFESSOR

Solomon E. Asch
Economics and Social Science

Philippa R. Foot
Humanities

Seymour J. Gray
Nutrition and Food Science

Erich Heller
Humanities

Gerald S. Heller
Electrical Engineering

Bert F. Hoselitz
Economics and Social Science

Lester Lees
Mechanical Engineering

Philip Morrison
Physics

Roland I. Robinson
Industrial Management

Howard H. Rosenbrock
Electrical Engineering

Arthur L. Samuel
Electrical Engineering

Jan Sandee
Economics and Social Science

Francis X. Sutton
Economics and Social Science

Hans H. Ziegler
Jerome Clarke Hunsaker Professor in Aeronautics and Astronautics

APPOINTMENTS AS ASSOCIATE PROFESSOR

Major Leverne E. Allen
Military Science

James M. Beshers
City and Regional Planning

Frank Bonilla
Economics and Social Science

Eugene E. Covert
Aeronautics and Astronautics

Major Joseph A. Hart
Air Science

Thomas P. Hughes
Humanities

Fred C. Ikle
Economics and Social Science

William J. LeMessurier
Architecture

Earle L. Lomon
Physics

Commander Joseph A. Matthews
Naval Science

James E. McCune
Aeronautics and Astronautics

Commander William R. Porter
Naval Architecture and Marine Engineering

Harold Y. Wachman
Aeronautics

H. Martin Weingartner
Industrial Management

APPOINTMENTS AS VISITING ASSOCIATE PROFESSOR

Ricardo Bressani
Nutrition and Food Science

Sukhamoy Chakravarty
Economics and Social Science

Robert M. Dowben
Biology

Raimo J. Hakkinen
Aeronautics and Astronautics

John W. S. Hearle
Mechanical Engineering

Gerhard M. Kallman
Architecture

Nelson H. Kemp
Mechanical Engineering

Jean P. Leinroth, Jr.[1]
Chemical Engineering

Ian M. Mills
Chemistry

Lee A. Segel
Mathematics

Joseph Weizenbaum
Electrical Engineering

APPOINTMENTS AS ASSISTANT PROFESSOR

Stanford O. Anderson
Architecture

Michael Artin
Mathematics

Carl J. Black, Jr.
Modern Languages

Lieutenant (j.g.) John B. Castano
Naval Science

Walter C. Clemens, Jr.
Economics and Social Science

Ziad M. Elias
Civil Engineering

Donald E. Farrar
Industrial Management

[1] Postdoctoral Fellow in Engineering.

Giorgio Fiocco
Geology and Geophysics

Jerry A. Fodor
Humanities

Janis Z. Gabliks
Nutrition and Food Science

Charles G. Gross
Economics and Social Science

Lieutenant Paul E. Guay
Naval Science

Alan V. Hein
Economics and Social Science

David M. Hercules
Chemistry

Tom D. Humphreys II
Biology

Thomas H. Jackson
Humanities

Russel C. Jones
Civil Engineering

Jerrold J. Katz
Humanities

James J. Linn
Industrial Management

Paul W. MacAvoy
Economics and Social Science

Samuel P. Mauch
Civil Engineering

Kristina Pomorska
Modern Languages

Paul M. Postal
Modern Languages

Alar Toomre
Mathematics

William L. White
Industrial Management

George M. Whitesides
Chemistry

APPOINTMENTS AS VISITING ASSISTANT PROFESSOR

Mrs. Kamini Adhikari
Industrial Management

Marcus S. Brooke
Biology

Luiz C. Gomes
Physics

Aidan D. McNamara
Mechanical Engineering

ASSISTANT PROFESSORS AND POSTDOCTORAL FELLOWS IN ENGINEERING (JOINT APPOINTMENTS)

Vidal R. Algazi
Electrical Engineering

Charles A. Berg
Mechanical Engineering

Arthur E. Bergles
Mechanical Engineering

Peter K. Bohacek
Electrical Engineering

Roger W. Brockett
Electrical Engineering

Franklyn M. Clikeman
Nuclear Engineering

Giles Cokelet
Chemical Engineering

Robert S. Cooper
Electrical Engineering

Wayne G. Custead
Metallurgy

Joseph L. Hall II
Electrical Engineering

Harry M. Horn
Civil Engineering

Thomas S. Huang
Electrical Engineering

Francis Kaseta
Electrical Engineering

David J. Kuck
Electrical Engineering

Richard C. Levine
Electrical Engineering

William A. Litle
Civil Engineering

Chung Laung Liu
Electrical Engineering

Leonard M. Magid
Electrical Engineering

A. M. Manders
Electrical Engineering

Emmanuel Partheniades
Civil Engineering

John P. Penhune
Electrical Engineering

Russell R. Pfeiffer
Electrical Engineering

Amedeus E. Profio
Nuclear Engineering

George S. Springer
Mechanical Engineering

Irvin G. Stiglitz
Electrical Engineering

Gerald M. Sturman
Civil Engineering

Mikio Suo
Mechanical Engineering

Armando Travelli
Nuclear Engineering

Oleh J. Tretiak
Electrical Engineering

Jay R. Walton
Civil Engineering

Thomas F. Weiss
Electrical Engineering

L. Anthony Wolfskill
Civil Engineering

ADMINISTRATION

DEATH

Robert M. Kimball
Secretary of the Institute

RETIREMENTS

Professor Ernest H. Huntress
Secretary of the Graduate School

Thomas P. Pitre
Director of Student Aid and Associate Dean of Student Affairs

RESIGNATIONS

Gary L. Benton
Industrial Liaison Officer

James E. Donahue
Industrial Liaison Officer

Douglas A. East
Administrative Assistant to the President

James G. Kelso
Assistant to the Chairman of the Corporation

John F. Maxwell
Industrial Liaison Officer

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

CHANGES

Martin J. Buerger
Institute Professor

George H. Dummer
Associate Director of the Division of Sponsored Research

Robert E. Holz
Associate Registrar

Owen G. Haselton
Assistant Registrar

Jay L. Marden
Director of Auxiliary Services

Richard N. Smillie
Assistant Director of the Division of Sponsored Research

Robert K. Weatherall
Executive Officer of the Graduate School

APPOINTMENTS

Frank T. Bauchspies
Industrial Liaison Officer

Professor Sanborn C. Brown
Associate Dean of the Graduate School

Jack W. Christensen
Industrial Liaison Officer

Frank C. Colcord, Jr.
Special Assistant to the Chairman of the Corporation

Francis T. Conroy
Assistant Director of the Division of Sponsored Research

Jack V. Drake
Industrial Liaison Officer

Jack H. Frailey
Director of Student Aid

W. Bradford Gove
Assistant Director of the Division of Sponsored Research

Professor Thomas B. King
Head of the Department of Metallurgy

Jacquelyn Mattfeld
Associate Dean of Student Affairs

Professor Harold S. Mickley
Director of the Center for Advanced Engineering Study

Ernest D. Phelps
Assistant to the Dean of the School of Engineering

Jon K. Rosenthal
Assistant Planning Officer

Peter T. Van Aken
Assistant to the Vice President, Academic Affairs

SCHOOL OF ARCHITECTURE AND PLANNING

TOTAL ENROLLMENT in the School of Architecture and Planning for the year 1962-63 increased slightly over the preceding year, from 190 to 193.

In the Department of Architecture the number of undergraduates increased and that of graduates shrank somewhat, contrary to the long-term trend. The number of second-year students recruited from the previous year's freshman class (22) was larger than usual. Another factor in increased undergraduate enrollment was the retention of students having difficulty in completing a satisfactory thesis. Shrinkage in graduate enrollment seemed to be caused by two circumstances, a relative shortage of highly qualified applicants, perhaps due to the nadir in birth rates occurring about 1938-39, and the unusual number of applicants who were offered admission but who did not enroll, including a considerable number who were offered scholarships at M.I.T. but who enrolled elsewhere, presumably with more generous treatment there. It is noted that Yale, Columbia, and the University of Pennsylvania have sharply increased their graduate enrollments in recent years.

In the Department of City Planning the growth has been more marked, and only space has prevented and will prevent any further increase. As a part of United States planning education, this Department faces a rising demand for graduates—for general planning practice as consultants and planning staff directors, for specialists in emerging new branches of planning, for teachers in other growing planning schools, and for U.S. and foreign planners to work in other countries. We face also the expansion and change of the content of professional education, as the supporting disciplines provide new knowledge, new insights, and new analytical methods. The problem of lengthening the basic professional course beyond two years is still unresolved, as is the twin problem of competing for brilliant students with other fields having brighter glamor and more generous fellowships. As a part of M.I.T., the Department is gradually developing healthy closer ties with other fields—through the Joint Center and through student elective choices—but more intellectual contact with other faculties would be desirable. The long-range solution to the immediate space crisis may, via relocation, help to make this easier.

TEACHING PROGRAM

Administration of the Master's degree thesis program was still further shortened, the theses terminating late in June with only the preparation of final presentation drawings and models occurring after the close of the spring term. Under the direction of Professor Eduardo Catalano, fourteen students successfully completed their projects according to this schedule, under a general theme of "buildings as systems." Particular attention was paid to the coordinated design of all mechanical and structural elements and to the discipline imposed by selected techniques of construction. A number of engineers in private practice and from industrial posts in the building industry served as consultants and lecturers. Three additional Master of Architecture degrees were granted during the year.

The undergraduate curriculum was the subject of intensive study during the year, particularly the subjects devoted to building technology. In this area a new more extensive and more highly organized group of subjects has been introduced. September, 1963, will see the first presentation of these, together with other adjustments in the requirements for the professional degree. Curricular studies by the faculty are expected to continue during 1963-64. The faculty granted thirty-one Bachelor in Architecture degrees in 1962-63.

In City and Regional Planning, Professor Aaron Fleisher's evolving material in transportation includes two new subjects approved last year and has generated two theses in progress, one M.C.P. and one Ph.D. Two other new subjects have been offered this year: Professor James M. Beshers' seminar in Urban Social Structure (financed by the grant of Arthur D. Little, Inc.), and Programming for Urban and Regional Development by Professor John Friedmann, Professor Friedmann's work in regional planning, involving recasting of other subjects also, is the source of several theses in progress. The special curricula in urban design have developed as it was hoped; four to five doctoral theses are now begun in this area, under the guidance of Professors Kevin Lynch and Donald Appleyard. There have been no significant changes in the basic core of the professional curriculum. For next year, in line with the trend to sacrifice "survey" classes for work in depth, the subject in Introduction to Planning will be dropped and more credit hours assigned to other first-term subjects. Also in line with this trend, the subject in Principles of Planning required of undergraduate architectural students will be dropped next year; instead, these and other undergraduates will be encouraged to elect one or two of the several first-year graduate subjects in planning which do not have graduate prerequisites. (This is not a new service to other M.I.T. departments.)

The annual two-week Special Summer Program in planning was under Professor Frederick J. Adams this summer, attended by over thirty-five in-service planners from all over the country. Professor Adams also organized a two-day working conference in December on planning education in developing countries, the proceedings of which have just been published; this conference was also financed by the Arthur D. Little grant. Professors Fleisher, Friedmann, and John T. Howard joined to offer a seminar in the freshman elective series.

RESEARCH

The current year saw relatively little activity in the field of sponsored research. The "instant schoolhouse" appears to have gone as far as our staff can take it, and its further development depends on industrial interest. As for the work in structural models, lack of financial support currently handicaps participation by the Department in the work of the Perini Laboratory.

The M.I.T.-Harvard Joint Center for Urban Studies continues as the main avenue of research in the area of planning. The Ford Foundation grant which has underwritten the Center since April, 1959, scheduled to run out at the end of 1963, has been extended an additional four years but with no significant increase in annual funds available. The interdisciplinary nature of the Center, which is a vital asset, also results inevitably in a splintering of research funds among many departments and individuals. The contribution of the Center to the Department of City and Regional Planning has nevertheless been invaluable in supporting research by our faculty and by this device in releasing academic funds for the expansion and diversification of the teaching staff. Professors Adams, Charles Abrams, Fleisher, and Bernard J. Frieden have all had formal support from the Center, either last summer or during the academic year; next year Professors Appleyard, Beshers, Friedmann, and Lynch will also be involved. The large regional and city planning project in Venezuela has directly aided the Department through use of subject matter and materials in workshop courses taught by Professors Appleyard and Friedmann (who had both spent the summer in Venezuela and will be there again), with occasional participation by the project directors visiting from Venezuela. The Department is even more strongly convinced than in previous years that the Joint Center is essential to the most effective conduct and development of its M.C.P. and Ph.D. curricula and to the extension of that knowledge and understanding of urban and regional structure and growth upon which our professional teaching program must be based.

FACULTY AND STAFF

As a temporary replacement for Professor Albert Bush-Brown, who resigned to become President of the Rhode Island School of Design, Professor Leonard Opdycke, who had just been retired from the faculty of the School of Fine Arts at Harvard University, was given a one-year appointment as Lecturer and presented subjects in the history of architecture supplementing those of Professor Henry A. Millon. The long-term replacement of Professor Bush-Brown was solved with the appointment as Assistant Professor of Stanford Anderson, who will begin his teaching duties in September, 1963.

Professor Ernest N. Gelotte reached the age of retirement following service to M.I.T. extending from 1926 to the present. He will return as a part-time lecturer, but the principal responsibility for the curriculum in structures will be assumed by his replacement, William J. Le Messurier, M.S.C.E. '53, who has been appointed as Associate Professor.

Three visiting critics took part in the architectural design teaching under the sponsorship of the Bemis Fund. Viljo Revell of Helsinki and Nils Fagerholt of Copenhagen together undertook responsibility for the first term of the fifth year, while Charles Correa of Bombay, M.Arch. '55, participated in teaching the graduate students in architecture who joined with city planning students for the study of a plan for a new industrial city in Venezuela.

Professor Marvin E. Goody had a leave of absence for the fall term, during which time he taught architectural design at the Royal Academy of Fine Arts in Copenhagen, in continuance of an exchange program of long standing.

A new program was undertaken through the appointment as Lecturer during the second term of Olav Hammarstrom, who offered an elective subject in architectural drawing and rendering.

The Department looks forward to the contribution beginning in September, 1963, of Peter Hornbeck, a young landscape architect who has been appointed as part-time instructor. This will be the first time in many years that this profession has been represented on our staff.

In the Department of City and Regional Planning, Professor Kevin Lynch has been promoted to a full professorship this spring. Dr. Beshers, who offered an advanced seminar in the spring term as a part-time visitor, will join the faculty as an Associate Professor next year; he is a mathematical sociologist who will fill a vital gap in our offerings in urban social structure and also join the Joint Center research program.

The subject in planning law was taught this year, and will be next year, jointly by two distinguished lawyers, Lewis Weinstein and Laurence Sullivan, who also lecture at the Harvard Law School. This area, however, remains a void in our permanent departmental arrangements.

Part-time aid in teaching the enlarged workshop classes this year was temporarily provided in the fall term by Harry Gold, urban sociologist, and in the spring term by Philip B. Herr and Justin Gray, planning consultants in practice in this area and both department graduates.

Thanks to the grant from Arthur D. Little, allocated this year to this Department, there was an unusually rich series of visiting lecturers who participated in various classes as well as offering formal talks. They included a series of economists, Dr. Thomas Vietorisz, Dr. Roland Artle, and Dr. Louis Winnick, and also two English planners, John R. James and Paul Ritter. Evening lectures were also offered by Dr. Teuber of the Psychology Department and by several members of the Department staff.

SCHOLARSHIPS AND FELLOWSHIPS

In the Department of Architecture at the undergraduate level, it may be estimated that about 12 per cent of our students have scholarship support. Most of these are also the beneficiaries of loans. Roughly one-third of all undergraduate students have either a scholarship or a loan or both. During 1961-62 the total of scholarships was on the order of $15,000, that of loans $30,000.

In recent years students in the Department have benefited by two new sources of special funds, both administered through the Student Aid Center. The Tile Council of America Award has gone for two successive years to the same recipient. The William E. Hartmann Scholarship, designated for incoming college transfer students, was offered in 1962-63 to an applicant who failed to matriculate and was then used in support of a college transfer student already established at M.I.T. For 1963-64 this scholarship will go to a promising graduate of New York University who will enter in the fall. In addition to these awards there is the Emerson Fund, administered by the Dean, which disbursed during the year $5,260 in grants to undergraduate and graduate students.

The year 1962-63 was unhappy for architectural graduate scholarships in that we were made to feel very sharply the competition with other schools, doubtless because of recent strengthening of their scholarship resources. Of eight awards totaling $16,500 offered to applicants, five totalling $8,800 were declined. A recent resurvey of actual awards used during the year reveals that of a total of eighteen graduate students only six actually benefited from awards offered by M.I.T., which ranged from a low of $400 to a high of $3,500 and totalled $9,650. In addition one foreign student was fully supported by his government. (This again excludes the Emerson Fund.)

The prospect in the Department of Architecture for 1963-64 is considerably brighter though yet far from opulent. Two awards from the Second Century Fund and one from the Avalon Foundation have increased our totals. Although there were again five refusals of grants, these funds have been reapplied to other candidates, thanks at least in part to new administrative procedures adopted by the Committee on Graduate School Policy. As a result, of twenty-three new graduate students expected to register in September, nine will have awards offered by M.I.T. to a total value of $15,750. Additionally, three foreign students will have government grants, bringing the total beneficiaries to about fifty per cent of enrollment.

It may be argued that the less privileged half of the graduate group in architecture lacks the intellectual distinction to merit scholarship support. This may be the case but is beside the point. The real issue is whether M.I.T. attracts its share of the limited supply of the distinguished students, in view of the increasing inducements offered at other centers.

Thanks to the Avalon Foundation grant for the School of Architecture and Planning, the Department of City and Regional Planning has for next year two tuition scholarships. Two fellowships have been awarded from general Graduate School funds. The Chandler Fund provides less than half a scholarship per year. Thus from M.I.T. sources the Department can count on roughly three fellowships or seven scholarships, or some combination of the two figures. In addition, four to five students are awarded part-time teaching assistantships each year.

Through the Sears-Roebuck, Pittsburgh Plate Glass, and Lasker Fellowship programs, six of our city planning students received grants this year; this seems to be our average performance. An average of six foreign students come to the Department with grants from their own or the U.S. government. In addition, four students held National Defense Education Act doctoral fellowships; next year, with the award of four new three-year grants, the number will be eight. The net of these sources has been that both last year and this year, and probably next year, only half of the Department's graduate students have had any form of current financial assistance (other than loans). Most of the others have been forced to borrow or work part-time outside M.I.T.; several have dropped out for a year or more.

SPACE AND LOCATION PROBLEMS

Both departments of the School suffer from an acute and immediate shortage of space. The Emerson Room, newly remodeled and redecorated, serves excellently as a seminar room and for evening lectures or social events; ordinary lecture classes are very adequately provided for in normal classrooms. The drafting rooms, however—the locus of the workshop subjects which are the core of the curriculum and which house the students during at least half of their scheduled class time and their preparation time—became overcrowded several years ago. This year in the Department of City and Regional Planning there is less than 45 square feet per student; next year it will be still less. (An adequate area would be 100 square feet.)

The other area of acute shortage is in faculty office space. Only the four full professors in the Department of City and Regional

Planning have private offices; one of these is substandard, and another (the department head's) serves also as a conference room. All associate and assistant professors share offices designed for single occupancy. For five student instructors and teaching assistants there are two desks in a windowless room. Only those Ph.D. candidates taking workshop subjects (four out of twelve) have any assigned space; the others have no desks, study alcoves, or other headquarters.

These immediate space problems present barriers to effective expansion beyond the prospect for next year (the increase from 46 to 56 students is possible only because it consists primarily of doctoral candidates at the dissertation stage, who will have to work at home).

There have been intensive discussions during the year on the problem of space for the School of Architecture and Planning. The faculty have made studies on the needs for improved accommodations and the possible sites for a relocation of the School. Assurance has been given of the administration's interest in providing such improvement, subject to shifts in occupancy contemplated in the vicinity of our present space. A resolution of our space problem, which has implications both for the near and the remote future, is expected soon.

A relocation to the eastern end of the campus, closer to a number of the departments with which we should have ties, would be consistent with the recommendations of a recent special M.I.T. committee which proposed the consolidation of Rotch Library with the libraries of the Schools of Humanities and Industrial Management. To attack the inadequacies of the Rotch Library collection, which have become more apparent as our doctoral program has increased its demands, the Department of City and Regional Planning has allocated funds from its grants associated with Sears fellowships to a special consultant, Mrs. Martin Meyerson, to develop a high-priority list of needed library acquisitions.

IN CONCLUSION

The faculty of the School are confident we can continue to grow in quality and diversity of staff as well as in quality and number of students and to retain pre-eminence among the architecture and planning schools of this country, provided we are alert to the new demands made of our profession in many fields. This means a constant reappraisal of our goals, the courage to innovate and to experiment in new ways of teaching.

PIETRO BELLUSCHI

SCHOOL OF ENGINEERING

By any standard the most significant event of the past academic year was the culmination of the campaign to fund the goals of our Second Century Program. The total of $98 million given or pledged during the fund campaign is indeed a stirring demonstration of respect for the values that M.I.T. now represents.

The multitude of activities that M.I.T. has been urged to undertake for these many years, and which now can be undertaken, are too numerous to enumerate as part of this report. But three activities now being aggressively pursued and which relate uniquely to emerging developments in engineering education will be cited.

These three are:

1. The program to enhance education in our School of Engineering;
2. The activities of a special faculty committee appointed by President Stratton to review the common core curriculum required of all students; and
3. The Center for Advanced Engineering Study, a new venture in higher education.

As a result of the magnitude of these three activities, their strategic timing, and the way their programs already have interacted with each other and will do so increasingly in the future, we now have a unique self-generative environment that can develop a powerful capability for improving the quality of education. That such an opportunity would ever exist was almost wholly unforeseen a mere three years ago.

The activity to enhance engineering education was funded by a grant from the Ford Foundation in 1959. This grant is of special significance for three reasons: first, because the amount of $9 million was the largest awarded as of that time to a single institution to enhance engineering education; second, because it was applicable across the whole spectrum of our teaching in engineering—faculty development, curriculum change, the restructuring of teaching laboratories, and faculty recruitment through endowed professorships and postdoctoral fellowships; and third, because it was received at the very beginning of the Second Century Fund campaign.

The reports of the School of Engineering for the years 1959-60, 1960-61, and 1961-62 dealt in considerable detail with actions already taken under this grant. In their reports for this year the several departments make frequent mention of changes still in process. But in the enthusiasm to discuss what these resources have done *for* engineering education at M.I.T., it is easy to overlook the equally important matter of what the grant has done *to* education within M.I.T. as a whole. Not only have great changes taken place within the School of Engineering per se, but these changes in turn have interacted with a wide range of activities throughout the Institute.

Engineering cannot be thought of as autonomous and apart from the rest of the community. Its students study in substantially every department. Engineering teaching must be continually modified to build on the most recent developments in science teaching. Engineering professors are involved in a multitude of interdepartmental and interschool activities. Changes in curricula and changes in professional activities and attitudes of both students and professors in engineering react on other elements of M.I.T. in a host of subtle ways.

The existence of these pressures and counterpressures on the processes of educational innovation are well known, but what is rarely experienced is the capability to respond promptly and efficiently to them so that they can be fully exploited.

As one example of this phenomenon of interaction, we shall comment later about the activities of the special faculty committee under the chairmanship of Professor Jerrold R. Zacharias of the Department of Physics as it has reviewed the core programs of study for freshmen and sophomores.

Not only has the Ford Foundation grant exerted pressures downward into the undergraduate programs of all engineering students, but in no small degree it has been a factor in revealing the degree of technical obsolescence of many practicing engineers—many of our own alumni who graduated a mere ten or fifteen years ago—and many professors engaged in teaching engineering at M.I.T. and elsewhere. That this situation will become even more pronounced as science advances and as our own faculty moves forward in its efforts to improve undergraduate education, is amply clear.

It was to this problem that Alfred P. Sloan, Jr., Honorary Chairman of our Second Century Fund, addressed an inquiry in a letter to Dr. James R. Killian, Jr., in July, 1962. Mr. Sloan was reflecting on the contributions to improved industrial management made through the Sloan Fellowship Program in executive development since its initiation more than two decades ago. From his keen observations of today's turbulent industrial scene, Mr. Sloan was then led to inquire whether the practice of engineering might likewise be advanced if engineers in industry were given similar opportunities for updating their knowledge and redirecting their activities.

Evidence presented to the Alfred P. Sloan Foundation at Mr. Sloan's invitation validated his inquiry, which history will record as having been the key that opened up a new epoch in advanced engineering education. About a month before the Second Century Fund campaign closed, the Trustees of the Sloan Foundation voted a grant of $5 million to establish a wholly new addition to our activities in engineering education—a Center for Advanced Engineering Study.

As a result of these three activities, all now being implemented, there is presently under way within the M.I.T. community an experiment that points up clearly the systems character of educational innovation in an institution basically oriented towards science and engineering.

A Systems Problem in Educational Change

Traditionally a single professor has been looked to for leadership in revising the substance and patterns of instruction in his own domain, and he has operated with a high degree of autonomy. In today's state of technological education, complex interactions occur between disciplines. Because the objective of a curriculum is to evolve an integrated body of knowledge, the activities of today's professor must be closely coordinated with those in other apparently quite diverse fields.

The pattern is similar to that which has become the dominant theme in large-scale, modern engineering practice. Whereas a decade or two ago relatively large engineering programs could be successfully accomplished by assigning engineers to separate, clearly prescribed tasks, today a single engineer or a single group of engineers can seldom work alone. The performance and demands of one element of a program react upon the performance of other elements; new science interweaves with old science and with new and old technology. The result is that compartmentalized disciplines no longer exist. Because the boundaries everywhere are blurred, the performance of modern engineering demands a breadth of competence and an integration of disciplines far greater than heretofore.

The systems approach now dominates most complex activities, and the conduct of educational change at M.I.T. in this decade of the 1960's is no exception. Whether it is by good luck or by good management that M.I.T. now has the resources to work at the systems level in achieving a renaissance in engineering education, others may decide. But the fact is that we are enmeshed in a complex systems problem that is Institute-wide rather than department- or discipline-wide. Fortunately we have the resources and are evolving procedures to cope with this expanded task.

THE UNPREDICTABLE NATURE OF CHANGE

When we approached the Ford Foundation in the summer of 1959 for support to undertake a major upgrading of our engineering curriculum, we outlined a set of goals that were as bold as could be stated with sincerity. Several programs for curricula development were outlined in broad perspective, and we indicated that a period of six to seven years would be required to carry them out. It is doubtful, however, that even the principals to the negotiation expected that, within the relatively short span of three or so years, so much would have happened to engineering within M.I.T. Furthermore, even these persons did not visualize that the program was to become self-generative and that the fallout from activities solely within engineering would instigate and provide guidelines for so many other changes across the broad spectrum of M.I.T. A few case histories, selected from many on record, will illustrate the scale of this effect.

In February, 1959, the growing interest in several departments in the general field of materials science and engineering prompted the faculty to establish graduate degree programs in materials engineering at the Engineer and Doctor's degree levels. The expanded graduate teaching and research programs rapidly spilled over into undergraduate teaching. Among the curriculum revisions in the several departments, the decision of the Metallurgy Department to offer a complete undergraduate option in materials science has had far-reaching consequences. Under the guidance of Professor Morris Cohen, the Department began to evolve a sequence of two subjects in materials science and one in materials processing. Support was given from the Ford Foundation grant for study groups, for preparation of new course notes and new illustrative problems, and, in particular, for extensive refurbishing of teaching laboratories. This greatly accelerated the development of the new subjects and, in addition, permitted a new type of laboratory experience for students.

Before this activity had gathered significant momentum, it was apparent that the needs of students in other engineering departments for instruction in materials would no longer be satisfied by an existing subject in Engineering Metals offered to sophomores or juniors by the Metallurgy faculty. Under the leadership of Professor John Wulff of the Department of Metallurgy, professors from five departments consolidated their efforts to develop a completely new approach, and funds were made available to implement their plan. The new approach was to place primary emphasis on material structure and its relation to observable properties and to draw upon and enrich the activities in several departments. In this way, sections could be offered in which the basic theme remained but in which more emphasis was given to electrical properties in one case or to mechanical properties in another. The new approach extended (as in many other projects then current) to the view of the laboratory as a place where the student should take part in comprehensive experimental projects designed to help discover for himself the profound influence of structure and the manipulation of structure on the properties of materials. Without flexible, long-term funding, the development of such a subject and the supporting laboratory facilities for a group of students numbering thirty-five initially and, last year, 250, drawn from eight departments, would have been impossible.

The story is not ended. As soon as the sophomores and juniors completed the new subject in Engineering Materials (3.14), subsequent subjects in materials by the students' individual departments were upgraded to meet the demands of modern engineering. Thanks to the mature nature of the Ford Foundation funding, the resources were available and there was no waiting while the enthusiasm of the faculty dissipated.

The offering of the interdepartmental subject has also had a direct effect on the option in Materials Science in the Metallurgy Department. The realization that even sophomores could readily absorb and, indeed, be stimulated by the instruction in Engineering Materials led the Department to upgrade, even as it was being developed, its own subject sequence in materials science for metallurgy majors.

Almost at the same time, Professor Wulff decided to offer a freshman elective, Structure of Materials (3.09). This was designed to satisfy the interests in real materials among freshmen, most of whom were then oriented toward physics or chemistry. Few had given much thought to engineering or the possibility of a career in engineering, but Professor Wulff awakened their interest. A coordinate laboratory subject—Structure and Properties of Materials Laboratory (3.10)—was then instituted at the request of the students themselves. These subjects now attract about sixty-five students per year. Undergraduate seminars in superconductivity, structural composite materials, and metal casting have also grown from the same initial root in materials science.

But these are not the only consequences of the parent project. It has created added demand for many of the advanced subjects in thermodynamics, statistical mechanics, and the physics of the solid state, on which materials science and engineering are based and for which students of engineering had not previously felt the same need. It has also instigated change in the upperclass subjects that build on a competence in materials. Throughout the undergraduate and graduate laboratories there is a reawakened interest in the relations between structure and behavior of real materials.

The surge of interest in developing laboratories built around project-type activities is illustrative of another way in which the availability of long-term resources at the critical time can foster much-needed advances. For several years prior to receipt of the grant from the Ford Foundation, the faculty in the Department of Mechanical Engineering had been painfully aware that their educational laboratories were too tightly linked to outmoded large machines. The staff aspired to develop a laboratory wherein students could devise experiments on their own initiative to explore situations that could not adequately be handled by analysis. The need was for a flexible combination of bench space, electricity, water, gas, and high- and low-pressure air, access to modest shop facilities, instruments for measuring a variety of electrical and mechanical quantities, and a modest amount of expendable materials.

Almost all schools face these problems and have found that the funds required for the changes in laboratory instruction exceed by several orders of magnitude the funds that any one department alone can provide from its operating budget. However, the Ford grant and the National Science Foundation's matching grant program in undergraduate laboratory development gave the Department of Mechanical Engineering the opportunity to make changes which represented a major break with tradition. For two years now the Department has been operating an undergraduate projects laboratory that brings forth expressions of motivation and creativity to degrees previously unknown in our younger students.

Similar developments have been fostered in several other departments. Almost concurrent with the laboratory evolution in the Department of Mechanical Engineering, the faculty in Aeronautics and Astronautics developed a similar project-type laboratory oriented toward their interests. The Electrical Engineering faculty has broken out of many of their constraints by the use of kits which enable their large numbers of students to achieve flexibility in imaginative electronic circuit innovation and design in economical ways. Interest in involving students in project-oriented laboratory experiences has spread widely throughout the whole School and has most recently appeared in the form of numerous laboratory activities offered in the Undergraduate Seminar Program. While these examples refer solely to activities within M.I.T., the interest expressed by other institutions implies that the effects will extend far beyond our own campus.

The story could be continued, but perhaps the point has already been made. The injection of resources into any curriculum development conducted by professors having imagination and the enthusiasm to devote their abundant energies to the task produces a dynamic state, with many far-reaching pressures, transients, and interactions. Whether these can be exploited efficiently and brought to fruition depends almost entirely upon prompt access to resources—working capital, if you will—to seize the opportunities of the moment.

The Zacharias Committee Activities

Further evidence of the broad systems nature of contemporary educational change is the interaction on the colleges of the work that Professor Zacharias and his colleagues started several years ago to improve the teaching of science in the secondary schools. Aided perhaps by Sputnik I, the stirring to strengthen secondary-school mathematics, physics, and chemistry have precipitated widespread dissatisfaction with the content and pedagogy of the courses offered to college students in their freshman and sophomore years. At M.I.T. the unrest is particularly acute because of the present mood of the faculty and their inherent propensity for self-criticism—and perhaps, too, because of the influence of the changes already wrought in engineering under sponsorship of the Ford Foundation grant.

The time was ripe, therefore, for the Faculty Committee on Educational Policy to recommend that President Stratton appoint an *ad hoc* study group. Professor Zacharias was asked to lead an examination of the content of the core curriculum offered to M.I.T. students. The substance of the charge to the *ad hoc* committee was to "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 the opportunity for achieving greater coherence in the over-all program will be explored in depth. The Committee 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."*

It would be premature to state that after only one year of study the committee has reached specific conclusions, but the questions that have been raised have already precipitated change. The mere fact that the President appointed an Institute-wide committee and gave it such a broad charter started a chain reaction which can now be allowed to run its course only because of the support M.I.T. has received through its Second Century Fund.

The School of Engineering is giving unqualified support to the study. Its interests and viewpoint are ably represented by its two committee members, Professors Holt Ashley (Department of Aeronautics and Astronautics) and P. L. Thibaut Brian (Department of Chemical Engineering). The Engineering Council met with several members of the Committee during the full week of June 24-29 for a most profitable exchange of views. Several trends are evident, among

* From an interim report to the faculty by the Committee on Educational Policy, March 14, 1962.

which the following are of special interest:
1. Core subjects in physics, chemistry, and mathematics will undergo substantial updating in the next few years.
2. Only by being fully aware of the extent of the changes in these subjects and of their current content can the School of Engineering develop subjects which will provide an effective bridge between these and the more professionally oriented subjects of the upper years. Professors in the School of Engineering consider it necessary that they have more familiarity with the detailed content of freshman and sophomore core subjects in physics, chemistry, and mathematics. One efficient way for them to achieve this familiarity would be to join their science-department colleagues in teaching these subjects, a procedure which would also make available their wide experience in applying the subject matter in modern engineering to enrich the teaching.
3. The sequencing of subjects in the first two years should be modified in order to expose students to several applied science subjects taught by faculty of the School of Engineering along with the basic courses normally taught by faculty in the School of Science. It is proposed to insert into the curriculum a category of elective subjects in the engineering sciences which would be offered by a wide segment of the Institute faculty. This chance to strengthen our students' engineering orientation would, without reducing the science-rich base of their programs, recognize that engineering is now based strongly on science, that the engineering faculty is highly competent in the sciences, and that students would benefit if many topics which an engineering department heretofore has asked a science department to teach were now taught by selected faculty in engineering.
4. The work of the engineer has attained an importance in society that should be more widely understood. The proposal has been made that every student at M.I.T. study a subject representative of engineering to achieve an understanding of how engineers work and to be sensitive to their impact on social, economic, and political change. If the faculty as a whole should adopt this proposal, the engineering faculty would be presented a task that would fully tax their imagination.
5. The role of the laboratory in the teaching of physics and chemistry should be revised. Much instruction heretofore taken by students in the laboratory can be incorporated in classroom demonstration. The work in the laboratory should be enriched so that the program is more representative of an original project or investigation. Many of the

experiments recently conducted in the engineering departments under Ford grant sponsorship have furnished guidelines for laboratory developments in the core curriculum.

The academic year 1963-64 will witness faculty discussion and testing of many of the suggestions and questions raised by Professor Zacharias' committee. The impact on undergraduate teaching in engineering of whatever changes are made will be profound; many results will be unpredictable. In many respects M.I.T. may be running counter to the national trend of pushing engineering upward into the graduate curriculum. We are instead strengthening it downward in the undergraduate program and even inserting it into the freshman arena—a notable experiment.

While we are about half way down the road in time, in terms of the original goals of the 1959 Ford Foundation grant, we now face a wholly unexpected set of problems because of the outrunners generated by our own activities in engineering, by earlier activities in secondary-school science teaching by Professor Zacharias and his colleagues, and now by the committee examining our first two years. We look forward to undertaking these broader and more demanding tasks with confidence because of the flexibility, the longevity, and the magnitude of the resources now available to M.I.T. Decisions as to timing and character now rest squarely on our faculty and administration, exactly where they should be.

The Center for Advanced Engineering Study

The spectacular advances in science and technology during the past ten to fifteen years have rendered inadequate the basic training of many practicing engineers. As a result, their fundamental understanding of the newer domains of technology is weak, and they are unable to take full advantage of modern developments. Viewed in a slightly different manner, it can be stated that a gap of serious proportions clearly exists between what is taught to today's undergraduate and what was taught to many practicing engineers who are still relatively young men. Wherever this gap involves wholly new domains of science, filling it by any of the usual kinds of self-study is known to be difficult no matter how highly motivated an engineer may be. Consequently, many engineers in positions of great responsibility have an urgent need for formal programs of study to update their knowledge of the frontiers of technology and to deepen their understanding sufficiently to enable them to bring to bear on the solution of their problems the most up-to-date knowledge of modern science.

These factors are germane to the current national debate about the crisis in technological education and the complaint of many industrialists that our country does not adopt new techniques as rapidly as it should to maintain its position in the international marketplace. The technical requirements of society are rapidly outstripping our capability to produce highly trained engineers. A gap exists in both numbers and capabilities, and one is led inevitably to the conclusion that the quickest, and probably the best, way to fill this gap is to embark on a formal program of updating and of reorienting the skills of the most promising men now in industry and in education.

During the past year the initial steps were taken to enable M.I.T. to embark on a bold and imaginative new program to cope with one segment of this problem. As mentioned earlier, Mr. Sloan asked our appraisal of this problem in the summer of 1962 and solicited suggestions for coping with it. In April, 1963, the trustees of the Sloan Foundation granted $5 million to enable M.I.T. to establish a Center for Advanced Engineering Study. Specifically, the grant will permit construction of a new building to provide the needed classrooms, offices, and supporting facilities and to give this new activity an identity commensurate with its importance. The grant will furnish funds to defray the operating costs in excess of fees to be charged participants for the first five years and will provide for needed experimentation through a series of programs designed to meet the needs of selected groups of practicing engineers and college professors.

M.I.T. is not alone in attempting to meet the needs of technical personnel in coping with the problems of obsolescence. A number of engineering schools offer extension programs with the hours scheduled in such a way as to be convenient for industrial participation. Several schools, including M.I.T., have in recent years offered short summer programs of one and two weeks' duration. Several companies not geographically convenient to engineering schools or operating in highly specialized technical areas offer in-house programs run either by their own personnel or by special consultants. The role of the professional societies in assisting practicing engineers in keeping abreast of technological developments is also particularly significant.

With the large numbers of engineers in the country (approximately 800,000) and the diversity of their needs, it is clear that if M.I.T. is to make an effective contribution toward the solution of this problem, it must concentrate on a program that will exploit its unique strengths. While existing programs help large numbers of engineers, in general they have the greatest appeal for the more junior men and particularly for those who are interested in attaining a graduate degree. Consequently, both to meet the needs of an important new group and to capitalize on the interest of our faculty who are generating new technology, it appears that M.I.T. should concentrate on a program designed specifically for those key practicing engineers and college professors who are particularly responsible for setting the pace of technological progress. These are engineers working in advanced research and development efforts, serving as technical managers of programs drawing on the latest developments of science and technology, or working as teachers to strengthen their engineering curricula. Admittedly, we will be dealing with a relatively small number of participants, but we feel that those who attend will exert a significant influence in their own organizations when they return. This proposal in effect follows the general M.I.T. policy by focusing its efforts on a small number of selected engineers in much the same way that M.I.T.'s regular undergraduate and graduate degree programs focus on quality rather than on numbers.

We recognize that if advanced material is to be presented efficiently and in an exciting manner to a group of practicing engineers from widely differing backgrounds, totally new presentations of subject matter must be developed. This will require a great deal of effort on the part of our most able faculty. The areas to be covered must first be identified, and then we must select faculty in science, engineering, and management who have the interest and ability to provide instruction in these areas to such a group. Detailed curricula must be evolved and supported with appropriate notes, demonstration experiments, and laboratory work.

We are currently thinking in terms of developing programs of eight- to ten-week duration—some designed to meet the needs of engineering specialists and some of engineering managers—and yearlong programs for practicing engineers and engineering faculty who wish considerably greater depth and breadth than is possible in the shorter period. In addition, we propose to strengthen the Special Summer Programs which have been offered to representatives from industry and government for the past thirteen years by M.I.T.

The Center for Advanced Engineering Study adds an important new dimension to M.I.T.'s endeavors in engineering education. We face many new and novel problems on which much experimentation is needed. Clearly we will be devoting significant effort to the development of the Center's many aspects for a number of years. Our immediate goal is to prepare for a pilot group of engineers to enter M.I.T.

during the autumn of 1964. The new building will serve as the focal point of these activities, and if all goes well it will be completed toward the end of 1965. The program cannot move into full operation much before that time.

The establishment of this new Center should offer us opportunity for a significantly improved flow of information back and forth between M.I.T. and the industrial community. It should serve, on the one hand, to meet an industrial need of major proportions and, on the other, to provide an opportunity for our faculty to gain a greater appreciation of the problems faced by industry. In the long run this activity should significantly strengthen all aspects of engineering education. Furthermore, we dare to think that programs under which practicing engineers return periodically to a university for advanced study in the latest areas of science and technology will become as well established in our society as has study for the Bachelor's, Master's, or Doctor's degrees.

As this report goes to press, we are proud to announce the appointment of Professor Harold S. Mickley to be Director of the new Center. As Chairman of the Faculty, *ex-officio* Chairman of its Committee on Educational Policy, and Professor of Chemical Engineering, Professor Mickley will bring to the new position a perspective on and knowledge of the problems of education and engineering which will be indispensable in the leadership of an effective program.

Personal Notes

The Institute, and in particular the Department of Civil Engineering, was saddened on July 24, 1963, by the untimely death of E. Phillip Gladding, an Instructor in Civil Engineering. In his relatively brief association with the Department, Mr. Gladding had played a major role in fostering the utilization of modern computing techniques in civil engineering. The high degree of interest and capability in computers currently evidenced in that Department was due in large part to his ability and enthusiasm.

On July 2, 1963, Charles M. Spofford, Hayward Professor of Civil Engineering Emeritus and former Head of the Department of Civil Engineering, passed away at the age of 91. Professor Spofford was associated with M.I.T. during almost all of his adult life. His S.B. degree was awarded here in 1893, following which he was a graduate student, Instructor, and Assistant Professor. After a short period away from M.I.T., he returned in 1909 as Hayward Professor and from 1911 to 1933 served as Head of the Department of Civil Engineering. Professor Spofford was an authority on structures and participated in a number of civil engineering projects particularly in the New England area.

In the fall of 1962 Professor Thomas B. King became Head of the Department of Metallurgy. He had served as Acting Head of the Department since Professor John Chipman's retirement in June of that year.

Professor Lan J. Chu became Webster Professor of Electrical Engineering on July 1, 1963, upon the retirement of Dr. Ernst A. Guillemin, who was appointed Edwin Sibley Webster Professor in 1960 and now closes a distinguished teaching career at the Institute.

In last year's report, we commented briefly on the establishment of the Kanpur Indo-American Program. Professor Norman C. Dahl of the Department of Mechanical Engineering has continued his residence in Kanpur as Program Leader through this past year and was joined by Professors Robert L. Halfman of the Department of Aeronautics and Astronautics and Alve J. Erickson of the Department of Mechanical Engineering.

GORDON S. BROWN, WILLIAM W. SEIFERT

Department of Aeronautics and Astronautics

Education for students interested in the science and engineering associated with the broad field of flight technology is provided by the Department of Aeronautics and Astronautics. Professional degrees are offered at the Bachelor's, Master's, Engineer, and Doctor's levels. The curricula cover the full spectrum of flight vehicle systems from helicopters through subsonic airplanes, supersonic aircraft, and ballistic missiles to interplanetary ships. Sound and broad background education in theory is provided by a systematic grouping of subjects that deal with the mathematics, science, and applied science that make up the foundations of aerospace technology. The engineering aspects of this area are introduced and developed by professional subjects combining theory and practice in ways that provide comprehensive experience with the integration of practical components and subsystems into complete flight systems able to meet accepted specifications. Flight vehicles are stressed in teaching these subjects because the behavior of these necessarily sophisticated and complex craft continues to be the limiting factor in the performance of overall systems. At the same time other essential elements such as communications, data handling, computers, control and guidance, life sciences, management, economics, etc., are studied with basic theory and practical limitations treated in the context of real operations.

The Department realizes that knowledge alone is not sufficient to insure competence in engineering or research, but it is also sure that education of the kind its teaching provides will be effective in stimulating graduates toward development of their full capabilities for service to society and the achievement of substantial rewards for themselves.

The full energies of the Department are devoted to giving students educational opportunities of the kind described, and in this endeavor it is exposed to the challenge of continuously adapting subjects and teaching methods to pioneering developments in all the pertinent areas of knowledge. The most important field is that of technology, which is currently changing so rapidly that acceptable education must prepare young men and women to attack not only the problems of today but also to cope effectively with the more difficult circumstances that will appear in the future. For this education to be most effective it must be continually modified by wise and experienced faculty members on the basis of knowledge drawn from the current state of science and technology. The objectives of this modification can be achieved only if past, current, and probable future states of the technology involved are all studied and judged for the purposes of determining policies and curriculum details. With its eyes open to the implications involved, the Department accepts all the tasks needed to keep its activities in the forefront of education associated with aeronautics and astronautics.

EXPERIMENTS IN ENGINEERING EDUCATION

During the 1962-63 academic year two experiments were carried out by the engineering section under Professors Otto C. Koppen and Rene H. Miller to determine how effectively students can be exposed to the true breadth of engineering within limitations imposed by the academic environment. The endowment of the H. N. Slater Professorship in Flight Transportation greatly assisted the initiation and progress of these educational experiments. Both of the experiments involved interdepartmental cooperation in teaching with participation by prominent authorities from outside the Institute. The basic elements in both experiments were air transportation systems and space systems, subjects that are included in the regular engineering teaching of the Department.

The air transportation enterprise under the direct supervision of Professor Miller stressed the interdisciplinary nature of this field by making the subject a joint undertaking with the Departments of Civil and Electrical Engineering and the School of Industrial Management. The problems of navigation, vehicle design, ground facilities, operations, safety regulation, and economics were covered by lectures from faculty members of the participating departments. These lectures were supplemented by a series of twelve seminars by outstanding speakers from the governmental regulatory agencies, from the aerospace industry, and from the airlines. Each of the twelve students who registered prepared a term paper under the supervision of a faculty member, covering in some depth a subject close to the primary interests of each individual. The staff was well satisfied with the results represented by these papers. The flight transportation subject will be expanded in hours to allow increased depth of coverage and offered during the 1963 fall term as a regular graduate subject.

Under the leadership of Visiting Professor William Bollay, faculty members in charge of several regular Institute subjects combined their efforts to teach space systems engineering during the 1963 spring term. Some seventy students registered for this interdepartmental subject, for the most part graduate students but also including a few properly qualified undergraduates. The design of a weather satellite system was chosen as the vehicle of instruction and the students were divided into five sections representing the basic elements of the system and, more approximately, their various areas of specialization. These sections dealt with the launch complex, the satellite vehicle, the communication system, data processing, and management. This last section was selected by a small group who wished to deal primarily with the problems of administration and procedure. Each section operated under the direction of one or more faculty members, but the decision-making process was left as much as possible in student hands. Group leaders and assistants were elected by the group with each member acting for one-third of the term, and a project leader was elected by the group leaders. Although this division into groups resulted in what would appear to be an undesirable degree of specialization, in practice the interaction between the groups was extensive and most students were acutely aware of the problems faced by other sections. Lectures by the faculty were kept to a minimum, but a large and distinguished group of seminar speakers provided excellent coverage of the many continuing problems of weather satellites.

The output of the subject was a single 350-page report to which all the students contributed. This report was presented to a critical audience of invited guests and faculty during a five-hour presentation at the end of the term.

In retrospect, space systems engineering was a most successful experiment in that it provided a valuable educational experience in group action and systems engineering analysis to the students. Although the subject will not be repeated in exactly the same form, it will be offered again during the spring of 1964 and, it is hoped, will become eventually a permanent and important part of graduate education for aeronautics and astronautics.

The two subjects described above were designed primarily for graduate students, but both were open to qualified undergraduates as senior electives. A regular undergraduate subject in systems engineering is offered and is required for those electing the engineering option of the Department. The Department faculty is currently debating whether such a subject designed around the broad implications of systems engineering should not also be required of those electing the engineering science option. It is the feeling of some that the experience in the exercise of judgment and the interplay of many disciplines provided by such a subject is very valuable for engineering research as well as the practice of engineering. In the meantime, the undergraduate engineering subject is being continually modified in order to find the best form for its presentation to the undergraduate student.

DEPARTMENT OPERATIONS

During the academic year 1962-63 student enrollment in aeronautics and astronautics remained substantially unchanged at both the undergraduate and graduate levels. The Classes of 1963, 1964, and 1965 had, respectively, forty-one, forty-nine, and fifty-seven students, a total of 149 as compared with 151 for the corresponding number of one year ago. There were 165 full-time graduate students in June, 1963; a corresponding number for June, 1962, was 149. Student quality remains good in both schools with a satisfactory number of applications from which to make selections. During the 1963 calendar year the Department awarded forty-three Bachelor's degrees, fifty-nine Master's degrees, four Engineer degrees, and ten Doctor's degrees.

The Cooperative Course for undergraduates continues to attract about one-fifth of the total enrollment. It appears this form of education is a very worthwhile experience for students interested in balancing theoretical studies with practical work. Academic records of

Cooperative Course members are not significantly different from those of other students in their class.

HONORS GROUP

Qualified students continue to be attracted to the Honors Course which, beginning in the junior or senior year, builds a five-year program of study leading to both Bachelor's and Master's degrees at graduation. This course is under the inspiring leadership of Professor Holt Ashley, with able assistance from Professors Winston R. Markey, Saul S. Abarbanel, and Myron A. Hoffman. Approximately one-quarter of the senior class accept the Honors Course and become active in dinner meetings held monthly to hear talks by distinguished guests.

SEMINARS AND LECTURES

In the fall term, the Flight Transportation Seminars (reported elsewhere) dominated the seminar series. In the spring term, an active program of lectures was organized by Associate Professor Judson R. Baron. These ranged over the various sub-areas of aeronautics and astronautics, including lectures in magneto gas dynamics by Dr. G. C. Cherny of Moscow State University and Dr. Eugene E. Covert of M.I.T.; non-equilibrium and slip flow by Dr. T. H. Hodgson of Cranfield, England, and Dr. Henry T. Nagamatsu of the General Electric Research Laboratories. Professor Seymour M. Bogdonoff of Princeton University, Richard Barakat of Itek Corporation, Professor Boa-Teh Chu of Brown University, and Professor Julian T. Cole of the California Institute of Technology also presented seminars in gas dynamics. Dr. George Gerard of Allied Research Associates lectured on the stability of orthotropic shells. Two lectures in the field of instrumentation and control were given by Dr. A. Straszak of the Polish Academy of Science and by Dr. K. R. Magnus of the Technische Hochschule, Stuttgart. Finally, commercial aviation was discussed by Najeeb E. Halaby of the Federal Aviation Agency and Clarence L. Johnson of Lockheed Aircraft Corporation.

The fifth Lester D. Gardner Lecture was presented on May 1, 1963, by Elmer A. Sperry, Jr., under the title of "Early Airplane Instruments." Mr. Sperry is widely recognized as one of the great pioneers of aeronautics. His talk was delivered to an enthusiastic audience, including a number of his contemporaries and many members of the Institute community.

The Gardner Lecture was affected by a note of sadness, for Admiral Luis de Florez, who had accepted an earlier invitation to present the lecture, died suddenly on December 5, 1962. The Department considered cancellation of the lecture but decided that both Major Gardner and Admiral de Florez would wish the event to be carried through, and Mr. Sperry graciously consented to compose and present a lecture based on his personal experiences as a contributor to the technology of aircraft instruments.

FACULTY AND STAFF

The Department has continued to make changes in its faculty with the objective of increasing its overall strength while improving the balance among its various divisions.

Flight transportation, under the encouragement of support from funds given to the Institute by Commander H. N. Slater, recently developed to a level at which it required more attention than the existing faculty could supply. In response to this situation, Professor Miller was made the H. N. Slater Professor of Flight Transportation and Professor Secor D. Browne, a distinguished consultant on flight transportation, and Norman D. Ham, who is especially qualified in operational analysis, were given appointments as Assistant Professors.

Engineering for flight vehicles and their systems is another area supervised by Professor Miller in collaboration with Professor Koppen. As noted in a preceding section of this report, experiments in teaching the engineering of flight vehicle systems received special emphasis during the past year under the leadership of Dr. Bollay as Visiting Professor during the past academic year.

Professor Gerald Corning of the University of Maryland spent the year working with Professor Miller on the problems of teaching engineering design.

Professor Paul E. Sandorff continued on leave with the Lockheed Aircraft Company. He will return for the term beginning in February, 1964, to lead a comprehensive subject in the engineering of flight systems for recoverable launch systems. Professor Sandorff is especially well qualified for teaching of this kind and will surely provide students with an excellent opportunity to become familiar with the methods of modern aerospace engineering.

Professor Raymond L. Bisplinghoff has completed the first half of a two-year leave to the National Aeronautics and Space Administration. His position as Director of Advanced Research is providing him with knowledge and experience that will surely increase his professional stature and provide his students and colleagues with new enthusiasm when he returns for the academic year 1964-65.

Members of the faculty have watched the Institute's collaboration in on-the-spot foreign education with great interest. This interest was reduced to practice during the past year by Associate Professor Robert L. Halfman, who took his family to India for a three-term leave of absence to serve with the Indo-American Program at the Indian Institute of Technology in Kanpur. Professor Halfman will return to his duties at M.I.T. for the spring term of 1964.

In the field of fluid dynamics, Dr. Harold Y. Wachman, on leave from the General Electric Company, served as Visiting Associate Professor to become a colleague of Professor Leon Trilling on surface effects in low-density gas environments. Also in the general area of fluid dynamics, Dr. Marc A. Kolpin was appointed Assistant Professor and Ford Postdoctoral Fellow. His work was principally in fluid dynamics and was carried out in collaboration with Professor Erik L. Mollo-Christensen.

Dr. Laurence R. Young was appointed Assistant Professor to work with Professor Yao T. Li in the field of measurement and control. Dr. Young is primarily interested in human organs as operating control elements, a field in which he has several distinguished publications and continues to carry out pioneering research.

Dr. Walter M. Hollister was made an Instructor to assist Professor Walter Wrigley in subjects on flight vehicle guidance systems.

Professor James L. Stockard, who has been on leave from the Institute to work with the A. C. Spark Plug Company, decided to extend this experience and resigned from his faculty position.

The teaching staff of the Projects Laboratory has been strengthened by the appointments of John Barley and Allan R. Shaw as Technical Instructors.

STUDENT HONORS

Awards for outstanding ingenuity and creativity in engineering, honors founded by the late Admiral Luis de Florez, were given to Peter B. Rhines '63 and Victor D. Scheinman '63. Mr. Rhines carried out a research program on mixing of salt and fresh water of different temperatures, a problem of great importance to oceanographers. Mr. Scheinman's award was for the design and construction of an ultrasonic altimeter to determine height above the water for the immersion control of a hydrofoil craft. Honorable mentions were awarded to Steven R. Croopnick '64, Ramunas J. Skrinska '64, and Ronald W. Matlin '63.

The James Means Memorial Prizes for professional promise as indicated by excellence in flight vehicle engineering were awarded to Xenophon P. Stathatos '63 and Henry Ziegler '63. The Henry Webb Salisbury Award "for outstanding work in the Department of Aeronautics and Astronautics" was won by Charles P. Gardiner '63.

RESEARCH ACTIVITIES

Research activities in the Department are based on two divisions: the Instrumentation Laboratory under the direction of Professor C. Stark Draper and the Aerospace Research Division directed by a steering committee of faculty members under the chairmanship of Professor Morton Finston.

INSTRUMENTATION LABORATORY DIVISION

Instrumentation Laboratory projects have continued to be successful in terms of operational results achieved by industry-produced inertial guidance systems designed and reduced to practice at M.I.T. *Polaris* and *Titan* ballistic missiles are now accurately guided through full-range flights by Instrumentation Laboratory systems. Inertial navigation systems from the Laboratory are now under test for ships and submarines, and components for *Minuteman* guidance systems are starting production. The overall guidance system for manned lunar flight *Apollo* vehicles is now well on the way to completion for engineering tests. Limited production will follow shortly after manned flight qualifications trials are completed.

Several new developments of components and systems have now reached states at which they are ready for design into operational systems. Support from the Air Force and the Navy is available on the basis of urgent needs for improved equipment. Some possible projects have been rejected in the interests of controlling the magnitude of laboratory operations. Other projects will be considered in terms of a balance between the needs of national defense and the proper size for a laboratory associated with an educational organization.

AEROSPACE RESEARCH DIVISION

The Aerospace Research Division is made up of the Aerophysics Laboratory, the Fluid Dynamics Research Laboratory, the Aeroelasticity and Structures Research Laboratory, the Gas Turbine Laboratory, the Space Propulsion Laboratory, and the wind tunnels; in addition, the Division supplies support for members of the faculty who wish to carry out research without being formally associated with an established laboratory.

AEROPHYSICS LABORATORY

The Aerophysics Laboratory is directed by Professor Finston with Dr. Covert as Associate Director. Supervision for laboratory activities is provided by Professor Baron, Dr. Leon H. Schindel, Dr. Beverly J. Beane, and Frank H. Durgin. The Laboratory has recovered successfully from the very bad fiscal situation which existed two years ago and now finds itself in stable circumstances, although no substantial resources providing for operating contingencies are available at the present time.

In operation the Aerophysics Laboratory has changed its nature from a sponsored research laboratory to an activity more typical of a university group primarily interested in teaching and basic research. The subjects of concern are now problems in gas dynamics that are compatible with the needs of aerospace technology. The work in progress includes studies of real gas phenomena at high velocities, low-density gas dynamics, and the flow of ionized media. Also being given attention are situations of more immediate importance such as the factors controlling sonic booms and the difficulties of realizing efficient lifting surfaces for supersonic transport aircraft.

Basic techniques of measurement are being studied, especially the application of magnetic suspension systems to improve aerodynamic data on slender bodies of revolution. The success of these efforts offers increased confidence that such systems will make possible better measurements of dynamic parameters for bodies in high-speed gas streams. Very-high-speed tunnels based upon magnetic acceleration of ionized gases are being developed. Means for carrying out accurate measurements of physical quantities are being studied with good prospects that the Laboratory will be able to make substantial contributions to this frontier region of fluid mechanics.

FLUID DYNAMICS RESEARCH LABORATORY

The Fluid Dynamics Research Laboratory is a loosely-knit group of faculty members who more or less by individual effort carry out research on interesting subjects with facilities of various departmental laboratories or with special equipment installed in any convenient space.

Professor Trilling, working with Professor Wachman, investigated gas-surface interactions and made progress in the construction of a molecular beam analyzer. With support from the Office of Naval Research and the Air Force Office of Scientific Research, an electron gun with a mechanical chopper was built and is now being tested with standard thermal beams.

Professor Mollo-Christensen divided his activities between fluid dynamics and the Aeroelastic and Structures Research Laboratory. He supervised the design and construction of apparatus for the investigation of Couette flow by David L. Kohlman. Collaborating with Professor Marten T. Landahl and working with Richard E. Kaplan, Professor Mollo-Christensen continued his studies of fluid flow over compliant and wavy surfaces.

Professor Landahl continued theoretical research on unsteady transonic flow in addition to the boundary layer work mentioned above. He also collaborated with Professor Holt Ashley in giving advice for a project on unsteady flow over hydrofoils and hydroelasticity, sponsored by the Office of Naval Research, which is being carried out under the leadership of Sheila E. Widnall.

Professor Ashley, in addition to the hydrofoil work already mentioned, cooperated with Professor Landahl on studies of unsteady high-speed flow sponsored by the Air Force Office of Scientific Research. This work was focused on subsonic, transonic, and supersonic wings oscillating near the ground in non-planar and other configurations. Professor Ashley continued his supervision of N.A.S.A.-sponsored work by Dr. Pao T. Hsu and Robert A. Greenberg on time-dependent bending loads of large rocket boosters.

AEROELASTIC AND STRUCTURES RESEARCH LABORATORY

Theoretical and experimental research intimately connected with both the graduate and undergraduate programs has continued in the Aeroelastic and Structures Research Laboratory on a wide variety of aerodynamic, structural, and aeroelastic problems under the direction of Professor Emmett A. Witmer. These activities are associated with the following fields of interest: aerodynamic noise; aerodynamics of helicopter rotors; stability, transition, and turbulence of flows over wavy and compliant surfaces; unsteady airloads on subsonic, supersonic, and hypersonic vehicles; static and dynamic behavior of structures in the linear and nonlinear ranges of deformation and material behavior; properties of composite materials; aerothermoelastic problems; and aeroelastic instabilities of inflatable re-entry vehicles. These problems afford fertile areas for student, faculty, and staff research. In addition to providing student support and research problems of both academic and timely practical interest, the Laboratory realizes important academic dividends through the upgrading of present subjects and the introduction of new subjects stemming from research results. Faculty members supervising and participating in this research include Professors Ashley, Landahl, Miller, Mollo-Christensen, John Dugundji, James W. Mar, Theodore H. H. Pian, Witmer, and Ham.

GAS TURBINE LABORATORY

The Gas Turbine Laboratory research has been supported during the past year by grants-in-aid from the General Electric Company and the Allison Division of General Motors Corporation. The Laboratory also had contracts with the David Taylor Model Basin (Office of Naval Research) and with the National Science Foundation.

The annual sponsors' conference for the purpose of discussing the research program with the sponsors was held on December 18, 1962. The conference was attended by over twenty representatives of the sponsors.

Professor Philip G. Hill of the Mechanical Engineering Department has been lecturing at Imperial College of London University this year. The laboratory has been happy to have Professor Bernard W. Martin of London University who exchanged with Professor Hill.

Professor William R. Hawthorne of Cambridge University has also been with the Gas Turbine Laboratory this year and has been active in the research program.

Professor Edward S. Taylor is making a film on secondary flow with Educational Services, Inc.

SPACE PROPULSION LABORATORY

Research in space propulsion and power generation has expanded considerably during the last year. The work on two-temperature plasmas continues, while a new program for study of pure alkali-metal vapors in the wet, ionized state has been initiated. The fluid mechanics of nuclear rockets is also being studied. Three Ph.D. candidates and eight S.M. candidates were involved in the research, under the direction of Professors Jack L. Kerrebrock, Hoffman, and Gordon C. Oates.

EXPERIMENTAL ASTRONOMY LABORATORY

During the past year, the Experimental Astronomy Laboratory, directed by Professor Markey, has made measurements of sky brightness from a high-altitude balloon vehicle; provided telescope stabilization instrumentation for stellar scintillation measurements, which were made from a manned balloon gondola; and studied other atmospheric properties by making color photographs of the horizon, also from a high-altitude balloon vehicle. Under a grant from N.A.S.A., analytical studies including three Doctor's theses have been carried out on problems in navigation for space vehicles.

The work of the Laboratory continues in the general areas of atmospheric effects on the propagation of light and on space vehicle navigation. These programs continue to provide support for theses at the Bachelor's, Master's, and Doctor's levels.

WIND TUNNELS

The Naval Supersonic Tunnel has ended the last fiscal year with the deficit in its operating account eliminated. Operation of the large tunnel has amounted to 100 hours as against 180 hours in the previous year, with prospects of less time next year. With no funds for major maintenance or reconstruction, consideration is being given to whether or not operation of the tunnel should be continued, and a decision on this matter will probably be made within the next year. The supervision of the tunnel has been relinquished by Professor Joseph Bicknell and is now the responsibility of the Aerophysics Laboratory under the direction of Professor Finston.

The Wright Brothers Wind Tunnel has been used on a sponsored research project for the past year. Commercial testing has been eliminated.

EDUCATIONAL ACTIVITIES

Academic year 1962-63 has been a period of bringing toward completion the many activities in undergraduate educational development that were initiated and supported by the Ford Foundation grant to the School of Engineering. Subjects organized and given for the first time, laboratories started and equipped, notes written, assistants provided, books published, re-education for faculty members—all make up great benefits for education that the Department owes to Ford funds. These benefits have been spread so widely that it is meaningless to attempt a recital of details. Ford help must be given a major share of the credit for recent progress in most of the divisions of the Department. Brief reviews of activities in several divisions not covered elsewhere in this report are noted here.

In the fluid dynamics and gas dynamics area, Professors Ashley and Landahl are preparing a text on the aerodynamics of wings and bodies, based on their experience and notes written for the graduate elective subject of the same name. Professor Wachman offered an elective subject in solid-surface effects in a low-density gas.

Professors Mar and Pian have completed a text for the first subject in solid mechanics. The higher level of mathematical development now reached by students in their third year has made it possible to teach the basic concepts of solid mechanics with more physical understanding. The authors are now working on a text for the second course in solid mechanics.

Professor Taylor has continued to supervise the development of course material for teaching propulsion. A text for the first subject in a three-subject sequence in propulsion by Professor Hill of the Department of Mechanical Engineering and Professor Carl R. Peterson of this Department is nearing completion. The title is *Mechanics and Thermodynamics of Propulsion.*

Professors Kerrebrock, Hoffman, and Oates have been reducing theory and experiment to class material for the fields of conventional and exotic propulsion.

Professors Yau T. Li and Young have developed a new subject in the study of measuring instrumentation, aimed at coordinating the essential techniques used in the design of measuring systems and organizing them into a functional pattern to aid in solving new measurement problems.

Professor Wallace E. Vander Velde has expanded the material presented in his subject on Statistical Problems in Automatic Control. He also conducted a seminar for a number of doctoral candidates to discuss special topics in automatic control.

THE PROJECTS LABORATORY

The Projects Laboratory subjects have continued to be an outstanding success in education. Students who have taken this Laboratory rate it the most interesting and rewarding work in the undergraduate curriculum.

Purchase of equipment, mostly electronic measuring devices, has continued during the past year. More and more interest is evident in high-vacuum experiments for which suitable pumps are being acquired. The policy of buying slowly over a long period has proven to be a wise one.

Professor Walter McKay has been in charge of the Projects Laboratory work for the past year, a position rotated among the staff members to maintain fresh and enthusiastic leadership.

CHARLES S. DRAPER

Department of Chemical Engineering

Significant changes are being made in the educational programs of the Chemical Engineering Department as a result of its work on new subject materials and techniques. Greater emphasis has been placed on the fundamental disciplines, on process design engineering, and on experimental work of a research type. The experience obtained from these experimental studies is now being incorporated in the regular subjects with larger numbers of students.

UNDERGRADUATE LABORATORY AND RESEARCH

In the early years most engineering students do not have a comprehension of the nature of the problems they will face in professional work, and with the large amount of science in the undergraduate program they often do not develop such an appreciation until almost at the end of their four-year programs. As a result, many students fail to grasp the professional significance of much of the science they are studying, and they fail to obtain real inspiration from it. The Department believes that experimental work of a research type can be an important method of introducing the concepts of engineering to a student.

The development of an augmented program of laboratory work has been continued during the year, and experimental work combined with classroom discussion is now offered in all four of the undergraduate years. These studies are of the research or project type, and none involves set experiments. All involve planning, experimentation, and analysis, and at all stages emphasis is placed on oral presentations and written reports.

During the past school year seven members of the faculty were involved in the undergraduate seminar program; six seminars were given in the fall semester and five in the spring term. These included seminars on the History of Science, Chemical Processes, Arc Reactions, Engineering Problems in Medicine, and Electrochemistry. These seminars brought small groups of the freshmen students together with members of the staff in an area of the staff interest. Most involved group discussions, planning, and laboratory work. The students were taken into considerable depth in the area of each seminar under conditions where the staff members could evaluate their reactions and interest better than in normal subjects.

The undergraduate research program for sophomores, juniors, and seniors developed by Professors Warren K. Lewis, Herman P.

Meissner, and Harold C. Weber was given in both semesters and involved students from all three years. The best problems used so far have come from the area of industrial chemistry, because in the earlier years the students' background is more adequate in this area than it is in the physics and engineering science disciplines. The problems are multi-faceted, and the solutions require the integration of such knowledge and judgment as the students possess at this early stage. They must analyze and understand the problem, propose a program of alternatives designed to lead to a solution, organize as a group for the effort, execute the program, analyze the result, and present the conclusions in a report. The most successful cases investigated to date are studies of proposed modifications of presently employed processes. This type of problem is most effective in an area where there is a large background of information in the literature but, due to the modification proposed, there are gaps in the information needed before a sound evaluation and proposal can be made; and where some of these gaps can be filled only by securing new experimental information in the laboratory. Such cases give students the opportunity to organize and execute a laboratory program as an aid to answering the key questions. This is an area in which they have had little experience, and initially they have considerable difficulty in developing their ability to proceed. It is desirable that the experimental work required be largely of the engineering process type; furthermore, the amount of time and effort required for at least a preliminary appraisal should not be excessive nor the laboratory equipment needed too complicated in character. Attention to these details in the choice of the problem to be assigned is essential if the experience is to be of maximum value to the students. The staff acts as consultants and critics, but the initiative and leadership are left to the student group. This program gives the students an understanding of how real engineering is handled. Forcing the students to take the initiative assures them an all-around professional experience which is not attained in classroom subjects at this early stage. The student response to the program has been excellent.

A similar type of experience is given to chemical engineering students in the senior laboratory subjects in applied chemistry and engineering. In these subjects, the cases to be investigated are suggested by the whole departmental staff, and the students, in groups of three, are given three problems to investigate during the semester. All of the cases require obtaining experimental data in order to make sound recommendations on the problems, and the students are given almost complete freedom in organizing and carrying out their programs. The member of the staff who has suggested the particular case serves as a consultant to the group. The staff members in charge of the subject establish the schedule for the oral and written reports which are an important part of the program, and they assist the students in obtaining equipment and supplies. There are no set laboratory hours, and the students do the experimental work when it is most convenient for the group. A formal report is required from each group for each case, and the reports for all previous years are bound and available to the students. The cases are equivalent to senior theses in scope and depth, since they are planned for students who have all of their background science and most of their undergraduate engineering training. The reports are reviewed in detail with the students because training in oral and written reporting is one of the major objectives of the subject. This is one of the very important subjects in the undergraduate chemical engineering curriculum.

All seniors in chemical engineering do an individual thesis, and the experience they have obtained in the group investigations has prepared them to take a problem of real significance and to handle it effectively.

This series of experiences in handling comprehensive cases develops each student's ability and confidence to solve significant engineering problems. They serve as a proper balance to the increased emphasis on science in the undergraduate engineering program.

UNDERGRADUATE SUBJECTS

In addition to the laboratory subjects that develop the student's ability to integrate his experience and make sound judgments, the Department has been developing classroom subjects in process engineering design. The general approach is to prepare cases which are examples of design requiring the use of principles from several areas. These cases are carefully prepared examples of real engineering design problems and are sufficiently complex to require three weeks of class time. Preparing cases which require the exercise of judgment in choosing between alternative solutions is a time-consuming job and one of the limitations on the subject. An instructor who has had considerable experience in this area is needed in order to lead the class discussions effectively and to show that qualitative judgments based on good analysis are an integral part of any important engineering problem, and that the ability to make such judgments is a skill that can be developed just as well as the ability to solve mathematical equations. The cases that have been developed in the last two years in this subject by Professor Thomas K. Sherwood are being assembled in book form and will be published this summer by the M.I.T. Press.

The work reported last year on the development of our instruction in the unit operations and in the transport rate area has continued under the direction of Professor Harold S. Mickley. We have gradually gained experience in developing and presenting this new material most effectively to the students. During the coming year it is planned to offer these subjects to an increasing number of our undergraduates.

As the chemical and petroleum industries have developed and become more advanced, one of the critical elements of almost all plants is the chemical reactor. Most of the problems of calculation related to energy transfer, mass transfer, separation processes, and materials flow can be handled effectively, but frequently it is difficult to scale up the results of a laboratory reactor to the full-plant size. In designing large reactors it is often difficult to make the contact between the catalyst and the reactants as effective as it was in the laboratory, and the energy transfer in the reactor may be a limiting factor. Also, side reactions or catalyst contamination may be more difficult. The chemical engineer should be the leader in the conception of new processes, in the research and development on the systems, and in the engineering of effective commercial reactor units. He must understand the fundamentals of catalysis and of applied kinetics involving the chemical kinetics, fluid mechanics, mass transfer, and energy transfer characteristics of various types of reactor systems.

The increasing importance of catalysis to the chemical engineer was emphasized last year by the inauguration of a new elective subject on catalysis by Professor Charles N. Satterfield. The subject was repeated in the fall term of 1962-63, and student interest continued to be high. The interplay between catalytic phenomena and mass transfer is one aspect of the field of particular concern to chemical engineers. With support from the Ford Foundation grant to M.I.T., Professors Sherwood and Satterfield prepared a set of class notes entitled "The Role of Diffusion in Catalysis", which has been used in the subject in catalysis and also in the subject on applied chemical kinetics. A book which developed from the revision and improvement of these notes will be published under the same title by Addison-Wesley in the fall of 1963.

The instructional and research program in catalysis in the Department have been strengthened by a seminar subject in catalysis directed by Professors Satterfield and Raymond F. Baddour which was initiated last year and continued in the spring term of 1963. As a part of the program a number of individuals distinguished for their contributions to the field were invited to visit the Department to give lectures and participate in conferences with students and staff. The visitors from outside M.I.T. included Dr. Benjamin W. Howk of the Eastern Laboratories of the du Pont Company; Drs. Heinz Heinemann and Harry P. Leftin of the M. W. Kellogg Company; Dr. W. Keith Hall of the Mellon Institute; Professor Pierce W. Selwood of the University of California, Santa Barbara; and Dr. A. U. MacRae of the Bell Telephone Laboratories.

During the past year the Department has made an effort to more effectively introduce the sophomore students to their first chemical engineering subjects, helping the students to understand both the material and our objectives. A more tutorial type of instruction is believed by many to be desirable for this purpose, but the availability of adequate staff time has been a limiting factor. Such individual attention should be especially valuable in the student's early years, because by the time he is a junior or senior he is fairly well adjusted to the Institute. The Electrical Engineering Department had initiated the system of having extra graduate student assistants work closely with the students on specific subjects, and this technique was investigated with our sophomore subjects in stoichiometry and thermodynamics. The assistants, chosen from the best of our doctor's students, were mature and had outstanding ability; they worked with the students reviewing various aspects of the subjects to illustrate how an engineering problem should be organized and handled and at the same time giving them an understanding of the Department's standard of performance.

For several years the Department has been working to determine what is the most effective background in physical chemistry for chemical engineering students, and a number of students have taken a program involving several subjects in chemical physics instead of the regular physical chemistry. This gives them more depth in statistical and quantum mechanics and in the interaction of waves, fields, and matter. We were fortunate that Professor Peter Debye of Cornell University was able to spend some time with us during the spring term reviewing and discussing our work and plans in this area.

GRADUATE PROGRAM

The number of men who have passed the general examination for the doctorate and are working on theses is at an all-time high of approximately eighty. There are, in addition, about an equal number of graduate students on Master's and pre-doctoral programs. The Practice School stations at the American Cyanamid Company in Bound Brook and at the Esso Refining Company at Bayway, where students have the opportunity to work on real engineering problems and evaluate their judgments against that of professionals in the field, are operating at capacity. Student quality is high.

The large group of students on doctoral programs gives the Department a very active research operation, and it is believed that a further expansion in this area would be desirable. Increasing numbers of engineers will benefit by advanced study enabling them to handle broader problems more adequately. This trend to more graduate work has been increasing rapidly in the engineering field, and it will continue to accelerate during the next decade.

Graduate education is expensive because of the individual attention which each student requires and because of the laboratory facilities and equipment needed for effective work. A considerable proportion of the cost of operating the research work in the Department is obtained from project funds, mainly from government agencies, and as the research program is expanded this must be one of the major sources of financial support.

The research activities of the Department have also been augmented by the Ford Postdoctoral Fellowship appointments, of which there are now five in the Department. This fellowship program strengthens and augments the research activities of the Department and at the same time enables outstanding doctorate men to get a start in engineering education.

STUDENTS AND STAFF

A number of awards were given to chemical engineering students during the past year. At the junior-year level, Lita Lynn Markley received the M.I.T. Woman's Association Award and Robert L. Blumberg was given the Scott Paper Foundation Leadership Award. Four of the seniors were honored: Arthur B. Krewinghaus received both the American Institute of Chemists Award and the Society of American Military Engineers Award; Charles W. Selvidge received the Hunneman Prize; Harold R. Gregg, the Robert T. Haslam Cup; and Kenneth L. Weyler, the Professor of Air Science Award. Samuel W. Bodman, III, was given the Eastman Kodak Scientific Award for his excellent performance as a graduate student in chemical engineering.

The principal awards to members of the faculty are listed elsewhere in this volume. Professor Mickley served as Chairman of the Faculty and Professor Sherwood was a member of the U.S. Delegation to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas, held at Geneva.

During the past year the Department had Professor Vincent Uhl of Drexel Institute (now head of the Chemical Engineering Department at University of Virginia) as a National Science Foundation Faculty Fellow and Dr. Peter G. Redpath of the University of Sheffield as a Guest. Dr. Nathaniel Schneider continued as a Visiting Associate Professor.

RESEARCH

The Department conducts its research work as an integral part of the educational program, with the major objective being the training of students to handle complex engineering problems effectively. The thesis work of the students is the research program of the Department. These activities cover many areas, and some of the current work is summarized in the following sections:

CATALYSIS AND APPLIED KINETICS

A new technique for the study of reaction kinetics has been developed by Professors Sherwood and Jean P. Leinroth and its value demonstrated in an investigation of the catalytic hydrogenation of ethylene. A very short bed of catalyst is placed in a reactor loop in which the gases are circulated. This is operated "semi-batch:" one or the other of the two reactants is fed at the rate required to maintain a constant pressure. By this procedure it is possible to vary only one reactant composition while holding temperature, pressure, and the other reactant composition constant. The importance of the technique lies in the fact that the kinetics of the reaction can be studied over wide ranges of concentrations of both reactants in two experiments of a few hours' duration.

Obtaining adequate data on the kinetics of heterogeneous reaction is difficult and tedious, but they are essential for the design of chemical reactors. It has been demonstrated in work supervised by Professor Mickley that an adiabatic packed-bed reactor can be used as an experimental device for determining such data. The results show than the adiabatic reactor technique is particularly advantageous in certain reaction systems, particularly those involving large heat effects.

Most industrial catalytic processes employ porous solid catalysts, and frequently diffusion through the porous structure is a major limitation on the observed rate of reaction. A large amount of mathematical analysis has been published in the last few years concerning various special cases, but predictions have been adequately verified quantitatively by experiment only for a few simple cases. A substantial research program under the supervision of Professor Satterfield is aimed at improving the usefulness of the theory by clarifying experimentally those aspects which are poorly understood at present.

A research program under the direction of Professor Meissner is investigating the characteristics of a transport reactor, a device for carrying out gas-solid reactions in a duct of suitable dimensions through which is passed a gas containing suspended solids. Velocities are so chosen that the solids travel with the gas, without settling out. The solids are recovered at the end of the duct and recycled. Gas velocities are high, so that capacity of a given duct tends to be high. Contact times are relatively short, so that transport reactors are best adapted to faster reactions. In the study now under way, exploration is being made of the effectiveness of gas-solids contact as affected by solids loading, particle size, gas velocity, tube dimensions, and the like.

Determination of the kinetics of homogeneous reactions is often complicated by reaction effects encountered at the wall of the reactor. An investigation of the confined jet reactor for homogeneous kinetic studies is being carried out by Professors Robert C. Reid and Satterfield. The objective is to develop a reactor to minimize contact of the reacting gases with the wall. A porous wall reactor has been studied in which an inert gas diffusing through the porous wall would decrease the transfer of reacting species in the bulk gas to the wall. With this jet reactor, the apparent first-order reaction rates of the wall could be reduced to about 3 per cent of the rate without injection.

The effect of the residence-time characteristics of a continuous flow stirred tank reactor on the conversion obtained in a second-order isothermal reaction has been investigated in a program directed by Professor Edwin R. Gilliland. The residence-time characteristics of the reactor were determined by salt tracer techniques, and the alkaline hydrolysis of ethyl formate was used as the reaction system. The dynamic characteristics of the system under reaction conditions were compared to several theoretical models.

In carrying out a reversible exothermic catalytic reaction, careful attention must be given to the temperature profile to be used in the reactor. An optimum temperature profile may be calculated for any reaction system, which specifies a high temperature at the inlet and a continually decreasing temperature through the reactor. An important practicable way of approximating the optimum profile is in an autothermic reactor, in which the catalyst bed transfers heat to the incoming gas in a countercurrent flow arrangement. A steady-state analysis of such a reactor has shown that a minimum temperature exists for the inlet gas to the reactor below which the reactor is unstable and "blowout" will occur. In order to design a suitable control system to permit operation near conditions for maximum productivity, the dynamic behavior of this type of reactor is being studied by Professors Baddour and P. L. Thibault Brian.

The characteristics of well-stirred reactors are being studied in a program under the supervision of Professors Hoyt C. Hottel and Glenn C. Williams. The validity of the well-stirred reactor as a tool for studying high-speed exothermic reactions depends on knowledge of the detailed structure of the mixing process, now under examination with the light-scatter technique. Related problems are burning rates in the well-stirred methane-air system and turbulent flame propagation in relation to scale and intensity of turbulence at the flame front.

The kinetic factors involved in catalysis by acid-base ion-exchange resins are being investigated by Professors Harris J. Bixler and Gilliland. The relative importance of mass transport across the liquid boundary layer, mass transfer through the porous resin, and chemical reaction at the active sites is being investigated. The hydrolysis of sucrose and ethyl acetate is being studied with free mineral acid, oligomeric polystyrene sulfonic acid, a straight-parallel ion-capillary model, a conventional ion-exchange resin, and a macroreticular ion-exchange resin.

One of the most difficult problems in the area of chemical process optimization and control is that of obtaining a mathematical model for the dynamic behavior of the operation. An investigation of the effect of material recycle and heat recovery on the reaction of such systems has been carried out under the direction of Professors Gilliland and Leonard A. Gould of the Electrical Engineering Department. The behavior of such systems has many of the characteristics of regenerative feedback systems. The systems show higher sensitivity to disturbances and slower dynamic response than would be expected from the individual components and may exhibit instability when the individual process units do not.

The prediction and evaluation of the performance of a chemical reaction is important in chemical process design. Residence-time studies have been used for this purpose, but unless the reaction is homogeneous first-order these data do not define the conversion, and various models have been proposed for the limits. Professors James R. McCord and Gilliland are investigating the general validity of these models for isothermal and adiabatic reactions of various orders.

A study of the partial oxidation of o-xylene in a vanadium pentoxide melt, under the supervision of Professor Satterfield, has shown that such melts indeed will catalyze this oxidation reaction. With mixtures of o-xylene and nitrogen, bubbled through a vanadium pentoxide-potassium sulfate eutectic, conversion in the present reactor is small, but a high selectivity to ortho-tolualdehyde is found. With a vanadium pentoxide-potassium pyrosulfate melt, conversions of 18 to 30 per cent were obtained. Mixtures of o-xylene and air show more rapid reaction in both melts and a greater diversity of products.

Professor Baddour is directing a program on measurements of the surface electrical properties of a doped germanium catalyst during the course of the catalytic decomposition of ethanol. Crushed germanium is prepared under an oxygen-free condition and the kinetics of the ethanol decomposition are determined at low pressures in the range of 10^{-4} to 10^{-6} torr, so that the germanium surface remains essentially free of oxygen during the course of the studies. An r-f mass spectrometer tube is used to measure the compositions in this pressure range. To determine the electrical properties germanium wafers will be used under similar reaction conditions.

The effect of radiation in the visible and ultraviolet range on the rate of a solid catalyzed reaction is being investigated in a program directed by Professor Baddour. The purpose is to study the increase in the rate of a solid catalyzed reaction obtained by irradiating it with light in the visible and the ultraviolet range and, by the use of infrared spectroscopic studies of the chemisorbed species in combination with this irradiation, to measure directly the active intermediate species in the chemical reaction and determine rate constants for the individual intermediate steps.

The effects of irradiation on the catalytic, electrical, and surface properties of semiconductor catalysts are being investigated by Professors Reid and Edward A. Mason of the Nuclear Engineering Department. The work has indicated that high-energy beta-irradiation on cuprous oxide catalysts affects the catalytic activity for the carbon monoxide oxidation in a detrimental way. The activity of cuprous oxide catalysts decreased approximately in proportion to the total dose of radiation. There was an approximate corresponding decrease in the number of current carriers (p-type catalyst). Interestingly enough, there was an increase in surface area after irradiation. The irradiation of pure zinc oxide crystals and the determination of the kinetics of the carbon monoxide oxidation for these crystals is now being investigated. At the same time, electrical measurements will be made on a pure zinc oxide crystal comparable to those used in the kinetic experiments.

A method to determine the degree of dispersion of metal in a commercial copper-on-alumina catalyst has been studied by Professor Leinroth. The method was based on measuring total catalyst area by physical adsorption of ethane and measuring the area of the metal by chemisorption of carbon monoxide. The measurement of the total catalyst area was made in a simplified B.E.T. type of adsorption apparatus, but ethane rather than nitrogen was used. Expressions were developed that allowed the fraction of the total area covered by copper to be calculated.

HEAT, MASS, AND MOMENTUM TRANSFER

The rate of heat transfer from a solid wall to a gas mixture can be substantially affected by rapid reversible homogeneous reactions occurring between components in the gaseous mixture. Examples of this phenomenon include air dissociation effects upon the rate of heat transfer to reentering missiles and satellites and the very high heat transfer coefficients observed when transferring heat to nitrogen tetroxide-nitrogen dioxide mixtures. The problem of understanding and predicting the effect of a simultaneous chemical reaction of finite rate upon the rate of heat transfer has received relatively little attention. A theoretical treatment has recently been published by Professors Brian and Reid for the effect of chemical reaction of finite rate in the limiting case of a very small temperature driving force.

Experimental and theoretical investigations of the velocity vector and turbulence spectrum in the recirculating region behind bluff objects is being carried out under the direction of Professor Mickley. The systems under study include the early wake behind a cylinder and the recirculating region in the interstices of beds of packed solids. The properties of the recirculating region affect the radial transport of matter and energy in a chemical reactor and introduce a sequence of hold-up times which affect the ultimate performance of the system. Measurements to date have indicated an extremely high level of turbulence, of the order of 60 per cent turbulent intensity, and this has necessitated the development of new measuring techniques.

Work directed by Professor Mickley and Dr. D. F. Fairbanks has been aimed at determining the factors responsible for the formation and growth of voids or "bubbles" in fluidized beds. At low fluidization velocities, the measured size and frequency of bubbles formed in the bed agrees with the values predicted by application of the stability theories of Taylor and Helmholtz. These results provide a means for predicting the initial size of the voids and their frequency of occurrence.

The problem of understanding and predicting the effect of a simultaneous chemical reaction upon the rate of interphase mass transfer has occupied a prominent role in chemical engineering research for a number of years. An investigation directed by Professors J. Edward Vivian and Brian involves theoretical analyses of the effects of multistep chemical reactions upon the rate of interphase mass transfer, with particular emphasis upon types of reaction mechanisms which can give rise to mass transfer rates markedly different from those obtained when simple chemical reactions accompany the mass transfer process, and an experimental study of this behavior to elucidate the role of a complex chemical reaction mechanism in simultaneous diffusion and chemical reaction.

Gas absorption systems constitute an important part of many chemical processes and systems for environment control, and the performance of these systems depends to a large extent on the behavior of liquid flowing over packing as well as associated diffusion and chemical kinetic processes. Professors Vivian and Brian are using the short wetted-wall column technique in investigations of the interrelationship of diffusion and kinetic processes in gas absorption. The behavior of liquid on packing, particularly liquid distribution and surface lifetime as affected by liquid properties, is being studied with a view to obtaining a better understanding of the effect of liquid flow pattern on the mass transfer process in the liquid phase. In a related study the effect of liquid flow pattern on the additivity of gas and liquid phase resistance is being investigated by comparative studies of selected absorption systems in the short-wetted wall column and in packing.

Professors Mickley and Kenneth A. Smith have extended their work on the transpired turbulent boundary layer. Their earlier experimental work indicated that the transpired turbulent boundary layer is an equilibrium layer in the sense of Clauser. These experimental results have been given theoretical support, and calculations show that a class of equilibrium outer flows exists with respect to the maximum shear in the boundary layer.

Work is continuing under the direction of Professor Baddour on the problem of separating the contribution of mass transfer to the dispersion of the bands in a gas chromatography column from the other dispersion effects. The main basis for this process is the preparation of a column which does not sorb the bands being studied, so that the amount of dispersion caused by factors other than mass transfer may be subtracted from the total dispersion.

Studies already completed under the direction of Professors Baddour and Gilliland on the flow of gases through adsorbent solids indicate that the total flow rate can be considerably enhanced because of rapid surface migration of gas molecules. The mechanism of the adsorbed flow has not been satisfactorily explained, and work in this area is continuing to determine the effect of the magnitude of the bond between the solid and the gas on the overall transmission rate. Chemisorbed gases are of particular interest because of their relationship to the mechanism of catalysis.

Processes wherein heat and mass are transferred simultaneously from a gas to a refrigerated surface are encountered in many industrial operations. There are no satisfactory methods available at the present time to calculate *a priori* rates of heat and mass transfer under frosting conditions. This problem is being investigated by Professors Reid and Brian under a National Science Foundation award. A heat exchanger has been built and is being operated which will allow the measurement of rates of heat and mass transfer to a cold wall at –320°F under various conditions of inlet gas temperature, Reynolds number, and inlet humidity.

Experimental studies on gas absorption are being directed in two areas by Professors Vivian and Brian. The factors that influence the individual phase resistances to mass transfer are the subject of one project. These resistances depend upon the fluid dynamic properties of the phases, the diffusivity of the component transferred, and in systems involving chemical reactions, the kinetics of the reaction. Additional factors of concern in the case of liquid phase resistance are the interfacial properties of the system, surface tension and wetability, and the body forces causing flow over the irrigated packing. Information on the effect of interfacial properties and body forces on the liquid phase resistance is being obtained. In this project the performance of a typical packed column absorber mounted on a large centrifuge at the M.I.T. Instrumentation Laboratory Flight Facility, which is capable of developing body forces many times that of gravity, is being studied.

The second gas absorption study is concerned with the effect of a chemical reaction on the rate of absorption accompanied by chemical reaction. One of the systems under study both theoretically and experimentally in this project is the chlorine-water system. Numerical solutions to the absorption equations based on the "penetration theory" model and first-order forward and effective third-order reverse kinetics have been obtained. Experimental work on the absorption of chlorine in water using a short wetted-wall column developed in this laboratory and shown to follow closely the penetration theory model has produced results which agree closely with theoretical predictions. However, theory as presently developed and experiment do not agree in the case of the reverse process, desorption of chlorine from water.

Professors Edward W. Merrill, Gilliland, and G. Roy Cokelet have been continuing studies on the flow properties of normal human blood in collaboration with the blood bank of the Massachusetts General Hospital, using an electromagnetic viscometer made available to the Department by Professor Charles S. Draper and the Instrumentation Laboratory. Considerable effort has also been devoted to studying abnormal bloods—for example, human blood that contains abnormally great concentrations of fatty material or unusual kinds of fatty material—in collaboration with Dr. Frederick Hatch of the Massachusetts General Hospital. Also recently completed was an important test in collaboration with Dr. Edwin Salzman at the Massachusetts General Hospital on a patient whose blood is totally lacking in fibrinogen. Special attention has been directed toward the important blood additives called dextrans which are used in combating shock and sludging of blood in emergency situations in hospitals. The M.I.T. group is collaborating with Dr. Salzman and others in the Massachusetts General Hospital blood bank in studying the effect of dextrans on human blood and with Professors Herbert Berman and George Fulton of the Department of Biology of Boston University in studying the effect of dextrans on hamster blood.

Professors Sherwood and Smith are conducting an experimental investigation of turbulence very near a solid surface. The equipment permits a direct investigation of the turbulence near the wall of a pipe. The working fluid is water, and sub-micron-size particles are introduced as tracers. The particles in the region of interest are tracked by using stroboscopic light and dark-background photography.

Work is being carried out on the effect of gamma-irradiation on the density of growing potassium chloride crystals by Professors Reid and Mason. Some early data indicated that the density of potassium chloride grown under irradiated conditions was about 10 per cent less than the density of unirradiated potassium chloride crystals. This is being explored in detail in order to formulate a mechanism to account for these changes. Work is also being carried out to determine whether high-energy gamma-irradiation significantly affects the growth rate and/or habit of crystals. This work is sponsored by the Atomic Energy Commission.

SURFACE CHEMISTRY AND PHYSICS

The growing importance of "secondary-oil" recovery techniques has motivated continuing studies of the effect of reverse-wetting agents on water-oil displacements from porous media under the direction of Professor Alan S. Michaels. The transient adhesion-tension alterations imposed on the system by injection of a slug of hexylamine in the water flood results in the spontaneous concentration of oil into discrete regions of the medium. Observations of these phenomena in a two-dimensional glass micromodel indicate that "excess" oil is a prerequisite for oil-mass formation. In addition, it has been found that the wetting and dewetting processes both result in oil accumulation in continuous masses.

The effect of mechanical agitation in causing spontaneous agglomeration of powders containing particles one-half micron and smaller in size has been studied in a program directed by Professor Meissner. Special attention has been paid to zinc oxide powders. The agglomerates formed tend to be spherical pellets whose density and crushing strength increase as agitation is prolonged. The evidence indicates that van der Waals forces are responsible for this agglomeration.

The influence of impurities on the growth of adipic acid from aqueous solution is being investigated under the direction of Professor Michaels. Certain types of trace impurities have been found to alter significantly the rate at which crystals grow from solution. To study the nature of this effect, the growth of single crystals is being observed under controlled conditions by means of time lapse microcinematography.

POLYMER CHEMISTRY AND PHYSICS

Active investigation continues of the structure-property relationship in polymers under the direction of Professors Michaels, Baddour, Schneider, Bixler, and Wolf R. Vieth. A study was recently completed on the permselective properties of a polyethylene barrier to the structural isomers of xylene and the geometric isomers of acetylene dichloride. Particular emphasis was given to the effects of solvent treatment of the polymer prior to measurement of barrier properties. Although some alteration in the permselectivity of polyethylene to structual and geometric isomers can be achieved by preconditioning with a solvating liquid, the most marked effect is an increase in permeability apparently resulting from a redistribution of the crystalline polymer phase. A study of the effect of thermal annealing on the gas transmission properties of polyethylene has brought to light some interesting morphological characteristics of this polymer. Annealing below the melting point, while causing an increase in crystallinity, brings about an increase in gas diffusion constants. These findings suggest that the thermal history of a fabricated article is more important in determining mechanical and other physical properties than heretofore expected. The effect of uniaxial stretching on the gas permeability of polyethylene has been the subject of a recent study. A minor but significant reduction in permeability results when the polymer is stretched until necking occurs. However, subsequent stretching beyond the neck region results in a dramatic decrease in permeability and increase in the apparent activation energy for permeation. These findings suggest that severe hindrance to amorphous chain segmental motion is imposed by the stretching process. Just prior to the break point the permeability increases rapidly, suggesting the creation of microvoids or pores in the film. Simultaneous measurements of sorption and degree of crystallinity as a function of temperature, concentration of solvent, and thermal history of polyethylene are serving to better explain the nature of the structure of semicrystalline polymers and how this structure can be modified to enhance the utility of these materials as selective barriers.

As part of the general permselective barrier screening program, the liquid permeabilities of polypropylene, polyethelene oxide, and oriented polyethylene-diethyl maleate copolymer to a number of organic liquids have been measured. In general, one concludes from this work that the size and shape of the diffusing molecule are controlling transport factors in a group of chemically similar liquids. Solvent conditioning of a film at elevated temperature increases the permeability but decreases the permselectivity of a polymer film to chemically similar liquids.

Work on the rheology of bulk polymers is being continued by

Professor Merrill and David A. Gibbs on the interpretation of data obtained from their shear creep viscometer, both the transient response (time-temperature superposition) and the steady-state viscosities extending from the post-Newtonian regime well into the non-Newtonian regime. A key part of this program is aimed at resolving the dilemma of the shape of polymer molecules in the bulk, molten state, i.e., Are they balled-up into tight, separate balls, or are they expanded and entangled deeply with each other?

By coreaction of oppositely charged ionizing polymers (polyelectrolytes) it is possible to form an interesting new class of materials. The resulting polysalt complexes display an array of unusual chemical, electrical, and mechanical properties distinct from those of conventional polymers, perhaps lying closer to certain properties of biological polymers. Current studies by Professors Michaels and Schneider of the mechanism of complex formation and of the microstructure and electrical properties of the polysalt materials deal with the products formed by reaction of poly(styrene-sulfonic acid) and poly(vinyl-benzyltrimethylammonium hydroxide) or by coreaction of their salts. The study of the electrical properties of thin cast polysalt films shows that they are extremely sensitive to environment. Dry microion-free films exhibit high a-c resistive impedance and moderate dielectric constant. When saturated with moisture, the resistivity drops by a factor of 10^6, the dielectric constant increases by a factor of almost 10^2, and both properties depend strongly on frequency. When traces of moisture as well as salt are present, the resistivity drops still lower and the dielectric constants reach astronomical values (ca 200,000). A recently initiated phase of this project, concerned with the viscoelastic properties of polysalt complexes, should also throw further light on the nature of the intermolecular binding and on the mobility and distribution of water and microions in the polysalt matrix.

ELECTROCHEMICAL ENERGY CONVERSION

The operation of a low-temperature fuel cell at current densities sufficiently high to be practicable is limited, with most fuels of interest, by the rate of catalytic oxidation of the fuel on the electrode. In a study recently completed under the supervision of Professor Satterfield, the mechanism of electrochemical oxidation of formic acid on plain platinum electrodes was investigated by chronopotentiometric and double-layer capacitance measurements.

Several studies on fuel cells are being directed by Professor Meissner. An investigation has been made of so-called "flow electrodes," in which electrolyte containing the reagent in solution is caused to flow through electrodes made of wire screens, porous carbon, and the like. Electrodes of this type are of interest since they afford certain operating advantages, such as ease of cooling, absence of gas-liquid interfaces, extensive use of internal area, etc. They are also convenient for exploring the overall mechanism of electrode performance and the nature of the rate-limiting step in electrode operation. Study of the electrochemical reduction of oxygen at platinum and silver surfaces using aqueous potassium hydroxide has indicated that mass transfer is the primary bottleneck in the operation of low-temperature oxygen electrodes of the usual porous gas-diffusion type.

Electrochemical cells can also be used for the conversion of heat into electrical energy, and a program in this area is being directed by Professor Meissner. A thermocell is a system in which two identical electrodes are operated "back-to-back" at different temperatures in a common electrolyte. The system now under study involves two chlorine electrodes in molten alkali chloride electrolyte at temperatures from 700° to 1200°C. Open-circuit voltages of as high as 1 millivolt per degree C are being obtained.

APPLIED CHEMISTRY

Chemical reactions of the carbon-hydrogen and carbon-fluorine systems in the high-intensity electric arc have been studied by a group under the supervision of Professor Baddour. In both cases the chemical species which might exist at equilibrium in the temperature range from 2000° to 5000°K were calculated using the best available thermodynamic data and a computer program. In the carbon-hydrogen studies at one atmosphere pressure, the principal product of the reaction was acetylene, with a concentration as high as 26 per cent. This is higher than the equilibrium composition at any temperature. This high acetylene concentration can be explained in terms of a mechanism involving free radicals which do exist in large concentration at high temperatures. When carbon vapor was reacted with methane, an acetylene concentration as high as 52 per cent was obtained. In the studies of the fluorocarbon reactions, carbon tetrafluoride was used almost exclusively as a convenient source of fluorine. The reaction of the material with carbon vapor in a high-intensity arc yielded a quenched gas whose composition was almost entirely carbon tetrafluoride and tetrafluoroethylene in yields of the latter compound of about 40 mole per cent at one atmosphere and 69 mole per cent at

0.1 atmosphere.

The reaction of hydrogen atoms with solid, thin films of olefin (primarily propylene, isobutene, trimethyl-butene) is being studied at a temperature of 77°K. The experiments are carried out in a cavity in an electron paramagnetic resonance spectrometer so that the concentration of the hydrogen atoms may be measured during the experiment. This project is supported by a National Science Foundation grant and is under the supervision of Professor Reid.

FUELS RESEARCH LABORATORY

The use of light scatter as a tool for studying turbulent mixing, radiative transport processes in high-temperature systems, the mechanism of growth and decay of luminosity in industrial flames, runaway fire, and fast gaseous combustion reaction mechanisms are presently the chief areas of interest in the Fuels Research Laboratory program under the direction of Professors Hottel and Williams.

The research of Professor Henry A. Becker on jet mixing and the measurement of turbulent concentration fluctuations has been followed by studies of intermittency of turbulence in free turbulent mixing fields and the formation of concentrated vortices in jets. Turbulent diffusion and the attendant concentration fluctuations in pipe flow have been investigated. A computer investigation has been made of moisture-diffusion controlled drying in commercial dryers. The success with light scatter by oil smoke used as a marker in isothermal mixing studies has caused initiation of work on the use of scatter-producing markers which survive the combustion process.

Research on the propagation of fire-fronts in simulated runaway wood fires continues with the development of a moving fuels bed to hold the fire-front stationary in a combustion wind-tunnel. An associated low time-constant gas calorimeter is being developed to obtain the heat of combustion, as a function of time and heating rate, of the gases evolved from the fuels bed.

The Department's extensive research in the area of radiative transport is being organized and assembled, for book publication, by Professors Hottel and Adel F. Sarofim.

The research on growth and decay of luminosity in hydrocarbon flames has been concentrated on the experimental development of systems for the generation of soot of known concentration and of a photoelectric pyrometer for measurement of radiant emission from luminous flames. A photoelectric pyrometer for measurement of temperature in plasmas partially opacified by addition of sodium has been designed, built, and tested. Pyrometer-measured temperatures of atmospheric argon plasmas agreed within 1.6 per cent with enthalpy temperature over the range 4000° to 8500°K.

PROCESS DEVELOPMENT

The use of polymer membranes for removal of salt from sea water by reverse osmosis is being studied by Professors Michaels and Bixler and Dr. Stanley Wasilewski. Probing studies have indicated that desalination can be achieved with membranes prepared from a stoichiometric mixture of a polyanion and a polycation, each derived from high-molecular-weight polystyrene. A study is also being made to determine effective methods of supporting and using the extremely thin (100 to 500Å) interfacial membranes which result when aqueous solutions of the two polymers are brought into direct contact. Professors Michaels, Baddour, and Bixler are also investigating the mechanism of reverse osmosis in a number of different semipermeable membrane materials such as cellulose acetate and polystyrene. Preliminary studies have indicated that water transmission through the ion-restraining film takes place by a diffusion mechanism.

Professor Baddour and Dr. Wasilewski are investigating glassy polymer films which would be suitable for use in a reverse osmosis cell. Two approaches to this problem are being explored experimentally. In one, a solution of a polymer is prepared and treating agents added to provide the desired porosity and pore size in the resulting film. In the other, a network polymer film is prepared in the presence of the treating agent which is subsequently abstracted to produce the desired porous film.

A project on the dynamic behavior of chemical reactors, supported by the National Science Foundation, is a joint effort between the Electrical and Chemical Engineering Departments. Professors Baddour and Gould are investigating the dynamic behavior of an electric arc reactor. In the experimental program, large d-c pulses are superimposed on a small steady d-c arc. The electrodes are made of graphite, and the reacting gas is flowed into the discharged region. The product composition is monitored continuously.

A desalination research program, directed by Professors Sherwood and Brian and sponsored by the Office of Saline Water of the U.S. Department of the Interior, has to do with the effect of salt build-up at a surface through which water is being removed, as when water passes through an osmotic membrane or when ice is being formed by partially freezing salt water. The underlying theory based on known principles of fluid mechanics and diffusion is being developed simultaneously with experimental studies.

Professors Vieth and Sherwood, together with James H. Porter, have developed a new "analogy" relating fluid friction and mass transfer in a turbulent boundary layer. Based on the assumption of an eddy conductivity proportional to the cube of the distance from the wall, this provides a derivation of the well-known Chilton-Colburn equation. The development has been extended to mass transfer with a simultaneous first-order reaction.

Direct contact vaporization of a refrigerant in a saline water solution is an attractive method for the freezing system of desalination. A study of the heat transfer rates for the vaporization of ethyl chloride droplets in water has been carried out under the direction of Professor Gilliland. The data indicate that the hydrodynamic behavior of the vapor-liquid bubble is close to that reported for non-vaporizing systems, that the vaporization occurs by surface evaporation from a well-mixed liquid pool at the bottom of the bubble, and that the heat transfer coefficients were of the same order as those predicted by the Handlos-Baron model, indicating that the external water film was controlling.

Professors Reid and Charles M. Mohr are investigating the development of a rapid, automated system for producing thermodynamic networks for pure gases and gas mixtures. The heart of the system is a continuous-flow device for the measurement of volumetric flow rate and heat capacity at selected values of mass flow rate, temperature, and pressure. These data are processed in a digital computer to produce thermodynamic networks.

EDWIN R. GILLILAND

Department of Civil Engineering

In the annual report for 1962 we announced a new program aimed at providing identity and direction for civil engineering at M.I.T. The underlying philosophy of our approach to civil engineering is of such importance in reporting on future progress that the report for this year is devoted to a statement of educational and professional philosophy. This seems of special importance because of the intensity of national interest in the status and future of civil engineering in the schools and in the profession. It appears that civil engineering may be at an important turning point in its history, with powerful forces pulling in divergent directions. While we do not pretend to have the best or the only answer, we wish to state clearly that we are deeply and firmly committed to strength and excellence in civil engineering at all levels—undergraduate and graduate education, research, and professional practice. We have carefully considered and duly rejected all suggestions that civil engineering should be replaced by one or more newly defined or labeled fields of a wholly different character. Such a statement is meaningful only if there is a clear understanding of what we mean by civil engineering and how we intend to approach it.

THE SCOPE OF CIVIL ENGINEERING

Civil engineering is an extremely broad professional field. The areas of interest may range from the psychology of automobile driver behavior to the chemistry of polymers, from the mechanics of dispersion to the language of computers, from traffic flow theory to the behavior of thin shells, from earth physics to microbiology. Civil engineering problems involve the physical, mathematical, life, earth, social, communications, and engineering sciences. Civil engineering projects involve many other professional areas, including architecture, planning, law, public health, economics, management, sociology, finance, and the other branches of engineering. The scope and complexity of the field, and its degree of involvement with other fields, has increased rapidly with the development of modern science and technology and the growth of populations and national economies. We can be proud to be a part of such a broad and important profession. Yet this extreme breadth poses some serious problems for civil engineering education and for the profession.

When any field becomes very broad, there is a tendency to subdivide the field in order to group related activities and interests. In engineering, the subdivision often involves the formation of a new professional branch. Such branches usually originate as technical divisions, but there is a tendency for such divisions to develop into independent professional branches. In the case of civil engineering, the field has been subdivided into such professional branches as structural engineering, sanitary engineering, hydraulic engineering, soil engineering, highway engineering, building engineering, construction engineering, traffic engineering, and others. As each branch develops, it tends to broaden its own scope of interests and activities, often overlapping the other branches but also expanding into areas which may have little relationship to the others. At the same time, responsibility for the leadership and direction of the field shifts to the branches with the potential loss of meaning and identification for the central field. Civil engineering is not unique in this respect, but the degree of divergence and fragmentation has reached rather extreme proportions, and civil engineering is in danger of becoming a collective term for numerous independent branches. Many of the problems of the profession can be attributed to this situation, and many solutions are now being proposed by an aroused leadership. It is our conviction that civil engineering as an area of education, research, and professional activity has validity and coherence which can be clearly demonstrated. We are determined to establish by our actions that, far from losing its significance, civil engineering is entering an era of great technological importance and increased relevance to the goals and aspirations of society. Some basic changes, major clarifications, and bold actions may be required, but we are dedicated to this task.

DEFINITION AND PURPOSE OF CIVIL ENGINEERING

The civil engineering profession can take pride in playing an essential role in the realization of some of the most basic goals, objectives, and needs of society. These relate to man's need for shelter, mobility, water, air, and productive land—the environment in which he lives and works. "The fulfillment of human needs through the adaptation and control of the land-water-air environment" has been proposed by the Department as a unifying theme of purpose for civil engineering. It is a purpose we share with many other professional groups, including architects, planners, applied scientists, and other engineers. Due to the broadness of our purpose and the involvement of other professional groups, it is important that we clarify how we make our particular contribution and direct our efforts. We define civil engineering as "the engineering of systems of constructed facilities." This simple definition of our role recognizes a number of important points which limits civil engineering to a well defined and clearly identifiable field of activity. First of all, it recognizes that we are primarily concerned with engineering. Although we must build on science and be involved in planning, sociology, and politics, we are engineers—not scientists, city planners, sociologists, or politicians. Secondly, we are responsible for engineering which relates to construction—not manufacturing, processing, or communicating. Thirdly, the things which are constructed are usually facilities which are composed of structures of many kinds, often large or extensive and commonly for public benefit or use. Finally, we recognize that such facilities must be engineered as operational systems of constructed components which interact with each other and with their physical and social environment. Hence, we make a distinction between a definition of civil engineering and a statement of purpose. Both are essential to establishing who we are and what we are trying to achieve. The purpose gives meaning to civil engineering, the definition gives identity.

In the research, planning, and design phases of civil engineering, the disciplines which may be called upon and the human activity required may be many steps removed from the actual construction process. However, if the activity is of an engineering character, is motivated by a serious interest in civil engineering problems, and ultimately leads to or contributes to the solution of a problem involving the construction of a structure, facility, or operational system of constructed components, such activity would be distinguished as civil engineering. If it is not so directed, although it may be a very important activity and may overlap the problems of the civil engineer, it is not civil engineering. Many attempts have been made to define what civil engineering is, but we feel that it is equally important to recognize what it is not. In recognizing the human and professional need for placing a finite limit on the breadth of civil engineering and the responsibilities of the civil engineer, we do so in order that the field and the individuals associated with the field can be clearly and accurately identified. Without such clarification and identification, there is no meaningful basis for deciding whether or not we are doing our job well.

STRUCTURE OF CIVIL ENGINEERING

Civil engineering involves the combined efforts of specialists representing a number of different disciplines. The contribution of each specialist will be more effective if, in addition to his particular competence, he is motivated by a personal interest in civil engineering problems and is generally familiar with related aspects of the problem outside his speciality. To illustrate, the structural analyst who is motivated by an interest in civil engineering structures and his counterpart in aerospace engineering derive their skills and knowledge from the same disciplines. Yet the former would not function at peak efficiency on a team concerned with the design of a missile, and the latter would not be fully effective in the design of an unusual building. This is not to say that each would not ultimately be effective in the other's field of interest, but such effectiveness would only be achieved after an appropriate period of experience and the development of professional motivation. In short, an engineer requires not only outstanding competence in the basic disciplines but depth of understanding of the class of problems to which his disciplines and skills are to be applied. It is quite natural that engineers (and members of engineering faculties) function best in those groupings which afford them close contact with colleagues motivated by an interest in the same general class of real-life problems. A department of civil engineering is one such grouping. In turn, a strong civil engineering faculty inevitably must include sub-groups of individuals concerned with the principle contributing disciplines who work together as a team.

In a particular department, certain basic groups may be expected to predominate at any one point in time, and the kinds of disciplines represented may be expected to change over the years. In recent years, it has become apparent that civil engineering teams often must include not only specialists from certain traditional disciplines but others not heretofore associated with our problem area. A strong department alert to changing opportunities and to the development of new technologies and new disciplines will find it appropriate to attach these different specialists to its teams. Thus it should surprise no one to see individuals with a background in operations research, physical chemistry, geology, management, or chemical engineering working closely and effectively within civil engineering groups. Whether the attachment of any such specialist to the group is temporary or of indefinite duration may not be initially predictable. Whether a particular specialist will be joined by others from the same discipline, with the ultimate development of a new major grouping, parallelled or not by the gradual disappearance of an existing grouping, is likewise not predictable. The tenure of any newly attached specialist is largely dependent upon the degree to which he finds a source of motivation in civil engineering.

Although the major specialist groups may be expected to undergo continuous change, their long-term stability and strength in depth is important in providing continuity of effort. Accordingly, such groupings provide a natural basis for organizational structuring of a department. At the present time, the major groupings in our Department are in the areas of structures, materials, soils, hydrodynamics, and systems. These particular groupings of individuals and their disciplines reflect the existence of substantial numbers of faculty and students, major research efforts and laboratory facilities, and significant academic subject offerings in each of the speciality areas. In turn, such activities imply that we choose to direct our current contribution to the advancement of civil engineering through these particular efforts. In the future, our response to the problems of civil engineering may be to place emphasis on quite different groupings.

It may appear that our recognition of the practical necessity for group efforts implies that fragmentation must continue—that we have simply replaced a number of professional-branch-oriented divisions by a few discipline-oriented groups. We feel there is a fundamental difference. The professional branches tend to look to civil engineering only as a mechanism for loose affiliation with related branches. Civil engineering serves a rather passive role, being a secondary—not a primary—source of identification and direction. While fully recognizing the role of specialists and groups of specialists, the interdisciplinary approach calls for primary identification with civil engineering as the source of direction and the principal focus of coordinated group activity. Such an approach can give civil engineering a dynamic character with both strength and flexibility in coping with the need for continuous change.

With the exception of the much greater ease in bringing in new disciplines and regrouping old, the basic change is largely psychological, involving a change in professional and mental attitudes. Such a change is not accomplished overnight, but excellent progress has been made in our Department. It is only through such changes that civil engineering as an educational and professional unit can justifiably continue to survive. We want it to do more than just survive. We are dedicated to making civil engineering a dynamic, exciting, rewarding, and challenging activity of first-rate professional men.

TECHNICAL EXCELLENCE IN CIVIL ENGINEERING

One of the currently popular attitudes toward civil engineering is that the important problems are not technical but social, political, and economic. It is true that a host of non-technical factors are involved in the projects which require civil engineers. Sociologists, psychologists, political scientists, economists, lawyers, and politicians must play their proper role in planning and executing major projects, in working partnership with competent civil engineers. Much remains to be accomplished in achieving more effective working relationships, and in many cases the civil engineer must take the lead. However, we believe the fundamental responsibility of the civil engineer is to insure technical excellence in the solution of the problem. If this is not forthcoming, the civil engineer will not be respected by the other professions and the public. Through brilliant engineering and creative technological innovation we can make our greatest contribution to the solution of what often may appear to be a non-technical problem.

It is our conviction that the primary role of civil engineering education is to prepare the student for achieving technical excellence in the engineering of systems of constructed facilities. At the same time, the engineer, as an educated professional man, must be deeply concerned with the impact of his work upon society. Hence the civil engineering student must develop social consciousness as well as engineering competence. This does not require a working knowledge of all of the related professional areas and disciplines. Such a working knowledge is clearly impossible. What is essential is that the young civil engineer develop an appreciation for the non-technical problems of society, a sense of professional responsibility, and the capability to effectively communicate and reason in non-technical terms. Once the student enters professional life, we hope he will aspire for a responsible position of leadership in the planning and realization of civil engineering projects. The man who reaches the top is seldom the one who starts out by knowing a little bit about everything. Most of our most successful engineers established their reputations and positions by their productivity in a particular specialty, their ability to move into new fields or specialties with changing times, and their demonstrated capability for giving leadership and direction to others. The professional man takes pride, receives satisfaction, and obtains confidence from outstanding competence in his chosen specialty. Hence, we are emphasizing study in depth as well as in breadth in the educational programs of our students. We believe that this is the best avenue to leadership.

Because civil engineering is a very old endeavor, and because many of the kinds of constructed facilities with which we are concerned have been required by society for centuries, it is quite erroneously concluded that our field does not draw heavily upon modern science and technology. The fallacy in the argument that the important problems are non-technical is the assumption that the important technical problems have all been solved. In contrast with many of the glamour fields of today, conventional technology in civil engineering will always permit a solution to be accomplished, leading some to assume that no higher technical development is necessary. Yet the continuation of conventional technology results in solutions which are accomplished with greater investments in resources of all kinds than are necessary and with lower performance levels than are possible. The costs to society involve billions of dollars and lower standards of living for millions of people. We find these technical problems to be exciting and challenging, and we are convinced that they are of extraordinary importance. Accordingly, technological advance through research in civil engineering is an integral and essential part of the activity of our Department.

CIVIL ENGINEERING AND INTERDISCIPLINARY PROBLEM AREAS

Considerable national attention is now being directed to such interdisciplinary problem areas as environmental health, water resources, and transportation. These are important problem areas of vital interest to our Department. However, we are interested in such problem areas and others to the extent that they involve the engineering of systems of constructed facilities. We are convinced that we can make the greatest contribution to such interdisciplinary fields through civil engineering. While fully recognizing that we have an extremely important role and responsibility in such problem areas, we believe that it is both dangerous and unrealistic to assume that civil engineering has the responsibility for the "total" transportation problem or "total" water resources problem. We reject the notion that civil engineering should be redefined or reconstituted around such themes and that it should encompass all of the related disciplines and professions. We feel that our role and responsibility should be well defined and limited to those disciplines and capabilities in which we are professionally competent as engineers. What is important is that what we do be done extremely well. We should expect the same from other groups which are involved in interdisciplinary problems, and we should not attempt to make up for their shortcomings.

While recognizing the finite role of our Department in interdisciplinary problem areas, it should be recognized that the civil engineering student and research worker with an interest in such areas has the total resources of the Institute to draw upon. The extent to which the faculty, research staff, and students of our Department are already exploiting the interdisciplinary resources of the Institute can be gauged by noting that we are currently involved in some kind of joint activity with the Departments of Aeronautics and Astronautics, Architecture, Chemical Engineering, City and Regional Planning, Economics and Social Science, Electrical Engineering, Geology and Geophysics, Mechanical Engineering, Metallurgy, Naval Architecture and Marine Engineering, Nuclear Engineering, and Physics; the School of Industrial Management; the Center for Materials Science and Engineering; the Joint Center for Urban Studies; the Computation Center; the Operations Research Center; and the Center for International Studies. In a typical academic term, students from civil engineering will be represented in over a hundred different subjects in other departments. Far from being in an isolated compartment of the Institute, our students and faculty are probably involved in more interdepartmental and interdisciplinary activity than any other group on the campus. Indeed, we are more likely to spread ourselves too thin than to be too narrow in our activities and attitudes.

Finally, we feel we should make our position clear with respect to such traditionally important branches as sanitary engineering and surveying. Much of the current difficulty in unifying civil engineering derives from attempts to define it broadly enough to encompass the far-ranging interests and disciplines associated with modern sanitary engineering and modern surveying. Both of these are extremely important fields, but both involve very major components which have very little in common with civil engineering. We feel that modern sanitary engineering, with its emphasis on chemical and biological processes, is much closer to chemical and biochemical engineering and the life and medical sciences than it is to civil engineering with its emphasis on the physical sciences, mechanics, design, and construction. Both civil engineering and sanitary engineering have a common purpose in that both are concerned with adapting and controlling man's environment, but they have relatively little in common in terms of modern technical problems and associated scientific disciplines. To the extent that sanitary engineering (or environmental health engineering) involves civil engineering disciplines and capabilities, we will play an active role in the solution of significant problems. We propose to work with sanitary engineers on the same interdisciplinary and professional partnership basis as we do with chemical, mechanical, and electrical engineers; and we will work at the interface with such fields. Much the same is true with respect to modern surveying. To the extent that surveying is an integral and essential part of the engineering of systems of constructed facilities, we will have a strong and active interest in the field. To the extent that mapping, cartography, photogrammetry, and geodesy are not so directed, we cannot assume a central responsibility. As painful as this position may be to many individuals and groups, we have concluded that it would be far better for our Department to concentrate on the central core of civil engineering than merely to provide a home for a collection of unrelated groups.

GRADUATE EDUCATION

Civil engineering is now predominately a graduate activity at M.I.T. Approximately 160 students are currently working for advanced degrees. The most rapid growth is at the doctorate level, and soon the number here may exceed the number of undergraduates. The increasing demand for outstanding men who have completed the doctorate, not only for positions in education and research but also in professional offices and industry, leads us to stress our doctorate program. At the same time, we are strengthening our Master of Science and Civil Engineer programs because of the key role they play as the focus of professional study for students who concentrated on a fundamental pre-engineering program as undergraduates.

An undergraduate degree in civil engineering is not necessarily required for admission to the graduate program. Assuming adequate undergraduate preparation in science, mathematics, and the humanities, students from a wide variety of undergraduate programs may undertake professional studies in the Department. For example, we now have graduate students who hold undergraduate degrees in such fields as architecture, chemical engineering, and mathematics. Conversely, our own undergraduates may shift to graduate and professional work in such fields as city planning, nuclear engineering, political science, and industrial management. This suggests one of the advantages of the four-year over the five-year undergraduate program: the professional career decision can be identified with the area of graduate study instead of with the undergraduate department for those students who do not develop a clear set of professional area motivations until the third or fourth year of undergraduate education.

Graduate education in civil engineering, particularly at the doctorate level, requires extensive and expensive resources. Hence our shift to graduate activity has resulted in a major increase in the need for faculty, space, laboratories, equipment, research support, financial aid, and related resources. Such resources are now at their highest level in the history of the Department. With the sole exception of undergraduate enrollment, every other measure of the size and strength of the Department has shown a significant increase in recent years. Although some modest additional growth in resources and graduate enrollment is proposed, we feel we are reaching an optimum and stable size for the Department which will permit us to offer a superior program in civil engineering.

At the present time, the main areas of graduate study which are being stressed in the Department are structures, materials, soils, hydrodynamics, and systems. Interdisciplinary combinations of these areas within the Department, and the educational opportunities in other departments are being emphasized; they now include structural materials, applied earth sciences, water resources systems, transportation systems, engineering and construction management systems, operations research and computer methods, and engineering information systems.

UNDERGRADUATE EDUCATION

Although the focus of professional study is now at the graduate level, participation of the faculty in undergraduate education and participation of the undergraduates in graduate-level activity remain essential components in achieving the total objectives of the Department. The decline in undergraduate enrollment over the past decade has been mistakenly interpreted as involving a corresponding decline in the interest of the Department in undergraduate education. It has even been interpreted as the disappearance of civil engineering at M.I.T. by those unaware that the Department was, in fact, growing in size and strength, but at the graduate level. Space does not permit a complete discussion of the many explanations for the decline in undergraduate enrollment. While a few of the factors are under our control and are receiving priority attention, many are completely beyond our immediate control. Although we expect that undergraduate enrollment in civil engineering at M.I.T. will continue to be relatively small, we shall definitely continue our undergraduate program, however small it may be. We are pleased to note that there is evidence of a possible reversal in the enrollment trend as the freshman Course selection figures for this spring show a 75 per cent increase for civil engineering over last year.

The reasons for our interest in continuing participation in undergraduate education at M.I.T. are: 1. The undergraduate student group, no matter how small in numbers, provides a nucleus of motivated individuals who develop an interest in studying civil engineering in depth; we feel we should respond to their interests and motivations as early as they are developed by making our faculty, teaching, and research resources completely accessible to them. 2. Our faculty must have strength and competence in fundamentals upon which professional study is based; continuous and active participation in the teaching and development of undergraduate subjects helps to insure such competence, and our own efforts to strengthen undergraduate education are also often of assistance to our sister

departments in other schools which are major sources of our graduate student population.
3. Our faculty enjoys the stimulation it receives from working with M.I.T. undergraduates; we find them to be very interesting and challenging, a source of real inspiration to those who are dedicated to launching the careers of young men.

For these practical reasons we are committed to involvement in undergraduate education; it insures a stronger—and more interesting—faculty and department.

Both the nature and the mission of undergraduate education in the Department have changed considerably over the past decade. Our mission now is to provide a basic education and not a professional training. We assume that the student will continue with graduate study for a total of five to eight years of formal study or the equivalent. Hence the emphasis is on fundamental disciplines in preparation for professional study at the graduate level. The required subjects in the undergraduate curriculum are in such basic disciplines as mechanics of solids, dynamic systems, thermodynamics, fluid dynamics, materials, particulate mechanics, geotechnical sciences, structures, and systems analysis. One of the characteristics of the curriculum is our assumption that no two students will follow exactly the same program. Each undergraduate is encouraged to utilize the liberal elective time in the curriculum to respond to his own personal motivations and interests in pursuing an area of study in depth. Since each student may take six to nine elective subjects selected from literally hundreds of possibilities, he has ample opportunity to develop his own program.

CURRENT EDUCATIONAL DEVELOPMENTS

NEW SUBJECT DEVELOPMENT

All of the required and specified elective subjects in the undergraduate program were under active development during the year. A revision of the first instruction in fluids continued in Fluid Dynamics (1.05), using notes prepared by Professors James W. Daily and Donald R. F. Harleman together with an associated laboratory program incorporating special features. The new synthesis comprising Particulate Mechanics (1.06) was continued on the basis of notes by Professors T. William Lambe and Robert V. Whitman; the notes for both of these subjects will be the basis for proposed new books. Professor Harleman spent the year at the California Institute of Technology on special studies which will enhance his contribution to the fluid dynamics development, and Professor Whitman will spend next year at Stanford

Research Institute on work which will contribute to the development of particulate mechanics. Professor Harleman is developing a new graduate subject in flow through porous media which will overlap these two subjects and feed into the undergraduate treatments.

We continued to participate in the teaching of Mechanics of Solids (2.01) and Dynamic Systems (2.021). Professor John F. Kennedy contributed to the preparation of notes for the latter, and faculty from our structures and from hydrodynamics groups have participated in the teaching of both these core subjects. Next year, faculty from our soils group will handle the civil engineering section, continuing our policy of rotating participation in these subjects among each of our groups concerned with applied mechanics and physical systems. We also continued in the teaching of Engineering Materials (3.14); Professor Edward M. Krokosky handled the civil engineering section and drafted a preliminary set of notes on cementitious materials, and these notes will be further developed during the coming year. Our strength in materials science and engineering is being increased with the addition of new faculty. A new graduate subject in Structural Materials (1.42) will be introduced next year by Professor Frederick J. McGarry. This will serve as a second-term elective following Engineering Materials for our undergraduates and will serve to develop new approaches to the teaching of materials to our students; it will also serve to bridge the gap between materials and structures.

With the addition of Professor Ernest F. Bisbee, Jerome J. Connor, and Robert D. Logcher to our faculty, our strength in applied mathematics has been materially increased. Although each is initially concentrating on the development of new graduate subjects, the longer range objective is to develop new material to strengthen our undergraduate curriculum. Our goal of having a first-rate capability in numerical methods of analysis and in operations research is being achieved. Undergraduate student interest in applied mathematics has been high. Student interest in the subject on Computer Approaches to Engineering Problems (1.15) continued to grow; we are now attracting students from a number of different departments. Three sections are planned for next year—freshman, undergraduate, and graduate. Each will be handled somewhat differently to reflect differences in student level. We continue to treat this as an educational experiment, subject to continuous change, and it is proving to be a very stimulating educational experiment. Faculty and staff from each of the divisions of the Department are now participating, insuring that this work does not become a separate technical specialty.

The two-term senior sequence Engineering I and II (1.07, 1.08), has evolved into a rather different subject from that originally proposed. The original idea involved an emphasis on formal approaches to engineering problem-solving. Now we find that we do even better by capitalizing fully on the extensive engineering experience of our senior faculty and their continuous involvement in significant civil engineering projects. Hence the case study and case project approach used by Professor Myle J. Holley in teaching the subject is being extended, and Professors Lambe, Alexander J. Bone, and Norman H. Brooks presented case projects this year. Next year six of the senior faculty members will present case projects based on current experience in real engineering situations.

The undergraduate subject in Geotechnical Sciences (1.01) has been shifted to the fourth year and will not be taught on a regular schedule again until the fall of 1964. During the interim a new graduate subject, Applied Earth Sciences Seminar (1.80), is being developed to provide an opportunity for the treatment and discussion of interdisciplinary approaches to problems in civil engineering and the earth sciences. The first presentation, given this spring, included students and faculty representing specialties in hydrology, soils, hydraulics, geology, geomorphology, engineering geology, and nuclear engineering. In addition to integrating material from the various branches of the earth sciences, the seminar is concerned with fully relating our own research in the applied earth sciences to our educational program. Thus it is planned to vary the subject matter and orientation in successive terms, treating the seminar as an experimental course. For example, during the spring term a detailed case study was conducted by the class on the overall feasibility of a sea-level canal, excavated with nuclear explosives. In the fall presentation, however, the subject will be oriented toward a broad but critical review of literature in engineering geology. In thus stressing the integration of departmental research with curriculum development, we assure that contributions from the graduate subject 1.80 will have an important bearing on the continuing evolvement of 1.01. Professor Philip A. Drinker, who is conducting 1.80 and who has taken over the responsibility for 1.01, will focus his attention on the further development of these two subjects during the coming summer and the next academic year.

We are convinced that more rapid progress in structures can be achieved through a more widespread understanding of the applicability of statistics and probability to the specification of structural safety. The relevant principles previously covered briefly in a number of subjects will be taught in a more comprehensive way in a new subject on Structural Reliability currently under development by Professor John M. Biggs. Three guest lectures by Dr. Alfred M. Freudenthal of Columbia University, a noted pioneer in this area, were enthusiastically received this spring.

LABORATORY DEVELOPMENTS AND TEACHING AIDS

The use of small-scale models in the teaching of structures represents one of our most important efforts in the development of new educational approaches and techniques. Most of the current work is devoted to perfecting methods of fabricating, loading, and instrumenting structural models within a time scale and cost level which will permit direct student participation. We are also conducting research on the source, significance, and control of errors in modeling. Major equipment acquisitions for the Laboratory for Structural Models have been delayed to take fuller advantage of the experience we are rapidly gaining in this field. A number of reports are in preparation, and a set of notes by Professor Robert J. Hansen and William A. Litle will be the basis for a new book on structural models.

Excellent progress has been made in developing the laboratory program associated with the undergraduate subject in Fluid Dynamics (1.05). The laboratory instruction is given in a tutorial atmosphere by assigning students to work in small groups with a single instructor throughout the term. Instead of routine fixed experiments, a varied program allows each group choice and individual expression. A special feature is an experimental project for each group, designed with the instructor and developed on the students' initiative. Experimental projects work in this case has two additional advantages—the laboratory work is coupled with the formal subject study, and it is conducted in the environment of a research laboratory, the undergraduate teaching laboratory and the graduate research laboratory occupying the same space. To facilitate such laboratory activity, flexible facilities and instruments are being created. Among new devices developed this year is an "erector set" airflow facility, together with hot-wire anemometry, with which students can demonstrate flow phenomena for themselves and can make bona fide investigations of boundary layers, separation, turbulence, and other flow problems. Two experimental areas unique to an introductory fluid laboratory are geostrophic motions and liquid-solid dual-phase flows. In these areas new apparatus was developed for rotating model dynamics, allowing study of

Coriolis-generated circulations, and for study of fluidizing dynamics.

In addition to the experimental laboratories facilities, there is concern with teaching aids including demonstration devices and films. A new approach to the latter was used this year in which a student group designed and photographed a series of experiments on stratified flow to produce a seven-minute 8-mm titled film. This was done as an integral part of their project work and proved to be especially instructive. It also demonstrated the feasibility and ease of amateur preparation of low cost film demonstration aids by which the laboratory can be extended into the classroom. Professor Daily is leading this work, and professors Philip A. Drinker and Ralph R. Rumer, Jr., and Frank E. Perkins are actively participating. Student response to the laboratory work for Fluid Dynamics (1.05) has been extremely favorable.

The development of an information system laboratory, to provide a student facility for work involving the acquisition, reduction, transmission, processing, storage, retrieval, and display of engineering information, was initiated during the year. The Department's 1620 computer is being provided with a general-purpose input-output system to facilitate its use as a component in information systems. A data exchange system, designed for maximum flexibility, is being developed to handle data originating in the experimental laboratories which are to be linked directly with the computer. Current emphasis is on the design and construction of the necessary hardware to achieve our objectives. We believe this to be a unique venture in civil engineering education, the results of which will be of interest and value to many schools.

The Department is pioneering in the development of problem-oriented computer programming languages for civil engineering. Two such languages are now operational—COGO for geometric problems and STRESS for structural problems. A student version of COGO was developed during the year and used in the computer subject this spring, and freshmen used COGO on assigned problems with complete success. A much more extensive student use of COGO is planned for next year. The group under the leadership of Professor Steven J. Fenves and including Professors Logcher and Samuel P. Mauch completed an operational version of STRESS in the spring. A major effort in this area will be underway this summer. We expect to start using STRESS in the teaching of structures next year, at both the graduate and undergraduate levels. Problem-oriented languages will have a very significant effect on the teaching of engineering. In particular, they open up a whole new approach to the teaching of design, since they render analysis almost completely automatic and make the results available essentially immediately. During the coming year we expect to initiate work on a number of additional problem-oriented languages, including the fields of soils, transportation, and management problems.

The Department is playing a very active role in developing the time-sharing approach to the use of computers in engineering education. During the year there was extensive use of the experimental time-sharing system at the M.I.T. Computation Center, primarily by Daniel Roos working under the supervision of Professor Charles L. Miller. A time-sharing version of the COGO system was developed and is now fully operational. Professor Logcher also worked with the experimental system and perfected a time-sharing version of STRESS. Both of these are providing excellent mechanisms for obtaining "hands on" experience. The Department received the first remote console this spring for experiments in cooperation with the staff of the Computation Center; the unit is now in operation and successful runs have been made. By next fall we expect to be in a position to use the teletype console as an integral part of our educational program. Work is also progressing to utilize the Department's 1620 computer as an input-output device in the time-sharing system. The 1620 will be used as an interim design console and for gaining experience with the equivalent of a more elaborate remote console.

Our educational facilities were expanded during the year by the development of four new rooms on the third floor of Building 1. These include a new applied earth sciences laboratory, a seminar and conference room, a student study room, and an educational workshop. All of these are designed to enhance the efficiency and effectiveness of our teaching effort, and each has educational experimentation as a goal. For example, the educational workshop is intended to bridge the gap between the formal classroom type of facility and the hardware-oriented laboratory facility. It is equipped with large tables for group activity and close interaction between instructor and students on case study, design, supervised problem, and discussion sessions. Files and cabinets for source material such as maps, plans, reports, and related data are being provided. We hope to develop a similar workshop on the second floor to associate with the structural models laboratory, and an educational workshop is also proposed for the first floor, to be designed around the time-shared computer terminal.

FACULTY DEVELOPMENT

Although our work on curriculum, new subjects, laboratory methods, teaching aids, and educational facilities is central to strengthening civil engineering education, faculty development is considered to be of even greater importance. All of the progress and activity previously outlined in this report has contributed greatly to the strengthening of our faculty. The opportunity to work on new subjects, laboratories, teaching aids, and educational approaches has been very stimulating and rewarding. While working hard to improve civil engineering education, we are improving ourselves. Hence the experience we are gaining is an important progress result in its own right.

In addition to faculty development through participation in these educational activities, we have embarked on a systematic program of formal and informal release of individual faculty members for the purpose of special studies in new areas. During the past year Professors Biggs and Peter S. Eagleson devoted their time to advanced study in other departments in such areas as applied mathematics, operations research, and systems analysis. During his year at the California Institute of Technology Professor Harleman participated in their regular academic program and also studied in mathematical physics and thermodynamics.

Our educational developments during the year were greatly stimulated by a number of visiting faculty members from other engineering schools, including Professor Fenves from the University of Illinois, Professor Robert L. Schiffman from Rensselaer Polytechnic Institute, Professor Brooks from the California Institute of Technology, and Professor Charles W. Lovell from Purdue University. Each of these men spent the full year at the Institute and actively participated in our program. We hope to continue such exchange activities with our sister civil engineering departments, since it has proved to be a mutually effective and efficient way to communicate advances and ideas.

We have also devoted considerable attention to the addition of new faculty members at the assistant professor level. Our objective is two-fold: to add new talent to our faculty in the areas of emphasis in the Department, and to provide a number of young men with the opportunity to obtain experience in engineering education and research in our environment. Excellent progress has been made in achieving these objectives, and we are pleased with the outstanding young men who have joined us. These include Professors Bisbee, Connor, Harry M. Horn, Krokosky, Logcher, Ronald T. McLaughlin, Mauch, and Rumer.

Finally, we would like to stress the extraordinary value of the Ford Postdoctoral Fellowship Program. No other single result of the

Ford grant has proven to be so valuable, not only to the young men holding these appointments but also to the total program of the Department. They are playing an extremely important role in the Department. All are participating directly and enthusiastically in teaching and research activities, producing significant contributions themselves, freeing senior faculty for participation in other Ford program activities, and providing an important stimulus for faculty and students alike. Thus they are proving to be a very key element in our educational innovations.

RESEARCH

Sponsored research conducted by the faculty of the Department now exceeds $1,000,000 per year in volume, an average of approximately $40,000 per faculty member. Our principal research units are the Hydrodynamics Laboratory under the direction of Professor Arthur T. Ippen, the Structures Research Laboratory under the direction of Professor Hansen, the Soils Research Laboratory under the direction of Professor Lambe, the Materials Research Laboratory under the direction of Professor McGarry, and the Civil Engineering Systems Laboratory under the direction of Professor Miller. Normally we would include a brief report on the research activities of each of these units; but space is at a premium and this omission is partially offset by the publication of an extensive document, "Educational and Research Activities in Civil Engineering at M.I.T.," which is available from the Department.

While the volume of sponsored research in the Department has grown by a factor of four in a relatively few years, considerable care is being taken to insure that our research activities are an integral part of the educational program of the Department. We are relying almost entirely on faculty and students to staff the projects, with a minimum of professional research employees. Over 90 per cent of our faculty is actively engaged in sponsored research, and we support one of the largest groups of graduate student research assistants at the Institute. Extensive use is also being made of part-time student help at the undergraduate level. Our goal is to have all of our students at all levels participating in the research program of the Department. We feel that the experience gained in research work, including the opportunity to work closely with the faculty and fellow students, is a very valuable part of our educational program. Due to the emphasis on faculty and student participation, our volume of research is not expected to continue to grow indefinitely. We feel that about $50,000 of research per faculty member per year is optimum, since with heavier commitments faculty members become more supervisors than investigators. This is not a magic figure, but it does suggest that we will be increasingly selective and cautious to insure that research does not divert energy from our teaching and unbalance our faculty activities. It appears that our present goal for research should be approximately $1,500,000 per year with approximately 100 research assistants. We should reach this level during the next two years.

The research funding situation in civil engineering has improved considerably in recent years. Previously, the most available funding was from military agencies or for narrowly defined industrial problems; such research was often a matter of the agency or company taking advantage of existing skills without much regard for the advancement of civil engineering. For example, many military-sponsored projects have been primarily concerned with using civil engineering faculty talents in such disciplines as applied mechanics for problems which may have little or no direct relationship to civil engineering. The same has been true of considerable industry-sponsored research. While such research will continue to have a place, the important change is that it is no longer the primary source of research support for the Department. Although government-sponsored projects will continue to predominate, there has been a definite shift to fundamental research and to problems related to civilian projects. Long-range funding and grants for broadly defined problem areas are becoming increasingly common from both private and government sources. We are taking full advantage of these trends to develop a research program which is directed toward the advancement of civil engineering. The changes in the nature and orientation of our research are playing a significant role in the implementation of the new program of the Department.

The new Inter-American Program in Civil Engineering is a significant experiment in the funding of research in civil engineering. It represents the first time that we have solicited large-scale funding as a department instead of through many separate technical proposals. With grants totalling $785,000 already received in one year, our goal of $1,000,000 appears to be realistic. The funds will be used to support a series of projects, each initiated and conducted by individual faculty members and their students.

INTER-AMERICAN PROGRAM

The Inter-American Program in Civil Engineering is now fully operational. Financial grants in support of the program have been received from the Carnegie Corporation of New York, the Agency for International Development, the Dow Chemical Company, and the Creole Foundation of Venezuela. Under the program, teams of faculty and students from M.I.T. and engineering schools in Latin America are conducting research on civil engineering problems which have technical, social, and economic significance in both Latin America and the United States.

Professors Ippen, Holley, Hansen, Lambe, Albert G. H. Dietz, Eagleson, Miller, McGarry, Whitman, Roberts, Horn, Egons Tons, and McLaughlin have made trips to various Latin American countries to explore the initiation of research projects. Projects are now underway involving students and schools in Colombia, Venezuela, Mexico, and Chile. Professor Roberts and two of his students, William Jessiman and Dale Gladding, are spending the summer at the University de Los Andes in Bogota, Colombia, participating in the establishment of an electronic computer center and initiating transportation research. Dr. Charles H. Savage, Jr., Research Associate in Civil Engineering, Professor Warren G. Bennis of the School of Industrial Management, and Andre Priem, a doctoral candidate at the Harvard Business School, are conducting an associated research project on the sociological effects of computers in South America. The new installation in Bogota, and another in Medellin, Colombia, are providing case-study information.

Because of their universal importance, water resources problems are being given priority for research under the Inter-American Program, and a number of investigations are being initiated under the leadership of Professor Ippen. Professor McLaughlin and Jonathan Bulkley of M.I.T. and Fernan Ibanez, research engineer from the University of Chile, have conducted an important study during the past spring aimed at identifying significant problem areas. Initial emphasis was given to the development of new systems methodology for evaluating water resources development projects, with special attention to the problems of limited data. Mr. Bulkley, a doctoral candidate in political science, is working on the social, political, and economic aspects of water resources developments and their influence in engineering decision-making. Professor Eagleson and two of his students, James Dailey and Richard Males, are working in cooperation with the Instituto de Ingenieria at the University of Mexico on problems of erosion and sand transport which influence coastal developments. A number of other projects are under active consideration.

The instability of soft soil is a major problem in construction of large structures in such areas as river deltas, lake shorelines, and filled land. Research on the mechanisms of settlement and foundation failure has been initiated under a project led by Professors Lambe and Horn, involving students and staff from the Universidad Catolica Andre's Bello de Caracas, Venezuela. Stephen C. Aldrich, a senior in civil engineering, is conducting field work in Venezuela this summer. Housing is another area of major significance in Latin America, and Professor Dietz has initiated a preliminary study of housing problems aimed at identifying important research areas we should pursue in depth. The study team includes Julio Silva, an architect from Uruguay who is now a graduate student in civil engineering at M.I.T., and Marcia Koth, a political science major at M.I.T. who has lived and worked extensively in South America.

ACTIVITIES OF THE STAFF

The faculty of the Department received a number of distinguished national awards during the year, details of which are given elsewhere in this volume. Professional activities have included the following: Professor Ippen served as the Honorary Chairman of the first Latin American Seminar on Hydraulics in Santiago, Chile; lectured at the Technical University of Berlin; and advised the Pakistan government on vital estuary problems. Professor Hansen served on the Advisory Committee on Civil Defense of the National Academy of Sciences; Professor Lambe served as a visiting professor at the Georgia Institute of Technology and visiting lecturer at Harvard and Purdue Universities, Professor Daily presided at the Symposium on Cavitation and Hydraulic Machinery in Japan and served as a member of the Board of Directors of the Boston Society of Civil Engineers. Professor Dietz served as a Director of the American Society for Testing and Materials and of the Building Research Institute. Professor Whitman served as a visiting lecturer at Harvard University.

CHARLES L. MILLER

Department of Electrical Engineering

THE UNDERGRADUATE PROGRAM

The evolution of the undergraduate program continues. Our experience with the new electromechanical energy conversion subject last year convinced Professors Herbert H. Woodson and James R. Melcher that our undergraduates needed more background in continuum mechanics. In cooperation with a number of the faculty of the Department of Mechanical Engineering, Professors David C. White, Paul L. Penfield, Jr., and David R. Whitehouse are developing a new joint subject to be offered in the fall to all electrical engineering sophomores, to replace the current sophomore mechanics subject.

The sophomore circuits subjects are presented in an excellent manner, but the manpower demands are high. This is especially true of the individualized problem grading. For this reason we plan next year to carry further the programmed instruction work which Professor Dean N. Arden started last year but which was interrupted by his visit this year to the Chiao Tung University in Taiwan.

During this year the new two-semester undergraduate elective in transistors was offered by Professor Paul E. Gray to the junior and senior classes. We began in September with about 160 students and finished with about 120 in the second term. The subjects were offered on a lecture-recitation basis with a required laboratory; the first semester was devoted primarily to the relevant properties of semiconductors, the internal physical mechanisms of diodes and transistors, and the development of circuit models for these devices, and topics covered in the second semester included the elementary circuit properties of transistors, limitations on circuit performance, multistage linear circuits with emphasis on feedback amplifiers, and multistage digital circuits.

These subjects are based upon the material being developed by the Semiconductor Electronics Education Committee and have used the text material, laboratory experiments, and movies and demonstrations prepared by this group. The classes experienced the usual difficulties which attend experiments in education, but on the whole the subjects have been successful in meeting the two original objectives:
1. They have given the students an intensive treatment in depth of a device of current technical importance, all the way from the underlying physical principles to moderately sophisticated circuit applications.
2. They have exposed the students to the many points of view which are essential to engineering design. That is, the subjects have stressed the use of judicious approximations in dealing with complex problems and have emphasized the formulation of design techniques that take in stride the uncertainties and complexities that always arise in design.

The experimentation with this subject is not a local phenomenon. Under the chairmanship of Professor Campbell L. Searle, the Semiconductor Electronics Education Committee, which includes forty-seven persons from eleven universities and eight industrial organizations, is preparing a paperback series of six books, formal and informal laboratory experiments, take-home laboratory kits, and six films concerning topics which cannot be adequately demonstrated either in a textbook or in the school laboratory.

Five of the books, ten of the experiments, and two of the films are now available. Fourteen hundred students in fourteen universities were taking the subject during the spring semester of 1963.

A cheap and small transistorized oscilloscope and signal source is being developed by Professor Richard D. Thornton for use in the take-home laboratory kits. During the spring term seventy-five of the sophomores in their first laboratory subject assembled oscilloscopes, doing a considerable amount of design. Not all of the oscilloscopes were done by the end of the semester, but an educational and rewarding time was had by both students and instructors.

In the new senior laboratory, Professor Robert L. Kyhl made a brave attempt at engaging 140 students in not very closely directed independent project work with considerable success. We will try next year to have more seniors do two-semester experimental theses rather than senior laboratory, so that a smaller group will remain for the laboratory and we can more easily provide the experienced help which such a program requires.

THE GRADUATE PROGRAM

NEW SUBJECTS

Faculty research and graduate student interest continue to generate new graduate subjects. This year's crop includes Electrodynamics of Continuous Media (6.583) by Professor Penfield; Structure of Computing Machines (6.535) by Professor Jack B. Dennis; Advanced Computation Systems Seminar (6.543) by Professor Herbert M. Teager; Switching Circuits (6.538-9) by Professor Fred C. Hennie; Theory of Optimal Control (6.609) by Dr. Michael Athans; Development of Inventions and Creative Ideas (6.512) by Robert H. Rines; Flight Transportation (6.671J) by Professors J. Francis Reintjes, Alexander J. Bone (civil engineering), Rene H. Miller (aeronautics and astronautics), H. Philip Whitaker (aeronautics and astronautics), and Paul H. Cootner (industrial management); and Flight Transportation Seminar (6.672J) by Professors Reintjes, Bone, Secor D. Browne (aeronautics and astronautics), and Cootner. The last two are interdisciplinary subjects offered jointly by four departments. They augment the five such subjects introduced last year.

SYSTEMS ENGINEERING

The new subject introduced in 1961-62, Special Studies in Information Systems (6.604J), has an interesting history. During the second term of 1961-62 the Departments of Aeronautics and Astronautics, Civil Engineering, Electrical Engineering, and Mechanical Engineering jointly offered the subject in Special Studies in Information Systems, with a primary goal of giving students an opportunity to participate in the preliminary design of a complex system. In order to delimit the activity somewhat, initial emphasis was given to systems in which information handling or data processing represented a major function —hence the name. A class of twenty-two students was subdivided into groups of four or five, and each group worked on a separate system throughout the term. Some general lectures were presented in an effort to unify the work. The reaction to this experiment was quite favorable, but the staff felt that an even more valuable experience could be obtained if all the students could work on a single project so as to illustrate more fully the trade-offs which must be made between the conflicting goals of designers of different portions of a complex system.

During the fall of 1962 the decision was reached that for 1962-1963 this subject would be developed around the design of an equatorial weather satellite. Furthermore, in order to involve students interested in the operational portion as well as in the data processing portion of a system, the decision was made to combine forces with the subject Flight Vehicle Engineering, offered by the Department of Aeronautics and Astronautics.

During the spring term of 1963 sixty-five students were enrolled in this combined subject. These were drawn from the Departments of Meteorology, Industrial Management, Aeronautics and Astronautics, Civil Engineering, Electrical Engineering, and Mechanical Engineering. All of the students were exposed to all of the major technical areas associated with the design of a weather satellite through a series of lectures given by outstanding guest speakers and by M.I.T. faculty. In addition to the lectures the group was subdivided into working groups concerned with the major subdivisions of the system, such as booster design, design of the instrumentation for the satellite, design of the necessary communication links, and so forth. These design areas were established in much the same way that they would be in an industrial situation, and the students elected their own group leaders and an over-all project manager. The students spent approximately the first eight weeks of the subject arriving at major design decisions, such as the altitude at which the satellite would operate, the launch location, the approximate gross weight of the orbiting vehicle, the means for collecting and processing the information to be transmitted from the satellite, and so forth. Since decisions on these factors cannot be made unilaterally but must involve each of the groups and since during this portion of a complex design numerous alternatives exist, the students were involved in a real experience in engineering decision-making.

The presence of students from meteorology insured that realistic specifications were established for the over-all system, while students from industrial management set up working schedules and insured that adequate communication took place between the various subgroups. To permit the group to appreciate more fully the complexity of the task of placing a satellite in orbit, forty-eight students and four staff members spent two days at Cape Canaveral inspecting facilities and listening to briefings.

At the end of approximately nine weeks the students finalized their decisions and then began to undertake the more detailed design of each of the subsystems. As an end product, the students prepared a final report to which each contributed a section on a particular facet of the design which he had selected as his particular area of specialization. Finally, on the last day of the term they made an oral presentation of the results of the study to the entire class and to a number of guests invited from outside the Institute.

In this subject the students were confronted with a broadly stated goal and faced with the problem of attempting to arrive at satisfactory compromises between a number of conflicting requirements. Although this is really the essence of engineering, most students have little opportunity to engage in projects of this complexity. Understandably, they passed through a phase during which they felt that nearly every decision they tried to make was contingent on a number of other equally difficult decisions and that little progress was being made. Actually, they were going through a very valuable period of weighing alternatives, and after several weeks of this they were able to decide upon a number of the basic factors of the system and to build the remainder around these. A subject of this type provides an excellent means for exposing students to a quantity of practical engineering facts and design concepts which there is no time to discuss in the usual theory subjects. While much of this type of information tends to become obsolete rapidly, it is of considerable immediate benefit to students in giving them confidence and an awareness of current technology and techniques as they begin their professional careers.

In this regard the contributions of outside lecturers were extremely valuable in exposing the class to the challenges and problems currently facing industrial and governmental groups working in this forefront area and in stimulating the students to see whether they could invent new ways to solve these problems.

The staff had never seen a group of students who were more enthusiastic about a subject. Furthermore, they were extremely favorably impressed by how well a group of students representing a diversity of backgrounds worked together as a team and by the high technical level of the results achieved. The staff plans to offer this subject again next year, developing the case study around some different but equally challenging problem.

ADVANCED STUDY

Last year I reported that Professor Arthur C. Smith was planning to make use of the resources of the Molecular Engineering Laboratory to offer a course to faculty from other institutions during the summer. With the comparatively recent increase in the importance of solid-state physics in engineering and physics curricula, many faculty members have been faced with the problem of developing competence in a new area. On the theoretical side, the publication of many good texts and the availability of special lecture series have eased this problem. However, it remains difficult to obtain experience in the experimental aspects of materials science. The techniques which are of importance in solid-state physics are of tremendous variety and often involve expensive equipment which is usually heavily committed to research and so is not often available to those who wish to learn experimental techniques.

To help this situation, Professor Smith and several other faculty members offered a program in experimental solid-state physics to interested faculty members from other institutions. Sixteen participants from fifteen institutions attended this five-week program during the summer of 1962. The support of the participants and the direct costs of staffing and operating the laboratory were provided from a grant made by the Ford Foundation partly for this purpose. Each participant carried out seven experimental projects during the five-week period. Each experiment involved about twenty hours of laboratory work plus preparation and evaluation. The experimental areas available were X-ray diffraction, infrared spectroscopy, magnetic resonance, galvanomagnetic effects, excess carriers in semiconductors, ferroelectricity and crystal growth, thermal properties of solids, superconductivity, and the Mössbauer effect. In addition to the laboratory work, lectures were given by the members of the staff and tours of M.I.T. research laboratories were arranged.

The participants all felt that this program filled a real need for them and that it was a very useful service for M.I.T. to offer. As a result of the success of this program and in view of the continuing need, we will offer the program again in the summer of 1963 with support from the National Science Foundation.

GRADUATE STATISTICS

The trend toward increased emphasis on doctoral study continues. The Department began the academic year 1962-63 with 511 graduate students. Of these, 373 were in degree programs, about the same number as the year before. The remainder were special students registered for only one subject. A total of 152, or 41 per cent, of the degree students were registered in doctoral programs, an increase from 37 per cent the year before. The fraction in the Engineer degree program was 7 per cent, and in the Master's degree program 52 per cent, a decline from 58 per cent the year before. For most students who complete the doctoral program, the Master's degree is a first step and an integral part of the over-all program. The full fraction of our graduate student population aspiring to the doctorate is, hence, over 60 per cent.

The fraction of our degree students receiving financial support for full-time study is increasing. The number changed from 98 in 1961-62 to 143 in 1962-63. Essentially all of this increase resulted from larger national and industrial support. The number of teaching assistants engaged in part-time graduate study also increased from 95 to 101, but the number of research assistants decreased from 106 to 99.

RESEARCH ACTIVITIES

PROJECT MAC

Project MAC (Machine-Aided Cognition or Multiple-Access Computer, at the reader's option) is an Institute-wide computer project which will be starting during the coming academic year. Professor Robert M. Fano is directing the project, and a number of faculty and students in electrical engineering will be involved. Its objective is the evolution of a large computer system that will be easily and independently accessible to a large number of users. An essential part of the project will be the development of improved terminal equipment, programming systems, and machine structure and organization. The emphasis is on improving the number and nature of interactions between man and the machine.

STROBOSCOPIC LIGHT LABORATORY

The school year of 1962-63 saw an increased student use of the Stroboscopic Light Laboratory under the direction of Professor Harold E. Edgerton. Besides weekly laboratory "experiences" in the subject on Electronic Light Measurements (6.202), each term saw a group of twelve first-year students in the Freshman Seminar Program. In addition to this there was the normal student thesis load, and there were many visitors from throughout the Institute with measurement problems to be solved by strobe lights and photography.

Sixty-five students attended a Special Summer Program on Techniques in High-Speed Photography in July, 1962, for discussion of the theory and application of numerous photographic methods.

Continued effort has been devoted to the study of the circulation of blood in the white of the normal human eye by Dr. Roe Wells of the Peter Bent Brigham Hospital, assisted by Robert Schildkraut. This photography problem is a difficult one and so far has not been completely solved.

A photographic system involving a double flash for taking superimposed photographs on a single film, as devised by David LaForge (a thesis student from last year), is in active use at the Clinical Research Laboratory of the Diabetes Foundation, Inc., in Brookline by Dr. Searle Rees. Information on flow rates in the circulation system of the white of the eye has been obtained. The double flash system will be used as a research tool on many types of patients.

The exploitation of underwater pulsed sound systems used for underwater searching and investigation continues to go forward. Experiments with "side-looking" transducers operating at 12 kc frequency seem to be especially promising, as shown by John Yules in his senior thesis which was completed in June. A double-beam device of this type has recently been installed aboard the bathyscaphe *Trieste* which is now in the Boston Navy Yard waiting to dive in search of the nuclear submarine *Thresher.* Since April 10, 1963, underwater strobe lights, cameras, and pingers of the type developed in this Laboratory have been used at the site of the *Thresher* tragedy in an attempt to learn details of the accident.

The use of large xenon flash lamps as beacons for lighthouses and airways has been considered. One such lamp five feet long excited with a 4-kv, 1000-watt-second system was found to be very obvious when mounted on the roof of M.I.T.

David Kocher is just completing a Cranz-Schardin ten-exposure camera system which operates up to about 0.5 microsecond intervals. The flash exposure of each photograph is less than 0.1 microsecond, and the interval between successive frames can be scheduled for different delays.

Development work continues on the "boomer" electromagnetic transducer system for creating coherent sound pulses of low-frequency output for sub-bottom seismic profiling.

ELECTRONIC SYSTEMS LABORATORY

Faculty and staff of the Electronic Systems Laboratory have centered their research on a spectrum of problems relating to electronic, electromechanical, and neurological systems. A total of seventy-eight students participated in the work of the Laboratory, under the guidance of Professor Reintjes as Director and Professor George C. Newton, Jr., as Associate Director. Of these students, four completed their research for the doctorate and six for the Engineer degree. Sixteen students undertook research for their Master's degrees in the Laboratory and seven performed work for their S.B. theses.

Professors Newton, Leonard A. Gould, and George Zames and their students continued their research in several aspects of control. In the realm of theory, two programs are underway in optimum control systems. One problem concerns the design and performance assessment of an optimal control system for a process whose parameters are not known with certainty. The other investigation aims to examine the sensitivity of system performance to small variations in the optimal control function.

Professor Gould, in collaboration with faculty members of the Department of Chemical Engineering, is engaged in a three-fold study of chemical process design, process dynamics, and process control. This group is attempting to verify its belief that, through an initial systems study, the design of a chemical plant can integrate more efficiently plant instrumentation and control. Three experimental projects are currently under way. They include a study of the kinetics of coke burnoff from a catalytic bed in a differential reactor, development of an ammonia decomposition reactor in portable form for supplying hydrogen to fuel cells in a space application, and a study of the dynamics of the chemical reaction in a high-intensity pulsed arc.

Professor Newton continued his research in sensors for control systems. His theoretical and experimental work in vibratory-output angular motion sensors has achieved the primary objective of experimentally demonstrating a scheme of double modulation as applied to a tuning-fork gyroscope configuration. It is anticipated that reduction of unwanted cross-coupling through use of double modulation may lead to significant increases in sensitivity and long-term accuracy of vibratory-output rate gyroscopes over conventional gyroscopes. Professor Newton and his group have also been successful in their attempt to design a high-precision sensor for measuring hydrostatic pressure for a range between 0 and 2,500 psi. They have demonstrated experimentally that their sensor, which measures ultrasonic velocity in liquids, will indicate pressures to a precision of 0.01 per cent over the design range.

The Neurology Group, under the direction of Dr. Lawrence Stark, is continuing to apply communications-engineering concepts and servoanalysis techniques to biological and neurological systems. These systems often respond to a number of inputs and have several outputs. A study of the interactions between interlocking systems is being developed by Dr. Arne Troelstra in order to learn about the laws of these interactions and to dissect the systems by studying various partially overlapping and partially independent pathways. Dr. Howard T. Hermann and Dr. Frank Baker are using sterotactically-placed stimulating and recording electrodes to actually enter the systems in animals such as cats and crayfish. A single-unit transfer function of a crayfish photoreceptor has shown complexity of response, non-minimum phase elements, and nonlinear operators even in these unitary elements of the nervous system. A describing function analysis has led to a demonstration that the human lens accommodative system operates either with only an even error signal or uses information from the associated binocular convergence servosystem.

The discrete nature of the eye movement control system has led Professor Fernando Naves to study the hand control system and demonstrate similar phenomena in this most complex feedback control system. An analytical model of the postural portion has clarified the output or plant adaptive characteristics and distinguished these from the input adaptive mechanisms. Further studies on drug effects on the pupil and eye movements have led to an expansion of the clinical application of these results. This approach offers the neurologist or neuro-ophthalmologist three distinct advantages over bedside observation. Transducers such as pupillometers and eye movement glasses enable objective records to be taken. The mathematical machinery of an on-line digital computer (G.E. 225) connected to hospital diagnostic laboratories by leased telephone lines is able to control the experiment (generating Latin Graeco square sequences) and the excitation function itself via digital-to-analog converters, store the response function via analog-to-digital converters, and then analyze the input-output relationships; the final display might be a Bode plot on an x-y recorder in the hospital laboratory available a few minutes after the test run. The third and perhaps most important advantage is a conceptual framework of the nature of the particular neurological feedback control system so that phenomena such as oscillations, refractory periods, and discontinuous changes of modes become understandable consequences of simpler properties of basic elements and topological configurations of these elements. Professors David G. Cogan and Robert C. Schwab of Harvard University and Gerald Whipple of Boston University have been cooperating in these biomedical engineering researches. Grants from the National Institutes of Health, the Office of Naval Research, the Army Chemical Corps, and the Air Force support these programs.

A Special Summer Program on Biological Servomechanisms offered during 1962 was well attended by engineering and medical faculty members from all parts of the country. A regular graduate subject on Biological and Neurological Control Systems (6.595J) was offered in the first term to sixteen graduate and undergraduate students.

Under the direction of Douglas T. Ross, the Computer Applications Group, in conjunction with faculty and staff of the Department of Mechanical Engineering, continued its work on computer-aided design. The research of the past year has been particularly fruitful, and many aspects of computer-aided design which were proposed and discussed in preceding years are now being brought into sharp focus. A new algorithmic theory of language and a companion operator theory have been developed. Both of these make use of highly generalized techniques for storing problem information in the computer in terms of interwoven, or "plex," structures. These structures provide a rigorous theoretical foundation for constructing a problem-solving system of broad generality. Theoretical results are now being reduced to practice through the construction of a compiler which will become the nucleus of a full-scale computer-aided design system. Nation-wide interest in the results of this research has been generated as a result of a symposium sponsored by the Industrial Liaison Office and a series of technical papers presented at the 1963 Joint Computer Conference. Mr. Ross was the recipient, jointly with his co-author Jorge

Rodriguez, of the award given for the outstanding paper presented at this Conference.

A key requirement of the computer-aided design project, as well as of many other groups at the Institute which require large-scale general-purpose computer facilities, is a computer-display system which enables graphical portrayal of input and output information. The Laboratory is playing a leading role in meeting this problem in man-machine communication. A display group under John E. Ward has completed the design of a display console incorporating special-purpose incremental-computer techniques to permit flicker-free operation and picture manipulation with minimum computational demand on the central computer. This system is now being constructed for use on the I.B.M. 7094 being procured by Project MAC. Mr. Ward's group is also investigating display systems which are appropriate for time-shared computation in which large numbers of consoles are operated simultaneously, some from remote locations.

A group under Professor Alfred K. Susskind has continued its work on synthesis of logical networks. One aim of this research is to find orderly synthesis procedures that exploit to the fullest logic blocks which are more powerful than those employed in the classical techniques. Another aim is to exploit techniques which are suitable for bulk-manufactured switching circuits. Additional goals include investigation of ways to utilize computers in the synthesis process and the development of techniques for the synthesis of sequential circuits which assure good circuit realizations with a minimum of trial and error. During the year the interest of the group in special-purpose computer design was oriented toward problems associated with data processing in space vehicles.

An analog-digital computation facility is being assembled under the direction of Mark E. Connelly. It consists of a PDP-1 digital computer, analog-digital conversion equipment, high-speed pulsed-analog components, and a solid-state analog computer with conventional functions. The primary objective of this work is a full-scale demonstration of the capabilities and advantages of hybrid techniques in the real-time simulation of complex dynamic systems, particularly aircraft. The facility will be sufficiently flexible to be used in the solution of other classes of problems, and background investigations have been carried out on the hybrid solution of partial differential equations, digitally-controlled filters, and steroscopic displays.

The radar research in the Laboratory continues under the leadership of Professor Reintjes and Laurence R. Swain, Jr. The activities of this group centered on system synthesis and circuit development. An experiment for measuring the reflection coefficient of the core surface of the planet Venus from a spacecraft has been defined, and an effort is currently being made to prove the feasibility of conducting this experiment within the weight limitations imposed by current size of spacecraft. The solid-state, high-power pulser work which has been underway for several years has culminated in highly successful results. Several industrial organizations have begun to take advantage of the new concepts which have evolved through this work. Several novel devices and circuits which should lead to compact radar-receiver design are under investigation.

In an area which interrelates radar, computer technology, and control, mechanisms are being investigated for compensating the deteriorating effects on high-resolution radar system performance caused by random motions of airborne vehicles. Because of the extreme precision required in airborne radars of this class, ultra precise instrumentation appears necessary. A laboratory simulation facility is being constructed to permit closed-loop dynamic-accuracy tests of combined motion-sensing and r-f systems and associated computational equipment. This work is being directed by Mr. Ward.

The thin-film devices group is engaged in the development of active electronic devices which will be constructed using techniques of thin-film vacuum evaporation. The effort is currently being followed in two related channels. Professor Martin S. Osman is studying the electronic conducting properties of oxide insulating films and their vacuum-emission characteristics. This work may lead to a thin-film triode device similar to the bipolar transistor where active behavior is achieved by injecting charge carriers into a region of high conductivity. Professor James G. Gottling is examining the conductive properties of semi-insulating cadmium-sulphide films in terms of the structure of the film and the nature of metal-electrode semi-insulator interface. This work may lead to a thin-film active circuit device which is a solid-state analog of the vacuum-tube triode.

ENERGY CONVERSION AND SEMICONDUCTOR LABORATORY

The work of the Energy Conversion and Semiconductor Laboratory has developed along two main lines: semi-conductor materials and devices related to energy conversion applications, particularly photoelectric and thermoelectric; and semiconductor materials and devices related to electronic circuit applications. The second line of endeavor has grown from the A.R.P.A.-supported Materials Center activity at M.I.T., and the first has been supported for the past year by the Office of Naval Research and by a separate A.R.P.A. program on energy conversion.

The laboratory, directed by Professors Richard B. Adler and White, aided by Professors George W. Pratt, John Blair, Gray, Smith, Thornton, and Bruce D. Wedlock, has supported eleven doctoral students, two Engineer degree candidates, twelve Master's students, three research associates, two D.S.R. staff, and one guest. The number of degrees completed was three at the doctorate level and eleven at the Master's level.

Topics of research related to electronic circuit or system applications have included: study and development of diffusion and epitaxial device technology, with a view toward producing hetero-junctions; investigation of space-charge-limited current flow in diode and triode insulating structures; study of the role of impurity concentration in controlling the characteristics of tunnel diodes; evaluation of noise performance of field-effect transistors; research on the temperature-dependence of p-n junctions; studies of micro-wave modulation of light by the effect of an electric field on optical absorption; research on ultrasonic amplification in piezoelectric semiconductors; and investigations of gain and bandwidth limitations of varactor amplifiers and performance limitations of transistors at the extremes of large signal, small signal, and wide bandwidth.

In thermoelectric processes and materials, work has touched upon temperature-dependence of effective masses in PbTe; theory of heat flow in crystal lattices; transport properties of ZnSb and of certain alloys of bismuth, tellurium, selenium, and antimony; band structure of PbTe and CdTe; magneto-optic effects in Bi_2Te_3; and design and construction of a thermoelectric generator to power a tunnel diode d-c converter.

Photoelectric conversion by graded-gap devices, especially using the solid-solution system HgTe-CdTe, has received major attention; and considerable study of the thermo-photo-voltaic effect in p-n, p-i, and p-i-n germanium converters has been undertaken. Related topics include the electron-voltaic effect in p-n junctions and neutron radiation damage to silicon controlled rectifiers.

The theory group under Professor Pratt has concentrated on magnetic and semiconducting properties. In the area of magnetics the research is concerned with spin-spin correlation functions which are the response functions of a spin system, Overhauser's spin density waves, anomalous magnetic moments in alloys, and a complete study of the magnetic and optical properties of Cr_2O_3. The magneto-electric effect, where an applied magnetic field induces a voltage difference across a sample or conversely an applied voltage generates a magnetic field, has been found in Cr_2O_3, but its origin is not well understood. A theoretical model for Cr_2O_3 capable of fully explaining the magneto-electric and other magnetic properties is being evolved by the group.

In the area of semiconductors the major effort has been on PbTe. This material, which has an enormous dielectric constant and very large carrier mobilities and is a very efficient direct converter of heat into electrical energy, is of great interest. The energy band structure including spin orbit coupling has been determined. These results are being related to the transport properties and to the electrical behavior of strained crystals, where it appears on theoretical grounds that very significant changes can be induced.

Contacts have been maintained with Professor Pierre Algrain of the University of Paris, who visited us again during the spring and once again supplied considerable impetus to our entire program.

HIGH VOLTAGE RESEARCH LABORATORY

The High Voltage Research Laboratory under the direction of Professor John G. Trump continued its studies on the formation and control of intense positive ion and neutral particle beams, on the electric phenomena associated with solid insulators subjected to high electrical fields in both compressed gases and high vacuum, and on the physical properties and medical applications of megavolt electrons and X-rays.

Five Master's theses and one doctoral thesis to be submitted to the University of Graz formed part of this research program this year.

The past twelve months showed an increased use of the 4-Mev Van de Graaff electrostatic accelerator for control of extensive superficial disease. During the 1962-63 academic year 208 patients received direct electron therapy in the cooperative M.I.T.-Lahey Clinic program. Observation of the effect on human tissue of controlled doses of monoenergetic electrons in the energy range 1.5 to 4.0 Mev was reported at the tenth International Congress of Radiology in Montreal during August, 1962.

This unique experience with low-megavolt electrons also proved of value in estimating radiation hazard in manned space flights. Information relative to the clinical and physical effects of low megavolt electrons was supplied by Dr. Magnus I. Smedal and Professor Trump in an evaluation by the National Aeronautics and Space Administration of the unexpectedly sustained electron hazard produced by the detonation of a high-altitude hydrogen bomb last July.

For several years the High Voltage Research Laboratory has cooperated with several medical institutions in the irradiation of bone and other tissue materials with high-energy electrons. Such bone has become a widely used replacement material. In recent months investigators from two of these institutions reported their first successes in obtaining promising regeneration in humans of electron-irradiated nerve sections.

LABORATORY FOR INSULATION RESEARCH

The Laboratory for Insulation Research under the direction of Professor Arthur R. von Hippel is now in a period of growth and transformation. The Center for Materials Science and Engineering should be operative by 1965; several of the Laboratory's groups are vitally needed in this new setting, and others will be closely allied. Bridging between past and future, the laboratory will sponsor its third and last Special Summer Program on modern materials research, entitled Molecular Designing of Materials and Devices, in August, 1963, under the cautioning motto: "Nature designs everything from atoms; hence, we should be able to design any kind of material or device with foresight, if we understood the periodic system in all its implications. At this stage—like weather forecasters—we are still members of the gambling profession." As on the two previous occasions, an outstanding group of colleagues from here and abroad will join us in the critical reappraisal: What do we actually understand today about the basic concepts that unify the whole field from atoms and molecules to living systems?

After the summer the Laboratory will begin to reorganize into a number of sections, each supported by its own contracts and carrying on research in the following fields: crystal physics (Professor Alexander Smakula), magnetics (Professor David J. Epstein), magnetic spectroscopy (Professor Perry A. Miles), structure analysis (Professor Robert E. Newnham), thin films (Professors Fred Chernow and Ronald B. Goldner), phonons and magnons (Professor Frederic R. Morgenthaler), mass spectroscopy (Professor Charles K. Crawford), and special problems in molecular science (Professor von Hippel).

The first seven groups will become allied with the Center for Materials Science and Engineering while the last group will finish the dielectric research projects of the Laboratory and then form a new link to the life sciences.

Within the Laboratory for Insulation Research these groups, sharing common interests, have cooperated as a close-knit team. In the process of reorganization it is hoped that many of these past associations will be maintained and that some may even be strengthened. As a case in point, Professors Epstein, Miles, and Morgenthaler, each now concerned with different aspects of the magnetic properties of solids, hope to unify their efforts in a joint program to be funded in common.

During the past year the Crystal Physics Group under the direction of Professor Smakula has continued to study the fundamental processes of crystal growth and the influence of defects on physical properties of crystals. A systematic study of various purification processes such as recrystallization, fractional distillation, zone melting, and ion exchange has shown that for highest efficiency these must be used in proper sequence. It is essential to know not only the amount of impurities but their distribution in the lattice. An investigation of mixed crystals has indicated that the concept of statistical distribution is not generally valid but that at certain concentrations a preferential structure is present. This has been revealed by a study of ionic conductivity and the trapping of electrons and holes in mixed alkali halide crystals. The influence of impurities and composition on dielectric constant and conductivity has been studied both in simple and mixed crystals of metal oxide semiconductors. The anisotropy of dielectric properties has been investigated on lead halides. A flotation method for high-precision density determination of small particles has been developed and used for density measurements of semiconducting (Type II) and nonsemiconducting (Type I) diamonds. The higher density of Type I diamonds indicates that impurities are in interstitial positions.

The Magnetics Group under the direction of Professor Epstein has been engaged in further studies of the magnetization process in ferrimagnetic garnets. The experimental work which in the past was carried out on ceramic samples is being extended to single crystals. Large single crystals of both pure and doped yttrium-iron garnet have been grown and are currently being prepared in a form suitable for studies of the dynamics of domain-wall motion. Results of such studies on doped crystals will permit a direct comparison with the theory of diffusion damped domain-wall motion previously worked out by James F. Janak.

The problem of wall velocity in pure ferrimagnetics is being reexamined. This is a problem which workers in the field believe was solved some years ago. The Magnetics Group is now convinced that the previous theory is in error and that any agreement between theory and experiment obtained in the past was entirely fortuitous. It is hoped that experimental and theoretical work now under way will provide definitive answers to the problem.

The Magnetic Spectroscopy Group under Professor Miles is currently concentrating on studies of the fluorescent properties of paramagnetic ions, the characteristics of optical maser sources, and the response of various atomic systems to submillimeter radiation.

Baldassare Di Bartolo and Robert D. Peccei have been measuring the effects of temperature on the fluorescent emission from metastable states of the Cr^{3+} ion in crystalline hosts and studying the mechanism of energy transfer between ions and lattice. The latter subject, much neglected, has become important with the use of such ions as sources of coherent light. A related problem is the change of optical absorption due to the presence of large numbers of excited ions, and techniques have been developed by David Sheres and Arthur C.-M. Chen for the observation of such transient spectra. Both these projects bear on the time-dependence and spectral emission of solid-state optical masers, and attempts have been made to understand in detail the dynamics of these devices on which will depend their ultimate stability as line sources.

Ralph C. White is working on the use of maser sources to produce beat notes in the microwave and submillimeter range, while spectroscopic measurements with gaseous masers are being carried out by Laurent E. Citti and Michael E. Mack using high magnetic fields to vary the emission frequency.

The absorption spectra of molecules in the wavelength region of 1 to 0.1 mm are being examined in gaseous and solid media by Silas J. Allen, both for information on molecular interactions and as possible sources of amplification.

Professor Newnham and his associates in the Structure Analysis Group have been investigating the crystal structures and physical properties of a number of inorganic solids. X-ray diffraction analysis of the $Bi_2Ti_4O_{11}$, YBO_3, and Al_2BeO_4 structures have been completed this past year, along with a neutron diffraction determination of the spin alignment in antiferromagnetic $CoTiO_3$. The magnetic properties of the Al_2BeO_4 solid solution series have been investigated by Ralph Santoro. The group is currently interpreting the spiral spin arrangement of low-temperature Cr_2BeO_4 and the crystal field spectra of Fe- and Cr-doped Al_2BeO_4.

Professors Chernow and Goldner have been concerned with a number of solid-state problems involving thin films. Studies have been made of electron tunneling through thin potential barriers into evaporated films and single crystals of various semiconductors (Ge, Si, Te, Se, and CdS) at liquid helium temperatures. The results of these experiments indicate that the tunneling process is a useful tool for examining the energy band gaps of such materials. These experiments are at present being extended to determine the effectiveness of this technique for measuring the energy distribution of imperfection levels in the band gap of semiconductors. The results will be examined in the light of independent luminescence, photoconductivity, and other optical and charge transport experiments, some of which are currently in progress. It is planned that all of the various experiments will be performed on the same sample.

Apparatus for depositing thin films on a heated substrate in ultra-high vacuum ($<10^{-9}$ torr) and simultaneously monitoring the nucleation and structure is nearing completion. It is planned to measure both electrical and optical properties of these films in situ, thus maintaining well-controlled environmental conditions. Studies have been initiated on the epitaxy of titanium and rutile (TiO_2) on single crystal sodium fluoride substates.

Professor Morgenthaler has been concerned with a variety of theoretical problems involving the interaction of microwaves with phonons and magnons. The parametric excitation of microwave magnons and phonons in magnetic crystals and their interaction make it possible to build high-resolution magnon and phonon spectrometers which allow a study of certain fundamental properties of ferrites, magnetic garnets, and other magnetic materials. An experimental program of nonlinear spectroscopy will commence in the fall with the aim of verifying certain predicted modes of magnon and phonon excitation. This program will also be concerned with the generation of coherent phonons and photons by means of nonlinear processes associated with ferromagnetic resonance.

During the past year the Mass Spectrometry Group under the direction of Professor Crawford has put into operation a quadrupole mass spectrometer. Its immediate application will be in studies of the decomposition of insulators at elevated temperature and to measure electron ionization cross sections. The decomposition studies are part of a high-temperature dielectrics program being carried out in the Laboratory for Insulation Research, while the cross-section measurements are being undertaken as a separate basic research project. The cross sections are needed for the construction of absolutely calibrated evaporation rate gauges, high-temperature chemistry studies, and general mass spectrometer analysis. A new method of measuring cross sections for low-vapor-pressure materials has been devised. It consists of intersecting one molecular beam with several pulsed electron beams. By carefully controlling the experimental geometry, all unknown instrument constants can be eliminated and the cross sections and absolute molecular flow rates determined.

COMPUTER GROUP

The donation of a PDP-1 digital computer to the Department by the Digital Equipment Corporation has given our students a valuable opportunity for extensive and informal contact with a powerful computing instrument. Under the supervision of Professor Dennis, the machine has been made available to students for term projects, theses, and informal experience with techniques of automatic computation.

With support from the Department and the Research Laboratory of Electronics, the capability of the PDP-1 has been enlarged through a time-sharing arrangement which gives several users concurrent access through individual typewriter consoles. The system uses a unique magnetic drum to store programs which are run in a round-robin queue. Much attention has been devoted to making the important features of the computer—the ability to have external events interrupt a program, for example—available to each user of the system. Time-shared operation provides convenient access to the PDP-1 for several users without sacrificing utilization of machine capacity.

RESEARCH LABORATORY OF ELECTRONICS

This interdepartmental laboratory conducts basic research in three broad fields—radio physics, plasma dynamics, and communication sciences and engineering.

Faculty and students from eleven academic departments participate in the research activities. The Department of Electrical Engineering is the largest contributor, with 51 faculty, 143 graduate students, and 48 undergraduate students currently engaged in a variety of projects in all of the above-mentioned categories. During the past year the Laboratory has provided support for fifteen doctoral, nine Engineer's, twenty Master's, and forty-five Bachelor's theses in electrical engineering.

A detailed report on the Research Laboratory of Electronics appears elsewhere in this volume.

LINCOLN LABORATORY

We continue joint work with the Lincoln Laboratory in the communications area, where Professor John M. Wozencraft and a number of workers in Dr. Paul Rosen's group at Lincoln Laboratory have designed and constructed SECO, the first long-constraint-length error-correcting coding system for digital data transmission. SECO is currently sending highly reliable digital data over a telephone line at about four times the data rate usually achieved. Professor Alan H. Barrett has been doing millimeter radiometry experiments at Lincoln, and several doctoral candidates have completed some work on computer manipulation of two- and three-dimensional figures on the TX-2 computer. We also continue to exchange people. Professor Wilbur B. Davenport has returned to Lincoln Laboratory as Assistant Director, and Dr. John V. Harrington has left the Lincoln Laboratory to become Professor in the Departments of Electrical Engineering and Aeronautics and Astronautics and Director of the new Center for Space Research.

PERSONNEL

We enjoyed association with a number of Visiting Professors during the year. Dr. Gerald S. Heller, visiting from the Lincoln Laboratory, helped in our experimental materials work. Professor Lotfi A. Zadeh from the University of California (Berkeley) spent a semester exchanging ideas on control and systems theory with us. Professor Mary A. B. Brazier from the Brain Research Institute at the University of California (Los Angeles) spent a few weeks with us, and Professor Chu-I Chang of the Chiao Tung University in Taiwan was here for the year helping in laboratory instruction and listening to some lectures while Professor Arden was visiting at the Chiao Tung University, teaching digital computer courses. Professor Kenneth N. Stevens was also abroad, spending the year in Sweden with his colleague Gunnar Fant at the Royal Institute of Technology, and Professor Harry B. Lee held a Fulbright Fellowship and lectured at the Royal Technical University of Denmark.

Professor Lan J. Chu succeeded Professor Ernst A. Guillemin as Webster Professor of Electrical Engineering. Harry C. Gatos moved from the Lincoln Laboratory in September to become Professor in the Departments of Electrical Engineering and Metallurgy, and Fernando J. Corbato, Associate Director of the Computation Center, joined the Department as an Associate Professor.

We record with regret the resignations of Assistant Professors

Edward Arthurs, Edward M. Hofstetter, Charles C. Robinson, and David J. Sakrison, and of Associate Professors Arthur Loeb and Moise H. Goldstein. Professor Goldstein will be a Visiting Lecturer in the Department next year, coming up from his new post at John Hopkins University from time to time to keep an eye on some students and projects here.

Retirements have taken a heavy toll this year. Professors Marcy Eager, Murray F. Gardner, Ernst A. Guillemin, and Parry Moon end their full-time service this June. Each has had many years of association with the Department.

Professor Eager was graduated *magna cum laude* in engineering from Harvard University in 1921. During the 1920's he worked with the New England Telephone and Telegraph Company, in the 1930's he was working on the design and installation of radio broadcasting stations, in 1942 he joined the staff of the M.I.T. Radar School, and in 1946 he joined the academic staff to supervise the Radar Electronics option of the Department whereby naval officers spent some time at M.I.T. and qualified for the Bachelor of Science degree. In the 1950's he assisted in the administration of our Cooperative Course and in the teaching of subjects in electronic circuits.

Professor Gardner was graduated from the University of Michigan in 1920 and came to M.I.T. in that year as a Research Assistant. He received the Master of Science degree here in 1924 and was associated with Dr. Vannevar Bush in the supervision of the Research Division of the Department. He served as Graduate Registration Officer for over thirty years, and during this period graduate enrollment in Course VI has increased from some 75 to more than 500. Professor Gardner's research has been on operational circuit analysis, and he has an international reputation in this field.

Professor Guillemin received his B.S. from the University of Wisconsin in 1922, his S.M. at M.I.T. in 1924, and his Ph.D. from the University of Munich in 1926, when he returned to M.I.T. as an Instructor in Electrical Engineering. He was named Professor of Electrical Communications in 1944 and Webster Professor in 1960. Professor Guillemin is internationally known for his work on network theory, and his books on this subject are classics. He holds, among other awards, the Institute of Radio Engineers' Medal of Honor. He was a leader in the pre-war revision of our electrical engineering curriculum and in introducing into engineering a greater emphasis on mathematics and science.

Professor Moon took his Bachelor's degree at the University of

Wisconsin. He joined the electrical engineering staff in 1924, took his Master's degree at M.I.T. in 1927, and has been continually associated with the Department for thirty-nine years. Professor Moon has done research in electrodynamics and is an authority on illuminating engineering, including related aspects of vision and color. His book *The Scientific Basis of Illumination* is the recognized standard work on this subject.

Professors Eager and Moon will stay with us part-time. Professors Guillemin and Gardner do not presently plan to do so, but we hope that we can entice them back to the campus from time to time.

PETER ELIAS

Department of Mechanical Engineering

Mechanical engineering is fundamental in most of the technological activities of men, ranging over the broad spectrum from the production of goods and services for daily life to the development of components and systems for the exploration of space. Our graduates serve these many ends in a wide variety of capacities as designers, researchers, teachers, developers, and operators, and our teaching programs are planned to serve this breadth of mechanical engineering activity. The Department program gives each undergraduate a thorough grounding in the engineering sciences of mechanics—both solid and liquid, materials, thermodynamics, electricity, and magnetism. It also introduces each student to creative engineering by means of classroom subjects in design and manufacturing processes and laboratory work in design and experimental projects. Advanced subjects in the engineering sciences, professional applications, and research follow in the senior and graduate years.

There is considerable work to enrich the academic experience of those enrolled in mechanical engineering, and much of this report is devoted to these efforts to improve and extend our teaching programs.

UNDERGRADUATE TEACHING

During this year there has been intensive activity to improve the content of many subjects and to experiment with new teaching methods designed to bring students closer to creative professional experience. The Department faculty, led by the Curriculum Committee under Professor Henry M. Paynter, have begun a review of the sophomore and junior subjects on which all subsequent mechanical engineering is based. To date detailed presentations, covering subject content, teaching techniques, assigned problems, laboratories, and demonstrations, have been made by Professor J. Lowen Shearer and his colleagues on Dynamic Systems (2.021) and by Professors Nathan H. Cook and Deane Lent and their colleagues on Engineering Design and Manufacturing (2.861), and this review will be continued next year by means of similar special presentations. Continuing changes in the basic science subjects as well as in the Department's sophomore and junior subjects make these periodic reviews by the entire Department faculty of special importance.

Important changes have been made in the teaching of undergraduate mechanics this year. In Mechanics of Solids I (2.01), two weekly lectures for the total group of 115 students and weekly tutorial meetings for groups of five students replaced the previous plan under which three lectures were given weekly to groups of twenty-five students. Professor Stephen H. Crandall gave this year's lectures, and Professors Douglas P. Adams, Cook, Steven I. Freedman, Robert D. Haberstroh, Gonzalo S. Leon, George S. Reichenbach, Prescott A. Smith, and John F. Kennedy (Department of Civil Engineering) participated as tutors. A questionnaire organized by Pi Tau Sigma, mechanical engineering honorary fraternity, indicated that students considered the new program superior to its predecessor; it clearly provides excellent education, although the new format is somewhat expensive in the use of faculty time. New subjects in Dynamics for juniors in the engineering science (2.031) and the engineering (2.03) options were given in the spring term for the first time by Professors Crandall and Dean C. Karnopp. These new subjects, the development of which was sponsored under the Ford Foundation grant to the School of Engineering, are based on a set of notes entitled *A Unified Approach to Dynamics via Hamilton's Principle* by Professors Crandall, Karnopp, Edward F. Kurtz, Jr., and David C. Pridmore-Brown.

In another new mechanics subject development, Professor Kurtz has been working with Professor David C. White of the Electrical Engineering Department in the preparation of an introductory subject in continuum mechanics to be given for electrical engineering sophomores in place of Mechanics of Solids II (2.02); the new subject, Introductory Mechanics and Electromechanics (2.001J — 6.00J), will be introduced into the electrical engineering curriculum next fall.

Dynamic Systems (2.021), which treats dynamic analysis and the response of physical systems from an interdisciplinary point of view, was taught for the second time this past year. It has assumed an important place in the core curriculum of the Department, with both students and staff marking it as an outstanding new development. The class notes are now being revised for publication as a book by Professors Shearer and Herbert H. Richardson, who were in charge of the subject this year, and Professor Arthur T. Murphy, Director of Engineering at the Pennsylvania Military College, who, as a Visiting Associate Professor in 1961-62, participated in the conception of the subject.

Work is in progress by Professors Joseph H. Keenan and George N. Hatsopoulos on a textbook in thermodynamics for both undergraduate and graduate students, a preliminary version of which is already being used.

Professor Frank A. McClintock has devised a series of audio-visual programs for a combination tape recorder and slide viewer which constitute a most interesting and promising teaching development. These programs provide carefully prepared instructions in the use of various kinds of laboratory equipment; they free the teacher from routine explanations in the laboratory and provide students with more precise and effective instructions. The result is that teacher and student have more time to concentrate on the laboratory results and their interpretation instead of on equipment details. This development is particularly important in project laboratories, on which the Department relies so heavily, where different groups of students work with different pieces of equipment in more or less random order. We also believe that the self-instructional feature of this development will be of value in new schools in this country and especially in developing countries, where practical experience with equipment and the tradition of its use have not been established. An unexpected by-product of this self-instructional program is that the teacher, who can concentrate on watching his students learn, can take a new and far more objective view of the quality of his work.

The final development by Professors Cook and Prescott Smith of a multi-functional machine for teaching and research has been one of the highlights of the year in undergraduate teaching. The machine, used by twenty sophomores this year, can conduct fully-instrumented tensile, compression, torsion, combined stress, hardness, fatigue, friction, wear, turning, punching, forming, wire-drawing, drilling, reaming, and tapping tests. All specimens are made on the machine, the materials tests can be conducted at elevated as well as at room temperatures, and the processing tests provide measurement of forces, temperatures, and wear. As a teaching aid, the machine permits observation, relation, and prediction of processing performance from materials behavior characteristics. It was developed under National Science Foundation sponsorship in conjunction with the subject in Engineering Design and Manufacturing (2.861), and the machine was exhibited at the national meeting of the American Society for Engineering Education this year.

Design and project activity are incorporated into both undergraduate and graduate subjects. Students, faculty, and industry to which our graduates go are responding with enthusiasm to the new pattern of student involvement in design work. Stereotyped exercises of engineering drawing, machine design, and heat-powered laboratories have been superseded by imaginative engineering projects, both design and experimental, which disclose to students the patterns and techniques as well as the challenges and satisfactions of applying fundamentals to problems characteristic of the real world. This year's problem in the sophomore subject in Engineering Design and Manufacture (2.861) was the design of a portable tool for cutting or bending the steel bars of reinforced concrete construction. This problem, originated by Professor Lent and others, related very well to the strength of materials content of Mechanics of Solids I (2.01), which is taken concurrently by the students, and to the material on plastic deformation in Engineering Design and Manufacture. In the junior engineering design subject, Engineering Design (2.731), students were asked to reflect upon aspects of their lives which could be enhanced by the existence of an otherwise unavailable device or process, to establish specifications for such an innovation, and to satisfy the design requirement of the device. Students responded with designs for devices ranging from steam-powered washing machines for underdeveloped countries to internal-combustion-powered pogo sticks. Particularly meritorious designs were for a battery-operated tape recorder with a novel tape-reel configuration and speed control and a device for automatically backing large trailer trucks into position at loading platforms. This latter proposal influenced one of the jurors, a director of an industrial laboratory, to express his company's interest in the idea and the student's approach.

The Design Division set forth the philosophy and implementation of the Department's design program to some eighty visiting educators at a two-week summer conference on Engineering Design and Graphics Education sponsored at M.I.T. by the National Science Foundation; the Division co-sponsored and helped to lead the Second Conference on Design Education at the University of California (Los Angeles) in September, 1962, and several papers were presented at the American Society for Engineering Education meeting in Philadelphia in June, 1963.

The Department faculty is particularly pleased by its increasing opportunities to work closely with freshmen, for we believe it desirable to introduce concepts of mechanical engineering to freshmen before they have completed their Course selection. For the second year Professor Paynter gave a freshman elective, Introduction to Engineering (2.00); with support from the Ford grant, the record of the development of this subject is now being prepared for publication under the title, *Signals Overseas from Telegraph to Telstar: A Freshman Introduction to the Engineering of Transatlantic Communications Systems.*

Eight undergraduate seminars were presented in mechanical engineering this year: Modern Marvelous Mechanical Motions and Engineering—a Foundation for Responsible Citizenship by Professor Adams, Combustion and Propulsion by Professor Tau-Yi Toong, Power and Power Machinery by Professors Kenneth R. Wadleigh and Charles F. Taylor, Systems for Recording Information by Professor Ernest Rabinowicz, Manned Space Flight by Professor Thomas B. Sheridan, The Conversion and Utilization of Energy by Professor C. Richard Soderberg, and Solid Surfaces by Professor Brandon G. Rightmire.

PROFESSIONAL ELECTIVES AND GRADUATE SUBJECTS

Change continues in the senior electives and graduate subjects. Professors Paynter and Karnopp have cooperated in the development of a new syllabus for Analysis and Design of Engineering Systems (2.751 and 2.752) which concentrates on developing student skills in establishing effective analog and digital electronic models for design and operating studies of engineering systems.

Professors Paynter and Dwight M. B. Baumann were responsible for the data processing portion of an interesting interdepartmental graduate subject entitled Special Studies in Information Systems (2.745J), led by Visiting Professor William Bollay of the Department of Aeronautics and Astronautics. The project chosen was the design of an equatorial weather satellite system, including ground support and booster.

Professor Ernesto E. Blanco has been preparing a new subject in descriptive geometry to meet the needs of architectural students. The new subject covers all theoretical concepts of spatial relationships and their analysis, with emphasis on the design and utilization of developable and warped surfaces and extensive treatment of shadows and intersections in orthographic projection as well as in perspective.

Two new subjects in fluid mechanics were presented this year, and a special subject on the Physics of High Temperature Gases (2.492) was given by Dr. S. C. Lin, Principal Research Scientist at the Avco-Everett Research Laboratory, a guest lecturer. Professor Ronald F. Probstein organized a second-level graduate subject in magnetohydrodynamics. Members of the Surface and Metals Processing Laboratories gave a new graduate subject, Theory of Material Interface Phenomena (2.864), which next year will be repeated and followed by another new subject, Applications of Material Interface Phenomena (2.865).

SPECIAL SUMMER PROGRAMS

Eight Special Summer Programs are scheduled by members of the Department for 1963. Professor William M. Murray will give four—Industrial Photoelasticity, Nondestructive Testing, and Fundamentals and Applications of Strain Gage Techniques.

Professor Paynter will offer Electronic Models for the Engineering of Multiport Systems, dealing with the effective and concurrent use of general-purpose, high-speed analog and digital computing machines as system simulators in the form of direct electronic models as distinct from mere mechanized computation. Professor Shih-Ying Lee will present Instrumentation for Measurement and Control, designed for professional and technical people in the aerospace, industrial, and military fields who are interested in the application and design of instruments and instrument systems for measurement and automatic control applications.

Professor Crandall's Program, Random Vibration, will survey recent developments in the art of dealing with vibratory systems subjected to stochastic excitations, with particular emphasis on problems associated with rocket-boosted vehicles.

Physical Measurement and Analysis, to be given by Professor Cook, will cover the techniques associated with measuring such mechanical parameters as displacement, force, torque, velocity, acceleration, pressure, vacuum, temperature, and flow.

HONORS AND ADVANCED PROGRAMS

Professor McClintock has served as adviser to the students in the Honors Course and the advanced undergraduate program. The first is made up of students of unusual promise selected at the end of their junior year to proceed with a two-year program leading to simultaneous bachelor's and master's degrees. The second 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.

Presentation of the Admiral Luis de Florez Award for outstanding ingenuity has been a major event for the Department for several years, and the award has been an important stimulus to many undergraduates. Admiral de Florez' death this year thus represented a great loss to the Department; he was a strong supporter of our activities, and his annual visit to present the awards and to examine the winners' work was always anticipated keenly. Professor Taylor, who had known Admiral de Florez through most of his professional career, presented this year's awards and summarized Admiral de Florez' many contributions. This year's winner was John H. Holly '63, who designed a stair-climbing wheel to enable a wheelchair to negotiate a wide range of staircases in terms of riser height and tread length combinations. Two honorable mentions were given to Ronald D. Rothchild '63 for an automatic truck-backing device and David B. Russell, Jr. '64 for a battery-operated tape recorder.

Melvin L. Potash, Jr. '63 won the annual student paper contest of the American Society of Mechanical Engineers for his paper "Electrochemiluminescence," and he received an A.S.M.E. certificate of merit in recognition of his outstanding efforts and accomplishments on behalf of the student section. The Wunsch Foundation Silent Hoist and Crane Company awards were presented to Juan H. Crawford '63 for the conception, engineering, and presentation of a steam-powered washing machine, to John P. Downie '64 for a billet loader, to Howard E. Kirkendall '64 for an automatic trash disposer, and to William A. Ribich '64 for an automatic hammer. The James F. Lincoln Arc Welding Foundation awards went to two seniors—Alvaro Mendoza for his paper on "Design of an Ocean Floor Corer" and George S. Wall for his paper on "A Deep Sea Research Probe."

ENGINEERING PROJECTS LABORATORY

The Engineering Projects Laboratory, having completed its second year, has established itself at the center of the Department's teaching and research activity. Its first annual report reveals that by the end of the Laboratory's first year some thirty-nine separate research and development projects were under way, including work in computer-aided design, sensory aids for the blind, man-machine systems, control systems and components, fluid mechanics, heat transfer, and two-phase flow. Some thirty-seven members of the faculty and staff of the Department were involved, together with eighty research assistants. There was an output of sixty-three undergraduate and graduate theses, twenty-seven reports, and thirty professional papers and books.

The second year has seen continued high-level involvement of undergraduate students in the professional and research activities of the Laboratory and a continued increase in its interdisciplinary activities. Some twenty term projects were completed by third-year students in Experimental Engineering (2.671), and most of these were drawn from the current professional interests of the faculty in the Engineering Projects Laboratory. Continuing interdisciplinary projects include the program on food processing carried on in the Refrigeration and Air Conditioning Laboratory in conjunction with the Department of Nutrition and Food Science, an active thesis program for students in the Department of Naval Architecture and Marine Engineering, and efforts in the bio-engineering field conducted in conjunction with many hospitals in the Greater Boston area and the Perkins School for the Blind.

New equipment, including several magnets and a closed-loop facility to handle NaK, has been installed for an investigation of magnetohydrodynamic problems as related to incompressible fluids such as the alkali metals. In addition to basic studies in this area of fluid dynamics, research will be conducted on such engineering applications as electromagnetic flow meters, electromagnetic pumps, and magnetohydrodynamic power generation using liquid metals. The new facility represents a joint effort of this Department, the Electrical Engineering Department, and the Research Laboratory of Electronics. Details of other current research activities of the Engineering Projects Laboratory are given elsewhere in this report.

The important educational aspects of the Engineering Projects Laboratory were presented through an extensive display and a series of papers at the 1963 annual meeting of the American Society for Engineering Education. The exhibit included new laboratory experiments, classroom demonstration equipment, and facilities, developed under the sponsored research program, for which preliminary models and concepts had been devised by undergraduate students during term projects in Experimental Engineering. Several of our students were present to demonstrate their equipment at the exhibition, and their presence at the meeting served as additional evidence of the important educational benefits which are being derived from the Laboratory.

The Laboratory played host to a large number of high school students who attended the Junior Science Symposium at the Institute.

Professor George A. Brown served as Chairman of the Steering Committee of the Laboratory during the past year, assisted by Igor Paul, Instructor, who served as Laboratory coordinator. The other members of the Steering Committee were Professors Peter Griffith, James Holt, and Leonard A. Gould (Department of Electrical Engineering). Major improvements in the instrument room and calibration area of the Laboratory were made during the past year, and additional laboratory floor space was provided by the removal of several large pieces of equipment whose utilization was found to be low.

RESEARCH

The Department continues to conduct outstanding programs of research in many areas of mechanical engineering. Though described separately on the following pages, this research constitutes an integral part of the Department's educational program. Graduate and—increasingly—undergraduate students undertake important parts in this work, and their professional competence is markedly increased as a result.

MECHANICS

Substantial contributions to the theory of damage due to random vibrations have been made in Professor Crandall's random vibration research, sponsored by the National Aeronautics and Space Administration and the Air Force Office of Scientific Research. In addition, the theoretical aspects of random vibration in nonlinear systems have been investigated, with contributions to the theory of peaks and envelopes in such systems; this work is now being extended to other statistical features of nonlinear response.

Professor Karnopp is continuing his research on systems optimization by random search methods and expects to apply some of these ideas to real problems next year when, on leave from the Department, he will be working in a German industrial concern on problems in control and system dynamics.

Professor Kurtz has studied the interaction of fluid flows with deformable solid media, his principal effort being a theoretical study, using numerical analysis, of the stability of laminar fluid flows over flexible boundaries. Flexible surfaces to serve as drag-reduction devices are sought for submarine vehicles and for use in pipes. A second area of his work is in the development of nonalgorithmic techniques for solving large systems of linear equations. The objective here is to develop techniques considerably faster than those which are now standard in digital computer programs.

MATERIALS AND MATERIALS PROCESSING

Last year we reported a plan to group more closely the several sections of the Department in materials and materials processing—the Materials Division, the Materials Processing Division, the Surface Laboratory, and the Textile Division—to secure greater cross-fertilization among faculty and students and greater utilization of equipment and space. Problems of securing space and financing have prevented action on this plan this year, but we have not yet abandoned our hope of bringing these groups into more favorable conjunction.

Professor McClintock has applied plasticity to determine fracture criteria for two limiting cases. It appears that in a wide class of materials from metals to plasticine and silicone putty, plastic deformation in fatigue may be kinematically irreversible under cyclic loading, so that surfaces progressively roughen. This instability, judging from a one-dimensional analysis, is inherent in any stress-strain hysteresis loop. Under monotonic loading, it has been possible to develop a criterion for fracture by the growth and coalescence of holes which provides for very ductile materials a fracture criterion analogous to the Griffith criterion for brittle materials. Unlike brittle fracture, ductile fracture shows a strong dependence on both stress and strain as well as on their history.

In a general study of the mechanisms of strain hardening and crack initiation in plastic deformation, sponsored by the National Science Foundation, Professor Ali S. Argon has studied the development of individual slip bands, the formation of accommodation kinks at slip band intersections, and the growth of highly stressed, long kink bands by photoelastic, X-ray, and etching techniques. It has been shown that, in the absence of kink accommodation, the high stress concentrations at slip band intersections cannot be relieved, and nucleation of cracks results. Together with Dr. Samuel Maloof, a guest in the Department, Professor Argon has investigated crack nucleation in high-purity tungsten single crystals, concluding that ductility at low temperatures is limited by crack nucleation at twin band intersections, though various mechanisms of accommodation may be at work.

Solid rocket fuels are representative of a group of composite materials consisting of small rigid particles bonded by an elastic matrix; the factors determining the mechanical behavior of such fuels have been investigated by Professor Leon. Experiments on and analysis of models indicate that local residual stresses rising from shrinkage of the binder during curing are important, tending to increase the strength of the composite while reducing its ductility. The nature of the fracture of these materials seems to relate to these residual stresses, as does the change in the glassy transition temperature which is observed to rise with an increase in the density of filler particles. These results may be applied in developing solid fuels with desired properties. The implication of these results for other composite materials with similar structure has yet to be reviewed.

In the Materials Processing Division, Professors Cook and Prescott Smith have conducted studies during the year on induced embrittlement in ductile materials for processing purposes, ductile fracture characteristics, punching processes, dynamic processes for controlled fracture of brittle materials, the influence of steel microconstituents on the machining process, laser machining, and electromagnetic forming processes. An experimental-analytical procedure has been developed for distinguishing those steel additives which affect machinability through changing the activation energy associated with the wear process from those which affect the temperature of an operation through plasticity considerations.

In the Surface Laboratory, where the aim is the study of the fundamental aspects of the interaction of sliding solids and the practical implications of this interaction in the technological phenomena of friction, lubrication, and wear, several significant pieces of research have been conducted. Professor Rightmire has studied factors affecting lubrication breakdown, attempting to determine the principal causes of failure of gyro ball bearings—failure being defined as an increase in bearing torque which is associated with formation of a thin film on the balls and races. Also he has studied two aspects of solid-solid interfaces—static relationships between compliance, load, and electrical resistance and static and steady-state sliding behavior of both liquid and solid unimolecular films with regard to their ability to resist removal—and on the basis of these results has attempted to develop a more complete explanation of friction and wear.

Professor Rabinowicz has studied the behavior of low-melting metals when used as high-temperature lubricants. If the metals wet the surfaces to be lubricated, they give high friction below and low friction above their melting temperature; if they do not wet the surfaces, they do not affect the friction at any temperature. This study is reducing to systematic form many of the random and/or contradictory data in the literature.

Professor Reichenbach is continuing his study of space lubrication using two test chambers operating in the 10^{-6} to 10^{-9} torr range. From this work it now appears that, contrary to earlier beliefs, many of the common lubricant additives—such as sulfur and fatty acids—do not enter into direct chemical reaction with metals but rather promote a complicated set of reactions involving air, water vapor, metal, and additive.

FLUIDS, PLASMAS, AND ENERGY PROCESSING

This has been a year of great activity in the general areas of fluid mechanics, high temperature gas dynamics, and magnetohydrodynamics. The return of Professor James A. Fay from leave of absence and the appointments of Professors Ronald F. Probstein and William H. Heiser and Dr. George S. Springer have greatly accelerated the work in this area. This group, also including Professors Ascher H. Shapiro and William C. Moffatt, has accomplished a considerable amount of basic research.

A new three-year program on entry physics, sponsored by the Advanced Research Projects Agency, has primarily concentrated on theoretical and experimental investigations of heat transfer in plasmas, acceleration of shock-ionized gases, turbulence in conducting fluids in the presence of magnetic fields, two-dimensional incompressible magnetohydrodynamic flows, magnetohydrodynamic shock waves, electrostatic shock waves and boundary layers, rarefied gas flows, radiation, and the heating of meteors. Preliminary reports of the results of this research are being issued in a new series of publications listed elsewhere in this volume.

A weekly conference was organized for discussion of fluid mechanics research being carried out by students and faculty in the Departments of Mechanical and Electrical Engineering, and members of this group participated in a series of interdepartmental continuum plasma dynamics seminars. Professor Arthur R. Kantrowitz, Director of the Avco-Everett Research Laboratory, has participated as Visiting Institute Professor in the research activities and seminars in magnetohydrodynamics and plasmas.

Professor Shapiro is continuing to devote a large amount of time to the work of the National Committee for Fluid Mechanics

Films, of which he is Chairman. The work of this Committee, including a number of half-hour films on experimental phenomena in fluid mechanics and a large number of shorter films to be used to illustrate experimental points in lectures, all produced with support of the National Science Foundation, has had a great impact on the teaching of fluid mechanics. The members of the Fluid Mechanics Laboratory are independently undertaking production of an educational film on magnetohydrodynamic phenomena.

A new fluid mechanics laboratory, opened on the second floor of Building 3 late in the spring, provides facilities for a broad range of fluid dynamics experiments. Its central location and the diversity of interests of those associated with it suggest that this laboratory will greatly enhance the Department's fluid mechanics research and teaching.

In the Engine Laboratory, under Professor Augustus R. Rogowski, progress has been made on a method for detecting the presence and decay of small-scale turbulence in a gas confined to a fixed space, a basic parameter in constant-volume flame propagation studies. Work is also under way to correlate the cetane number of fuels with their spray combustion characteristics, using the special spray combustion equipment designed by the Engine Laboratory staff and built with National Science Foundation funds. Work has been completed on the effect of cylinder size and bore-stroke ratio on octane requirement, using pistons with annular quench areas; some unusual effects have been discovered which may lead to improved combustion chamber design. A study of the effect of size on compression-ignition engine performance using geometrically similar engines has revealed that operation is possible at about twice the rotative speeds used in commercial engines. In addition, other projects are in progress on air motion in modern turbulent combustion chambers and on ways to reduce exhaust noise.

Professor Toong has directed his research effort in the past year to problems in combustion instability, magnetogasdynamics of chemically reacting systems, and simulation of space environment. A better understanding of the mechanisms of combustion instability has been achieved through studies of the triggering mechanisms which lead to the onset of acoustic oscillations in a combustor and of the interactions of those acoustic oscillations with the triggering mechanisms. Both theory and experiment indicate strongly that boundary-layer instability is one important triggering mechanism causing combustion instability. Professor Toong has also made progress in the investigation of electromagnetic effects in the dynamics of chemically reacting and electrically conducting gases. A detonation tube and a flat-flame burner have been constructed, and experiments have begun to confirm the preliminary theoretical and experimental findings. Research has been initiated to examine the simulation of space environment on the basis of similitude considerations, and preliminary results indicate the possibility of investigating subgravitational effects in an earth-bound laboratory.

Professor Keenan's work with Emeritus Professor Frederick G. Keyes of the Department of Chemistry on the correlation of new experimental data on the properties of steam has made substantial progress during the year.

In the Energy Conversion Laboratory, Professors Hatsopoulos, Eustratios N. Carabateas, Freedman and Robert E. Stickney have continued to study problems related to the direct conversion of heat to electricity by means of thermionic processes. Recently the primary emphasis has been on the effect of surface properties on the performance of thermionic converters. A model for the distribution of work function patches on the emitter surface has been used to explain in part the output characteristics of any operational converter. Detailed experimental and analytical investigations of the effect of both cesium and oxygen on the work function of tungsten are in progress. The thermionic properties of an emitter depend markedly on the crystallographic structure of the surface, and a single-crystal filament has been employed to determine the nature of this dependence. The desirability of surfaces of uniform work function has led to investigations of monocrystalline surfaces, especially the structure of such surfaces at high temperatures. Measurements are also being made of the thermal conductivity of cesium vapor. The laboratory was moved to a new location and the facilities were significantly improved during the year.

Research in heat transfer continues. Professor Warren M. Rohsenow is conducting investigations of forced convection boiling heat transfer (film and nucleate), thermal contact resistance (at metal-to-metal surfaces), and boiling and condensation of liquid metals. Professor Griffith continues his investigation of the boundaries between various regimes of two-phase flow and his work on the explanation of the mechanism of heat transfer in dropwise condensation. In the latter, it is possible to say now that drops form at particular spots on the surface and that in their earliest stages the growth rate can be calculated from a pure conduction theory. With respect to capillary two-phase flow, it is now possible to determine when it will occur, predict the density, and estimate the pressure drop. Professor John M. Reynolds, III, is well along on his research program studying the effects of electric and magnetic fields on heat transfer to flowing fluids. Professor Freedman continues his work on thermal conductivity and other transport properties of alkali metal vapors. Professor John C. Chato has concluded one phase of his continuing study of the instabilities of multi-channel natural circulation systems, an investigation of the effect of differing header temperatures and the influence of boiling occurring in one of the channels.

Under the supervision of Professor George Brown, studies of the condensing ejector (two-phase jet pump) have been continued in order to obtain a detailed knowledge of the mixing, shock, and diffusion processes which provide a means of producing high-pressure liquid streams for use in space power and turbine exhaust systems. Additional results have been obtained for two-phase, two-component nozzle flows as related to propulsion and magnetohydrodynamic power systems. The study of two-phase, single-component nozzle flows is being summarized due to its importance in the problems of metastable liquid flows in jet-pumps and the reactor safety field. System studies of a liquid metal magnetohydrodynamic power system using a condensing ejector, performed in conjunction with the Research Laboratory of Electronics, have progressed well during the past year and have indicated acceptable system efficiencies for space power systems. A weight optimization study of one- and two-loop nuclear space power systems was completed. A system analysis of the nuclear rocket yielded information on heat transfer; thermal stress considerations will be studied during the coming year.

Professor S. William Gouse has continued his literature search on certain aspects of two-phase gas-liquid flow phenomena; he has completed the first part of an extensive index to this body of literature and has started the critical review and evaluation of the problem areas of void fraction measurement, compressible two-phase flow, and two-phase flow oscillations in closed loops. He has also continued a combined visual and quantitative study of natural and forced circulation flow through single and parallel vertical heated but transparent channels in closed loops under conditions of steady and oscillatory flow; considerable progress toward identifying the fundamental flow mechanisms has been made.

The heat transfer group is involved in planning the National Heat Transfer Conference, sponsored jointly by the American Society of

Mechanical Engineers and the American Institute of Chemical Engineers, and Professor Rohsenow is acting as Conference Chairman.

The Refrigeration and Air Conditioning Laboratory, under Professor August L. Hesselschwerdt, Jr., has continued its function as a teaching and service laboratory. Close liaison has been maintained with the Departments of Civil Engineering, Architecture, and Nutrition and Food Science, with joint projects on subjects ranging from the storage of bananas to the characteristics of bituminous pavement. Funds from the former American Institute of Refrigeration have supported a Brazilian student who has investigated form factors as they affect the freezing rate and moisture loss of food. A unique material closely simulating meat products has been utilized.

The national water shortage has stimulated interest in the utilization of large-scale air cooling equipment, and Professor Hesselschwerdt has become deeply involved in the preparation of Power Test Code 30 of the American Society of Mechanical Engineers for such equipment.

Professor Chato has led thesis work on the development of a small, inexpensive refrigeration device for household use in underdeveloped areas.

Two new helium liquefiers are nearing completion in the Cryogenic Engineering Laboratory, under the direction of Professor Samuel C. Collins. One of these is of relatively large capacity (60 liters/hr), the other a very small machine intended for maser cooling. Far greater reliability in continuous operation is expected to result from new features which these machines incorporate.

Magnetic fields of 40 to 50 kilogauss have been obtained in a nitrogen-cooled magnet with the aid of a modest bank of storage cells as power supply. Additional cells are being added with the expectation of reaching field strengths of 100 kilogauss.

Professor Joseph L. Smith, Jr., and students are investigating thermal regenerators for low-temperature applications.

GAS TURBINE LABORATORY

This Department participates extensively in the research and teaching activities of the Gas Turbine Laboratory, an interdisciplinary laboratory under the direction of Professor Edward S. Taylor of the Department of Aeronautics and Astronautics. This year, with Professor Philip G. Hill on leave of absence, this teaching and research has been the principal activity of Professor William R. Hawthorne of Trinity College (Cambridge University), who has been Visiting Institute Professor. Research in the laboratory includes: the prediction of separation of turbulent boundary layers, a prediction which is exceedingly important in compressors and pump design but is at present very poorly understood; the effect of Coriolis acceleration on a turbulent boundary layer, an effect which is important in all radial flow pumps, compressors, and turbines but still little understood; the behavior of a boundary layer in a highly favorable pressure gradient, which is important in the determination of friction and heat transfer coefficients; vortex motion in an unfavorable pressure gradient, important in the discharge passages of turbo-machinery, since even a small amount of circulation at the entrance to a diffusing passage can have a very large effect on the flow; and flow with an initial shear gradient around an obstruction, a condition which has important effects on the flow around blades in nearly all turbo-machinery.

Particularly important research results include a new method of analysis which now makes it possible to compute laminar boundary layers in strong pressure gradients and a rational approach to the design of outlet guide vanes for axial compressors which has resulted in a 50-per cent reduction of losses in this component.

BIO-ENGINEERING

The Department has a continuing interest in engineering problems related to human physiology, psychology, and therapy. Professor Blanco and his students have worked on a tape-to-Braille mechanical transducer which is ready to undergo testing at the Perkins School for the Blind. The machine input consists of a perforated tape in which the perforations are made in negative Braille patterns; the machine displays a continuous line of Braille characters on a moving belt at a wide range of speeds.

Under Professor Chato work has continued on further development of a refrigerated probe for use in such surgery as cataract extractions and retina reattachments. A grant from the Caspary Fund is now available for the development of a control system for such a device.

Professor Sheridan continues efforts to characterize mathematically human control behavior, with particular application to remote manipulation of objects undersea and in space as well as to mobility aids for the blind. This work has revealed some consistent discontinuous properties of the human operator which deviate markedly from predictions based upon available automatic control theory.

Continued student interest in bio-engineering problems was manifested this year by several bachelor's theses, two of which were concerned with the design and development of apparatus for brain surgery using focused ultrasound. This work was done at the Massachusetts General Hospital. A third bachelor's thesis was done in cooperation with the Children's Hospital, exploring a novel approach to a large class of spinal and lower-extremity bracing problems in children. The study, based on establishing a weight-bearing stabilized cite on the pelvis, has influenced the staff of the Children's Hospital to explore this concept through clinical testing on deformed children.

Professor John T. Rule's work on student adaptation, in cooperation with Dr. Benson R. Snyder, Psychiatrist in Chief, is described in detail in the annual report of the Medical Director.

DESIGN AND DYNAMIC ANALYSIS AND CONTROL

Among the highlights of research in the Department this year has been the work in computer-aided design, a joint project of the Department's Design Division, the Electronic Systems Laboratory of the Department of Electrical Engineering, and the Lincoln Laboratory. The computer-aided design program employs a digital computer to accelerate the trial-and-error process that is the heart of the mechanical design problem. Moments of creativity on a mechanical design are followed by very long periods of computations, detail drafting, and materials and standard parts selection which must be performed before the engineer can ask the vital questions about technical feasibility, cost, and efficiency. After these questions are asked, new solutions are suggested and the design process begins again. Clearly, the digital computer, if properly programmed, can conduct a considerable number of the calculations with great rapidity, so that the creative process of the engineer can go on without serious interruption.

The most dramatic of several developments in the project is SKETCHPAD, a system for making a computer the active partner of a design engineer by substituting a computer's cathode-ray tube screen for the drawing board. The engineer uses a light-pen, similar in appearance to a small flashlight, and a system of pushbutton codes to communicate his ideas directly to the computer, with the ultimate goal of producing a finished drawing without repeated sketches, drafting, laborious computations, and other unglamorous engineering tasks. Not only does the computer provide a storage for each element of the design as it progresses; it literally anticipates the engineer's desires, drawing straight lines and constructing perfect circles as well as reproducing and relocating design elements as necessary.

Professor Steven A. Coons is the Department's principal investigator in this field; Professor Mann and others in the Design Division are also active participants. Professor Coons has been called upon often to report these results to groups in industry, academic institutions, and government, and all of them are quick to grasp the implications. Clearly, this program and offshoots from it will be a central theme of research in the Design Division for some time to come.

Professor Adams' studies of nomographic, electronic, multi-specific-purpose computation (NOEL) have resulted in completion of several versions of the reading, writing, and arithmetic components necessary for this technique. Pulse shaping, modulation, and transmission problems have been largely solved, and application to the solution of ordinary and partial differential equations has begun. Professor Adams' work on simple, rugged, purely mechanical linear and space acceleration integration devices has resulted in satisfactory working models as well as mathematical models treating energy takeoff for "safeing" purposes.

The I.B.M. 1620 computer-plotting equipment is a major aid in conventional nomographic problems in Professor Adams' work; entire diagrams, normally requiring thirty hours of hard work, can be programmed by students and drawn in thirty minutes. Such a project is frequently a student's introduction to this new professional programming tool and is accordingly popular. The computer-plotter is even more valuable in the synthesis of linkages, where visual evidence of various possibilities of choice is essential for design purposes. The synthesis and drawing of coupler-point curves, function-generators, and four-position linkages can now be programmed and the results immediately drawn. These techniques have also been introduced into the field of descriptive geometry, where their usefulness for architecture and engineering design is being rapidly developed.

In the area of Dynamic Analysis and Control, Professors Shearer, Shih-Ying Lee, and Forbes T. Brown have supervised research on: fluid power control for air and space systems, a pneumatic rate gyroscope, a reaction-jet servomotor, fluid-jet amplifiers, the dynamic stability of pressurized gas bearings, and a number of other problems.

Professor Paynter's research includes studies of the control of an electric transmission network; governing of a hydroelectric unit;

utilization of new matrix exponential digital computation techniques, including the application of these to linear and nonlinear systems and to automated programming of analog computers; the use of digital computation, including the matrix exponential in a new design technique for linear control systems and the application of these techniques to problems in space vehicle dynamics and celestial mechanics; theoretical-computational work on pulsating variable stars; programmed instruction in system dynamics, making full use of on-line, time-shared digital computation where the student plays a model-building game with the computer; and a physical programming language especially suited to automated design synthesis and analysis of control and other active multiport systems.

STAFF

The Department has again been fortunate in having visitors from other academic institutions and industry participating in research and teaching who have brought the perspective of different experiences and talents.

The contributions of Professors Hawthorne and Kantrowitz and Dr. Lin have already been mentioned. The Department has also had two Visiting Associate Professors from England. Dr. Harold Billet, who is Deputy Head and Reader in the Mechanical Engineering Department of University College, London, has been lecturing in undergraduate and graduate subjects in thermodynamics, and Dr. Bernard W. Martin, who is Reader in Gas Turbine Technology at Imperial College of Science and Technology, London, has been doing research and teaching in the Gas Turbine Laboratory. Professor Martin's appointment has been an exchange appointment with Professor Hill, who has spent this year lecturing on compressible flow to graduate students at Imperial College while doing some research and writing.

Professor V. L. Narayanan, who is Principal of the Birla College of Engineering in India, spent several weeks as a guest in the Department at the invitation of Dr. James R. Killian, Jr., studying the substance and form of M.I.T. engineering education. Professor Karl-August Reckling from the Technical University of Berlin spent several weeks here during the spring, also studying engineering and science education at M.I.T., particularly in mechanical engineering; his trip was sponsored by the Ford Foundation and is part of a growing exchange between the Technical University of Berlin and M.I.T. A team consisting of Professors Max F. Millikan, Director of the Center for International Studies; Peter Elias, Head of the Electrical

Engineering Department; and the undersigned visited the Technical University of Berlin for one week in late January to survey this educational institution and to discover areas in which an exchange of personnel with M.I.T. would be most helpful to the University.

The Department has had two guests from Soviet Russia sponsored by the Inter-University Committee on Travel Grants. Nickolay P. Grechko from the Odessa Polytechnical Institute has worked with Professor Toong, and Yuri M. Issaev from the Leningrad Polytechnical Institute has worked with Professor Jacob P. Den Hartog.

Rolf Klinge from the firm of Siemens-Schuckertwerke, Erlangen, West Germany, spent five months working in the Engineering Projects Laboratory with Professor Shearer and others.

The Department continues its program of leaves of absence for our faculty to serve in important posts at other institutions and to conduct important professional activities in teaching. Professor Norman C. Dahl continues his leave of absence to lead the American team at the Indian Institute of Technology at Kanpur, and Professor Alve J. Erickson departed at mid-year to join Professor Dahl in this effort.

Professor Egon Orowan spent the year at the Carnegie Institute of Technology conducting seminars and lectures in his primary field of materials science and working on two research projects—one having to do with new theories in geotectonics and the other with political-social science.

Professor Hatsopoulos is on leave of absence with Thermo-Electron Engineering Corporation, but he has fortunately found time to give frequent lectures in thermodynamics and energy conversion and to participate in regular teaching conferences.

Professor Fay returned during the year from a year's leave of absence working at the Avco-Everett Research Laboratory in his field of magnetohydrodynamics.

The staff of the Fluid Mechanics Division was greatly strengthened by the appointment of Professor Probstein, who comes to us from a professorship in engineering at Brown University. Professor Probstein has participated actively in government-sponsored research and was director of the Advanced Research Projects Agency program on re-entry physics and of the U.S. Air Force program on hypersonic rarefied flow research at Brown. A distinguished leader in his field, Professor Probstein is warmly welcomed to the Department.

We regretfully report that Professor Shearer has resigned from the Department to become the first Rockwell Professor of Engineering at the Pennsylvania State University. He will be missed in our teaching and research and as a friendly colleague, but we note with pride the position of honor and responsibility that he assumes. We also regret that Professor Raphael Moissis, who has been on a leave of absence at TEPSIS, in Athens, Greece, leading an engineering effort in that industry, has resigned from the Department.

Following the retirement of Professor Holt, who for so long served as Executive Officer with great efficiency, the administration of the Department has been conducted this year by Professor Murray as Executive Officer and James H. Eacker as Administrative Officer. The affairs of the Department have flowed very smoothly under the direction of these men, who are assisted by Professor Holt part-time on problems of space and facilities.

H. GUYFORD STEVER

Department of Metallurgy

In the diffuse spectrum of materials science and engineering, the well-defined bands of metallurgy and ceramics are among the most important. During the past year, the Department has maintained its broad coverage, with a new emphasis on electronic materials to round out the well-established areas of mechanical and thermal properties.

UNDERGRADUATE INSTRUCTION

The undergraduate enrollment of fifty-five reveals a decline of two from the previous year. It has become evident that the typical M.I.T. freshman knows little of metallurgy, or indeed of most other engineering disciplines, when he is admitted. Since it is inconceivable that an M.I.T. graduate remain unaware of engineering, we consider it to be one of our functions to acquaint as many freshmen as possible with the excitement of engineering work.

The freshman seminars have proved an effective way to involve undergraduates in metallurgy, and seminars were offered by Professors John Wulff, Herbert H. Uhlig, Nicholas J. Grant and Merton C. Flemings, attracting a total of sixteen students. Professor Wulff's freshman elective in Structure of Materials (3.09) attracted more than sixty students; by popular demand, a laboratory subject (3.10) was instituted to follow this in the second term.

The interdepartmental subject in Engineering Materials (3.14) has continued to develop according to the needs of other departments. Three volumes of the four-volume text have been published in paperback form and will eventually be made available through a commercial publisher. The book has already been adopted as a classroom text in a large number of other schools.

Professor Arthur W. Mullendore, ably supported by a staff committee, organized a most effective metallurgy and materials display shown in the lobby of Building 7 during the freshman orientation period. The theme, taken from Agricola's ancient treatise on the metallurgical arts, *De Re Metallica,* was suggested and developed by Professor Mullendore and Alfred Duca, Research Associate and well-known Boston artist. The fine hands of Mr. Duca and Nicholas Negroponte, a fourth-year architecture student, were evident in the tasteful visual presentation. We believe that such displays, done well, fulfill a useful purpose at M.I.T.

In the past the Department has lacked an elective subject in the sophomore year; this deficiency is now remedied by Professor Harry C. Gatos' new subject, Introduction to Solids (3.11), which develops the structural and chemical-bond approach to the properties of materials.

The revision in thermodynamics teaching which was initiated last year by Professor John F. Elliott has seen Thermodynamics II (3.20) moved to the junior year, where it now follows the sophomore subject Thermodynamics I (3.00). Physical Chemistry (5.61) will no longer be required for metallurgy majors. The earlier exposure to thermodynamics is necessary for most subsequent courses.

Other curriculum changes have been minor, and the two options, Metallurgy (III-A) and Materials Science (III-B), the latter developed largely with funds from the Ford Foundation grant, have stabilized into coherent science-based offerings which do not attempt to develop specialized professional competence. The Materials Science option, with somewhat heavier concentration on the physics of solids, has been more popular and was elected by forty-one out of the fifty-five undergraduates.

Both options provide plentiful free elective units, enabling students to pursue particular fields in some depth. Students have generally made wise choices and have not indulged in a sampling of too many areas. There are fewer undergraduate electives in metallurgy, since several of the more professional subjects have been moved to the graduate curriculum where a more advanced treatment is feasible. The loss has not been severe, as most undergraduates have concentrated heavily in engineering science rather than professional courses.

Undergraduate laboratories often lack the impressive facilities available to graduate students. Professors Benjamin J. Averbach and Roy Kaplow, with the help of a grant from the National Science Foundation and matching funds from the School of Engineering, are constructing a scanning electron-diffraction apparatus for undergraduate use, thus putting a modern research tool into the hands of undergraduates, who show an increasing interest in research methods.

The senior thesis, which forms an important part of the experimental training of metallurgy students, must now be started no later than the first term of the senior year. Students report on their work at a thesis seminar and have produced theses of remarkable quality, spurred, no doubt, by the Dow Chemical Company Prizes, awarded this year to Frank Fradin for his thesis on self-diffusion and Franklin Cocks for his work on superconductivity.

The new Metallurgy and Materials Prize, to which further reference will be made, was awarded to Gary C. Rauch, who was also the winner of the American Society for Metals scholarship.

The Student Metallurgical Society has flourished in the past year, aided by the joint membership of the two principal technical societies which is a condition for joining the Society. The lack of a suitable staff-student meeting place has only slightly dampened student enthusiasm.

The Department graduated nineteen Bachelors of Science this year, a number which places M.I.T. among the top ten undergraduate schools of metallurgy in the country.

THE GRADUATE SCHOOL

With 155 regular and eighteen graduate students, the Metallurgy Department remains the largest in the world; 105 students were registered for Sc.D. or Ph.D. degrees, 47 for the S.M., and 3 for the degree of Metallurgical Engineer, and twenty-three doctorates were awarded—more than one-quarter of the total for the nation. More than one hundred students held positions as research assistants; the new head-count quota of 170 could be filled if more space and facilities were available, since applications remain at a high level.

It may be questioned whether doctorate candidates should stay in graduate school more than four years. In an effort to shorten their stay, we have revised the doctorate examination procedure. An early, qualifying examination is now mandatory before registration for the doctorate, followed by a single, comprehensive examination in the field of specialization.

We have moved towards consolidation of graduate subjects of instruction, dropping some and introducing others. Interdepartmental sequences are being developed in the physics of solids, mechanical properties, and process engineering. In the first of these, the laboratory subject directed by Professor Arthur C. Smith of the Department of Electrical Engineering and the lecture subject of Professor Robert A. Smith of the Department of Physics have been important parts. Professors Kaplow and Simon C. Moss have assisted in the instruction and have developed new laboratory experiments.

Many of our graduate students make use of the Computation Center in their research problems, and a new subject by Professor Kaplow on the metallurgical uses of computers has been very valuable.

The Metallurgy Colloquium, which for each of the past three years has involved a central theme, was concerned this year with the physics of solids. Professor Averbach was responsible for arrangements. The Robert S. Williams Lectures were delivered by Professor Bertram N. Brockhouse, Professor of Physics at McMaster University.

RESEARCH

The Department continued its heavy involvement in graduate research, hampered to some extent by crowded facilities and to a lesser extent by the vagaries of research funding. Although about 90 per cent of our research support came from government sources, including the National Science Foundation, Atomic Energy Commission, N.A.S.A., and the many agencies of the Department of Defense, it is only fair to record that broad-gauge, basic research has not lacked support and that all of the research has been graduate thesis work.

Generally, the research is concerned with exploring the micro and gross structure of materials, relating such studies to properties, and developing new ways to change and control such properties by structural rearrangements. The preparation and processing of materials, particularly metals and ceramics, are important, closely related areas.

MINERAL ENGINEERING AND SURFACE CHEMISTRY

Much of the work in mineral engineering is concerned with the physical chemistry of interfaces and ionic solutions, reflecting the extensive involvement of chemistry with almost every phase of separation and processing of minerals and other raw materials. Professors Antoine M. Gaudin and August F. Witt are continuing work on properties of interfaces in systems involving at least two fluid phases, which includes efforts to develop better methods for measuring contact angles, dynamically rather than statically.

A new theory has been developed for the disposition of molecules and ions at interfaces. This theory calls for a double layer, even though incomplete, at a water-mineral interface and a single layer at a hydrocarbon-mineral interface. The ultimate objective is to correlate into a single system both Young's equation and the Gibbs equation.

An electrochemical study of interfaces is continuing under Professor Philip L. de Bruyn's guidance; a theoretical study of the interaction of two large bodies, each characterized by a plane surface and separated by a fluid electrolyte medium, has been concluded, and an electrochemical study of the ferric oxide-aqueous solution interface is in progress. This work will be extended to other oxides such as ZnO, CdO, HgO, and TiO_2. The adsorption of mixed vapors onto ferric oxide is also being studied.

A study of the kinetics of dissolution of crystalline zinc sulfide in aqueous sulfuric acid solutions has been concluded. Comparison of activation energies with the quantitative rate make it possible to propose a tentative mechanism for the dissolution reaction which involves electron transfer in the solid to a reacting site occupied by a hydronium ion.

Under Professor Gaudin's supervision, polyelectrolytes have been studied for their rheological effect on suspensions of kaolin of known particle size distribution. Their efficiency in facilitating flocculation of kaolin is strongly affected by the kind of mechanical work given to the suspension after addition of the polyelectrolyte and by the duration of this mechanical work.

Professor Gaudin and Witt are also continuing work on flotation pulps. It is proposed to extend knowledge of the effect of the ionic composition of the aqueous part of pulps to those metallic ions which can be measured by flame photometry.

Research on the comminution of materials continues under Professor Gaudin, with present efforts directed to size distribution for sizes finer than 1 micron. A centrifuge, capable of operation at 4° C and designed so as to evaluate the solid content in a suspension by its nuclear properties, has been constructed and is currently in operation.

CHEMICAL AND PROCESS METALLURGY

Professor John Chipman has continued his research on the thermodynamics of molten alloy solutions, with specific attention to the important metallic system Fe-Si-C which is the basis of all cast iron; interactions among the three components in the molten state have been studied, using gas-metal equilibrium and distribution methods.

Thermodynamic aspects of the chemical reactions occurring in the hearth and bosh of the blast furnace at temperatures in the neighborhood of 1500 to 1600° C have been elucidated by a study of the reduction of SiO_2 in slag by carbon in iron. Activities in the slag phase are now firmly established.

Professor Chipman showed, from a study of all pertinent data, that the accepted free energy of silica was in error by at least 5 kilocalories.

Research was continued on the stability of materials at high temperatures with particular reference to carbides and oxides of vanadium, niobium, and tantalum; thermodynamic data on these carbides have now been obtained.

Professor Elliott has continued his fruitful work on high-temperature E.M.F. cells. The thermodynamic behavior of nickel in liquid Ni-Pb alloys has been established and an oxygen potential meter, for gas-phase measurements, has been developed. Cells using solid oxide electrolytes have undergone further development and a high-temperature halide electrolyte is being perfected.

Professor Elliott has completed work on the solubility of hydrogen in liquid iron alloys and is studying, in some detail, the kinetics of nitrogen absorption, using a newly-designed Sievert's apparatus. Some interesting kinetic results have also been obtained in a study of nucleation of deoxidant products in liquid iron; the thermodynamically stable phase is not the first to precipitate in most cases.

Improvements in high-temperature solution calorimetry include the use of the computer to analyze and interpret data and mastery of the technique for making hot liquid additions (at 1200° C).

Data on activities in complex solutions are being studied by Professor Elliott to obtain a solution model for predicting interaction coefficients.

The accuracy of Knudsen cell measurements is being evaluated by Professor Thomas R. Meadowcroft through use of a newly-constructed Knudsen apparatus. The primary purpose of this apparatus will be to determine the applicability and accuracy of the Knudsen technique in measuring the activities of iron, nickel, and cobalt in liquid alloys with other less volatile metals.

Professor Thomas B. King has continued work on the kinetics of CO evolution from liquid iron; the adsorption and desorption of CO from the liquid surface has been shown to be a complicated phenomenon.

Research on electrode kinetics in fused oxide systems, using galvanostatic relaxation methods, has shown that the anodic reactions are fast at high temperatures, diffusion control of the overall reaction rate prevailing.

Work on diffusion in liquid systems has resulted in measurements of the self-diffusion coefficients of sodium and oxygen in liquid silicates and of bismuth in bismuth-lead alloys. Improvements in the capillary effusion technique have been made.

A research topic of interest in the annealing of sheet steel is a study of the oxidation of iron at low temperatures in gas mixtures which, on thermodynamic grounds, should not permit oxidation.

MECHANICAL METALLURGY AND METALS PROCESSING

Professor Flemings has been concerned with the process variables involved in casting and solidification; a central aim of the research is to gain greater control over the structure and properties of materials through control of solidification. Among items of specific interest is an investigation of dendrite morphology and orientation which is directed at obtaining a clearer understanding of the mechanism of dendrite growth and of resulting morphology. In related work, studies are being made of the development and control of preferred directions of columnar growth ("texture") in cast metals and of solute redistribution in liquid and solid during dendrite growth. A computer program has been formulated for determining the extent of solid-state diffusion to be expected during dendrite growth of binary alloys. Agreement with experimental results has been excellent. The effects of fluid flow on the structure of metals solidified with plane front, cellularly, and dendritically are being investigated in an effort to correlate the effect of dislocation concentration; the orientation of cells, dendrite arms, and grains; and nucleation of equiaxed crystals. Analyses have also been conducted to determine the extent to which resistances to fluid flow between solidifying dendrites and/or cells influence the formation of microporosity.

A program of research under the direction of Professors Flemings and Walter A. Backofen on the influence of casting structure on mechanical properties has been continuing for many years; current work is concerned primarily with the effects of microporosity, microsegregation, and dendritic structure on the properties of low-alloy steel. It has been found that many, if not all, of the structural inhomogeneities resulting from solidification can be detected in varying degree in wrought products. Studies are also being made of the effects of ingot solidification variables on fracture toughness of high-strength sheet steels, and banded structures in alloy steels, directly related to ingot microsegregation, are being examined.

Research on refractory metal phase diagrams, under Professors Wulff and Jere H. Brophy, has continued, with the equilibrium phase relationships being studied in five refractory metal systems. Included in this study are tantalum-zirconium, tungsten-tantalum-zirconium, molybdenum-iridium, niobium-ruthenium, and tungsten-palladium. The molybdenum-iridium system has been completed.

In another project, it has been learned that the densification rate in sintering tungsten powder can be significantly increased by small additions of certain Group VIII transition metals. The mechanism of this process appears to be the selective acceleration or deceleration of the grain boundary mass transport path, found to dominate the sintering behavior of pure tungsten in the range 1000° to 1200° C.

Professor Wulff has also continued his studies of metallic composites, both filamentary and powder. Work on tungsten-iron-nickel composites has shown that the shear strength of the softer phase can be promoted to match that of the harder phase and that the tungsten particles will deform even at liquid nitrogen temperatures, where tungsten is normally very brittle.

Professors Backofen and William F. Hosford, Jr., have been concerned with research on deformation processing. A remarkable increase in combined-stress yielding resistance can be realized by texture control in anisotropic metals. Analyses of this "texture hardening" are under development for predicting relations between texture and plastic anisotropy that can find general application in material design and processing.

Studies of the mechanism of metal fatigue have been continued, and further work on single crystals suggests that stress-induced cross slip may play an important part in crack formation in polycrystalline assemblies. Work on brittle fracture in steel plate has clarified the role of processing history in the development of grain-size effects.

Interest in mechanical behavior at low temperatures has led to detailed study of fracture mechanisms at temperatures as low as 4° K. In contrast, work has continued on recrystallization kinetics under hot-working conditions. The time dependence of the growth rate seems too large to be explained by current views of the process.

The multi-faceted work on joining, deposition, and crystallization of Professor Clyde M. Adams, Jr., has continued, with some emphasis on the liquid-solid and vapor-solid transitions.

The mechanisms of solute migration during the freezing of aqueous, organic, and metallic solutions, particularly under high solidification rates, have been studied theoretically and experimentally. A theoretical model for mass transport during dendrite solidification has been confirmed experimentally. An interesting, related investigation has been that of the propane-water system as a possible water purification technique.

The structures and properties of heavy deposits produced by gas decomposition or reduction, electrolysis, and vacuum evaporation are also being studied. High-power, electron-beam evaporation has permitted achievement of deposition rates as high as 0.001 inch per minute. Multi-source deposition of alloys has been successfully accomplished.

Thermal cycles in or near welds can now be predicted with good accuracy, as a result of recent work on heat flow in fusion welding, thus allowing structural changes to be predicted and controlled. Weld cracking in hardenable steels has been studied as an associated problem.

Much attention has been given to high intensity sources, such as electron beams and lasers, in welding; these offer considerable advantages for certain applications.

CORROSION

The fundamental mechanisms of corrosion in aqueous solutions and oxidation at high temperatures have been studied for a number of years in the Corrosion Laboratory. Professor Uhlig has been particularly interested in the early stages of oxidation of metals, during which the electrochemical properties of the surface play an important role. Volta potentials have been used to study changes in surface structure and have also been correlated with the thickness of oxide films. The nature of surface films on metals has been related to electron sharing and chemical bonding in systems such as Cu-Ni, Cr-Mo, and Fe-Ni.

Studies on the corrosion of stainless steels have continued. The mechanism of stress-corrosion cracking has not yet been elucidated, but a great deal of progress has been made. The nature of the surface film responsible for the passivity of stainless steel has been studied by anodic polarization and coulometric techniques, but electron diffraction measurements can now be made and are expected to yield valuable information.

PHYSICAL METALLURGY

Research activities under the broad classification of physical metallurgy are now so extensive that it seems desirable to attempt further subdivision into metal physics, thermodynamics of alloys, electron optics, and high-temperature metallurgy; many metals processing research subjects may also be properly described as physical metallurgy.

Metal Physics. Professors Morris Cohen, Averbach, David A. Thomas, Kaplow, and Moss have studied various aspects of the relations between structure and mechanical properties. Structural studies deal mainly with atomic arrangements and the distribution of lattice imperfections.

The effects of the restricted solubility of a solute on its diffusivity have been examined. For example, iron in a silver or gold matrix seems to diffuse along short-circuiting paths such as dislocations. Enhancement of diffusion by plastic strain during compressive creep has been studied in iron, nickel, and gold; excess vacancies are introduced which facilitate diffusion. The combined effects of small solubility and compressive strain have been studied for cobalt in aluminum.

Short-range order studies by diffuse X-ray scattering were continued on gold-nickel and iron-silicon crystals. Other structural studies were carried out, using neutron and X-ray diffraction, on liquid mercury and gold-tin alloys. The long-range correlation has been measured out as far as 50 Å from a given atom. Neutron diffraction has also been used to study short-range spin correlations in magnetic materials.

Study of cleavage fracture in iron single crystals and polycrystals at low temperatures has revealed that the crystalline direction of the stress determines whether slip or twinning precedes cleavage and at what stress level this occurs. The generation of microcracks at carbide films in polycrystalline iron has also been investigated.

An interesting finding of other deformation studies has been that the grain-size dependence of the yield stress in iron does not follow the predictions of the Cottrell dislocation-pinning model. Additional questions remain to be answered concerning the temperature-dependence of the yield stress.

Transmission electron-microscopy studies of iron-nickel-carbon martensites have given further information on the carbon strengthening of martensite, which seems to arise from the carbon interstitial-dislocation interaction. The fine-scale structure of ultra-high-strength steels has also been investigated to reveal the strain-hardening components of the strengthening process, the nature of the tempering process, and the mechanism of fracture.

Similar electron-microscopy studies of heavily-drawn wires have revealed the nature of the great difference in strain-hardening ability between face-centered and body-centered cubic metals.

Thermodynamic and Kinetic Studies. Professor Michael B. Bever has continued his well-established work on the thermodynamics of alloy systems, mainly using calorimetric techniques. The heats of formation of tellurides and selenides, compounds which are of interest as electronic materials and which show ordering phenomena, have been measured. The heat capacities of several intermetallic compounds just below their melting points show non-linear increases, which are attributed to the development of a defect structure prior to melting.

Work on deformation and annealing has been concerned largely with explosive loading. Copper-gold alloys show a destruction of long-range order at an intermediate shock-pressure level. Gold-silver alloys, similarly deformed, showed well-defined annealing kinetics characterized by strong recovery as well as recrystallization. Although resistivity measurements have been used to follow the cold work and annealing behavior, measurements of stored energy are also planned.

Electron Optics. Professors John T. Norton and Robert E. Ogilvie have been concerned with further development of electron optical techniques which play increasingly significant roles in structure studies. A divergent X-ray technique has been developed with the aid of the electron microanalyzer. This Kossel-line method has made it possible to measure lattice parameters in nickel with a precision of one part in 300,000. It is also possible to determine the orientation of the small area (5 to 25 microns) contributing to the diffraction pattern. Kossel techniques have also proved useful in studies of the perfection of iron whiskers. The electron microanalyzer has been equipped with scanning display facilities so that analysis of an area can be presented in a manner similar to a photomicrograph, using back-scattered electrons or primary fluorescence. Work has been continued on techniques for analysis of elements of atomic number lower than that of magnesium; the problem is to secure adequate precision. The microanalyzer has been used to determine concentration profiles in diffusion couples with marked success. Diffusion in ternary systems—for example, Cu-Ag-Au—has been studied extensively, the aim being to verify the Onsager reciprocal relation. The dangers of trying to predict diffusion paths in ternary alloys from simple phase-diagram considerations have been amply demonstrated. Work on grain boundary diffusion of zinc in bicrystals of silver has been conducted to reveal the effect of edge dislocations on the diffusion process. The microanalyzer has found further application in studies of the effect of pressure (up to 50,000 atm) on diffusion in the iron-nickel and iron-vanadium systems; the former system is of great importance in meteorite studies, and it is hoped that the thermal history will be thus revealed. Professor Uhlig's continuing research on the origin of meteorites has also been facilitated by the availability of this apparatus.

Professor Ogilvie has developed a scanning attachment for the newly acquired electron-diffraction apparatus which should increase the utility of the instrument in studies of phase transformations. Techniques have also been developed for video display of electron-optical patterns, using modified closed-circuit television apparatus.

X-ray techniques have been applied to structure determinations in silicide and antimonide compounds of rhenium and titanium.

In magnetic work, the effect of lattice defects on the nature of the weak ferromagnetic component in antiferromagnetic hematite has been studied. Radiation-induced defects have been formed by bombardment at low temperatures with 3 Mev electrons and neutrons.

High-temperature Metallurgy. Professors Grant and Mullendore have made further progress in their research into the basic nature of deformation and fracture at high temperatures and the development of creep-resistant high-temperature materials. It has been shown that grain boundary sliding and its contribution to total creep strain is the same internally as on the surface of metals. Resistivity measurements and thin-foil electron microscopy have been used extensively to study the generation and annealing of vacancies and other defects during creep. Deformation studies have also been carried out on thermoelectric and semi-conductor materials.

The most promising high-temperature materials still seem to be dispersion-hardened alloys. The strengthening mechanism has been elucidated by transmission electron microscopy, which reveals the nature of the strain fields around hard particles, both oxide and intermetallic. Copper and nickel, strengthened by dispersions of alumina and thoria, have been shown to have remarkable creep properties; other refractory oxides have been added and the conditions which result in the largest increases in strength have been studied. Internally-oxidized materials have been used to obtain information on optimum oxide particle size and spacing.

Intermetallic compounds with wide solubility limits have also been examined as potential high-temperature materials; the effects of departures from the stoichiometric composition on the mechanical properties are being studied.

ELECTRONIC MATERIALS

Research under Professor Gatos has been devoted to investigation of the relationship between surface states and the ionicity of semiconductor compounds, using an ultra-high vacuum apparatus in conjunction with magnetic and electric field arrangements. The distribution of trace impurities in semiconductor single crystals and the physical characteristics of single-crystal, solid solutions of intermetallic compounds have been explored through the use of crystal-growing facilities. The lattice structure and parameters of the high-pressure metallic phase of InSb (above 23 kbars at room temperature) were determined in collaboration with the high pressure group at the Lincoln Laboratory. Work on the superconducting, β tungsten-type materials has already led to important results.

Professors Wulff, George W. Pearsall, and Robert M. Rose are engaged in a comprehensive investigation of superconductivity and its relation to structure in a wide range of materials, including pure metals, with special attention to anisotropy and dislocation density; intermetallic compounds, such as those in the Nb-Sn system; solid solution alloys, both binary, as in the system Nb-Zr, and ternary, as in Nb-Zr-Ti; and in eutectics, such as those in the systems Nb-Th and Pb-Sn. Synthetic microstructure techniques have proved very fruitful in developing hard superconducting materials with high critical fields and currents. Eutectic alloy studies are expected to reveal the basic characteristics of alloy superconductors in which a pure metal and a complex phase are matrixed.

CERAMICS

Research in ceramic materials is under the direction of Professors William D. Kingery, Robert L. Coble, Alfred R. Cooper, Jr., and Thomas R. Clevenger, Jr. The research continues to contribute to both the technology and science of ceramics and the processes by which they are produced.

In the area of materials preparation research, special attention has been devoted to compaction of ceramic powders; compaction has been shown to be achieved by particle rearrangement, sometimes preceded by fracture. Carbides, nitrides, and borides of controlled composition have been prepared by vapor-phase deposition. A study of mixing in glass systems has suggested techniques for obtaining homogeneous products.

Research on kinetics and the development of microstructure in ceramics includes studies of diffusion, the kinetics of dissolution of refractories in liquid slags, solid-vapor reactions, sintering and hot pressing, and nucleation and crystal growth.

The diffusion coefficient of oxygen in GeO_2 and in ice has been measured, and studies of silicon diffusion in SiO_2 and SiC are under way. Computer solutions, which will be tested experimentally, have been obtained for the diffusion-controlled growth or dissolution of finite-sized spheres.

Diffusion in the liquid phase has been shown to control the dissolution of refractories in liquid slags. Concentration gradients in such systems have been measured by the electron microanalyzer.

The vapor deposition of alumina has been shown to occur in either crystalline or non-crystalline form depending on experimental conditions. Sintering rates in alumina have been found to be controlled by lattice diffusion of aluminum, oxygen being transported at grain boundaries.

The effect of thermal history on nucleation is being studied in glass plates; nucleation in amorphous, vapor deposited films is being examined by X-ray diffraction and electron microscopy.

An additional field of interest is the relationship of properties to composition, crystal structure, and microstructure. Agreement has been demonstrated between creep rates and aluminum diffusion in bulk, polycrystalline alumina, which has led to the hypothesis that oxygen is transported at grain boundaries. A creep model for boundary diffusion has been derived from which the grain size effect on creep was found to be different from that for the lattice diffusion model. Thus, the observed grain size dependence of the creep rate supports the view that the rate-controlling process is lattice diffusion of aluminum ions. Studies of deformation in oxides are being continued on MgO and $MgAl_2O_4$ bodies.

The fracture strength of glass, as affected by surface preparations, has been further investigated.

Studies of thermal properties have been summarized recently; the electrical and optical properties of semiconductors such as ZnO and defect-structure glasses are now being investigated.

Investigations of the structure and properties of noncrystalline solids are also pertinent to the field of ceramics. Particular attention is being paid to artificial limitations on the compositions which can be made by classical glass-forming techniques. Since these are related to the kinetics of the crystallization process, the preparation of noncrystalline solids directly from the vapor phase is under investigation.

ICE RESEARCH LABORATORY

The Ice Research Laboratory, under the direction of Professors Kingery and Adams, has grown from interest in ice as a structural material and in aqueous solutions as desirable media for solidification studies. A number of research activities under the general heading of ice research are now included. Specific projects are being conducted in the following areas: snow metamorphism and communition; solidification; mechanical and surface properties of ice; and brine migration in sea ice. A Conference on Applied Glaciology, held at the Endicott House, has resulted in an M.I.T. Press publication, *Ice and Snow*, edited by Professor Kingery.

MICROSTRUCTURE OF METALS

Professor Cyril S. Smith is writing a summary of the basic principles of the microstructure of polycrystalline materials, showing the interaction between the requirements of topology, volumetric and surface energies, and kinetics in determining structure. Application of the principles will be extended to ceramic and geological structures where possible.

HISTORY OF METALLURGY

Metallurgical history is being critically studied by Professor Smith in an effort to illuminate the interaction between science and practice in promoting profitable applications of fundamental principles and stimulating theoretical advances. In addition, a collection of basic sources illustrating the growth of metallurgical science from the 17th through the 19th centuries is being prepared for publication. The origin of steel and its heat treatment is being studied by metallographic examination of iron and steel samples from various archaeological periods and places in the Middle East.

PUBLICATIONS

We have regretfully decided to discontinue periodical publication of the bound collections of staff publications under the title of *Metallurgy Reports*. In place of this, an arrangement will be provided through which former recipients of *Metallurgy Reports* and other interested persons will receive lists of available papers which may be obtained on request.

MATERIALS CENTER

The Department continued its heavy involvement with the Center for Materials Science and Engineering. Final plans have been made for the move to the new building of the largest units of physical metallurgy research, electron optics, ceramics, and electronic materials. It is a pleasure to record the spirit of interdepartmental cooperation in research, already tangible, and to be fostered by the Center organization. The major space changes resulting from the completion of the Center will afford the opportunity for other rearrangements in the light of modern research and teaching needs.

Center funds have been made available to support the research of Professor Gatos, who is temporarily housed in space offered by Professor Gaudin, to underwrite the expanded activities of the analytical laboratory and to expedite the purchase of equipment such as the electron microanalyzer.

In anticipation of the central facilities for research to be available in the Center for Materials Science and Engineering, electron optics apparatus, such as the microanalyzer and the high-resolution electron microscopes, have been made available on a service basis to research workers throughout the Institute. Similarly, the Analytical Laboratory can accept specialized work from other departments. Facilities for preparation of special ceramic materials are also available and are being expanded in size and scope.

Professors Grant and King serve on the Steering Committee for the Materials Center, and Professors Averbach, Gatos, and Kingery are members of the Advisory Committee set up by Professor Robert A. Smith.

STAFF

It is with regret that we record the resignations of Professors Thomas, Brophy, and Hosford. All have contributed enormously as effective teachers, with a deep interest in the welfare of students, and replacements will not be easy to find. Dr. William G. Moffatt, formerly Assistant Professor and latterly Research Associate, has also left to take up a position in industry. Dr. Massoud R. Simnad, who held a joint appointment as Visiting Professor in Nuclear Engineering and Metallurgy during the year, returned to his industrial position, leaving a considerable gap in the field of nuclear materials.

Professor Gatos was appointed to the faculty, with a joint Professorship in Metallurgy and Electrical Engineering, from the Lincoln Laboratory. His particular interests in the chemistry and metallurgy of electronic materials greatly strengthen the skills of the Department in this newer area. Professor Witt joined the group in mineral engineering and will help to maintain the Department's pre-eminent position in the field. Douglass C. Johnston, a Course III alumnus, was appointed Administrative Officer, where his organizational talents, coupled with his metallurgical background, will be invaluable to the whole Department.

Professors Rose and Clevenger completed their second year as Ford Postdoctoral Fellows and now hold regular appointments. Professors Kaplow, Moss, and Meadowcroft were appointed Ford Postdoctoral Fellows and Assistant Professors. The former two increase our competence in the physics of solids, the latter in thermodynamics and chemical metallurgy.

It is a pleasure to record the promotions to Professor of Drs. Backofen and Adams, both of whom have made outstanding contributions in their respective areas of metals processing.

Mr. Duca, who is well known as sculptor and artist, has completed one phase of his pioneering work on art casting techniques in the Foundry Laboratory. The success of this experiment in the marriage of technology and the arts leads us to hope that some day a way will be found for Mr. Duca to contribute his immense talent to a broader program that will allow engineers to appreciate creativity at work in a related human endeavor.

Professor Chipman spent part of the winter at the University of California at Berkeley, conducting seminars and taking the opportunity to do research on the Knudsen cell-mass spectrometer apparatus, a version of which we hope to acquire in the future.

Mention was made in last year's report of the Conference on Metallurgical Education and the International Conference on the Physical Chemistry of Steelmaking, both held at M.I.T. It was not indicated, however, that they honored Professor Chipman, the distinguished former Head of the Department. The Proceedings of the second conference will be published and dedicated as a tribute to his remarkable career.

The announcement of Professor Cohen's appointment as Ford Professor of Materials Science and Engineering was marked by a testimonial dinner given by his former graduate students who announced that, in his honor, a Metallurgy and Materials Prize has been established, to be awarded to the outstanding junior in Course III.

Singular honors also came to Professors Chipman, Cohen, and Smith in the form of election as Honorary Fellows of the Metallurgical Society of A.I.M.E. These three are among the first ten members of the Society ever to be so honored.

Among our graduate students we have been pleased to welcome Robert A. Karasev of the A. A. Baikov Institute for Ferrous Metallurgy in Moscow.

I make no apology for concluding on a personal note, recording my appreciation to my mentor and friend, John Chipman, and to the departmental staff, whose support has been invaluable this past year.

THOMAS B. KING

Department of Naval Architecture and Marine Engineering

The theme of the Department of Naval Architecture and Marine Engineering is the design and construction of marine craft and their components for naval, commercial, pleasure, and scientific research usage. The Department's work in this field presents challenging and creative professional activity for students and faculty. Today naval architecture and marine engineering is progressing on many new fronts: the ocean medium is a frontier for scientific research, and much more is now being learned about the conditions of the surface of the sea and underneath the sea; designers of ships today are using new knowledge to enlarge the region of ship operation—in the Arctic regions, deeper beneath the surface, and above the surface in the form of hydrofoil boats and ground-effect machines; naval ship performance demands are increasing; more efficient and economical commercial ships are in greater demand. Several new technologies—underwater physics, systems analysis, design, control, computer, and energy conversion—are providing new opportunities for the naval architect and marine engineer to use his imagination in changing and improving the design of ships and their components.

CURRICULA AND ENROLLMENT

The undergraduate curriculum gives each student a sound basis in naval architecture and marine engineering and allows a considerable latitude in the selection of electives to develop a specialized discipline applicable to marine technology. Four core subjects form the basis: 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). Each undergraduate, in addition, chooses six to eight subjects to increase either general naval architecture and marine engineering competence or some specialized discipline in related fields. Two year's experience with this new undergraduate curriculum shows that it does meet the demand for flexibility in the education of naval architects and marine engineers, giving them opportunity to pursue the new engineering sciences which are greatly affecting the component fields of naval architecture and marine engineering.

The Department offers a wide variety of elective subjects available to undergraduate and graduate students. These listings are expanded and modified from time to time to take account of new student interests and new technological developments. For example, this year in Preliminary Design of Naval Ships (13.46) a group of XIII-A students took part in an interdepartmental design of an equatorial orbiting satellite by designing a sea-based launching platform.

Application of Operational Methods (13.96) will be offered in the spring term next year by Professor Ernst G. Frankel. This will take the place of Introduction of Probability and Random Variables (18.10) for both the hull and propulsion groups of Course XIII-A. It will be tailored to cover the requirements of probability which are used in Naval Ship Propulsion II (13.23). Professor Frankel is offering new subjects and is revising material in existing subjects to stress systems engineering and operations research as applied to ship design, ship building, and ship operation. Subjects in Complex Systems Reliability (13.23), Power Plant Control (13.23), Decision Theory (13.93), and Operations Research (13.96) are presently part of the curriculum.

The Society of Naval Architects and Marine Engineers is sponsoring a complete revision of the two volumes of *Principles of Naval Architecture* which were originally written in the 1930's. Two of the chapters in this new text are authored by departmental faculty, one on Ship Vibrations by Professor Frank M. Lewis and one on Ship Maneuvering and Control by Professor Philip Mandel.

Professors Justin Kerwin and Frankel had a group of first-year students occupied in the Ship Model Towing Tank as part of the freshman seminar program during the first term.

There has been a further increase in the enrollment of civilian graduate students in Course XIII, from 23 to 26, and there is an expected increase to 33 for next year. One of the interesting changes in the Department program has been the increase in the number of research assistantships reflecting the increase in research activity within the Department; this increase was from seven in 1961-1962 to eleven in 1962-1963, and a further increase is expected next year. Four teaching assistantships bring the Department's total to fifteen assistantships available to civilian graduate students.

In Course XIII-A, a downward trend in applicants in the U.S. Navy has been reversed, with nineteen Navy students admitted in 1962-1963 compared with twelve in the previous year and fifteen in 1960-1961. Next year it is expected that twenty Naval officers will report, and it is hoped that the number of new graduate students from the Navy will stabilize at approximately twenty per year.

The Coast Guard has changed its program for graduate students to a two-year program leading to a Master of Science degree. Two officers are enrolled this year in such a program and three are expected to arrive for next year. The Canadian Navy has also found it necessary to reduce the time spent in the graduate education of its officer students; they expect to send three officers, only one of whom will take the three-year Course XIII-A program; the other two will enroll for the Master of Science degree. The group of five Brazilian naval officers who will arrive this summer will be the last contingent from Brazil; it is the intention to educate future Brazilian Naval officers at the University of Sao Paulo, which has been building its strength in this area for many years.

SEMINARS AND SYMPOSIA

A very active seminar program has been continued under Professor J. Harvey Evans' supervision during the current academic year, with one seminar scheduled each week. A wide variety of subjects were presented by authorities in their respective fields, including traditional topics such as ship motions, propulsion, and structures as well as a number of newer topics which are becoming increasingly important to the field, such as undersea exploration, the properties of sea ice and the problem of its penetration, and structural response to explosive loadings.

In cooperation with the Industrial Liaison Office, the Department sponsored a one-day symposium on Ships and Hydrofoils in October, 1962. The entire list of speakers and topics was drawn from within the Department, with almost every member of the faculty and staff participating; the symposium was very well received.

Plans are being made for another Industrial Liaison Symposium to be undertaken by the Department in the fall of 1963 on the theme of shipyard productivity.

RESEARCH AND RESEARCH FACILITIES

This year has been marked by an expansion in the Department's research program. The Ship Model Towing Tank has been under the direction of Professor Justin E. Kerwin in the absence on leave of Professor Martin A. Abkowitz. The use of the Towing Tank has increased rapidly during the year, mainly as a result of the addition of the new carriage and wavemaker. This use includes scheduled laboratories and theses in naval architecture and marine engineering, civil engineering, and aeronautics and astronautics, testing in connection with sponsored research projects, and tests for industrial users. A principal research effort has been in the development of equipment to generate irregular waves with a prescribed energy spectrum and in the analyses of ship motions and hull structural loadings in irregular waves. The work is under the sponsorship of the Maritime Administration as a part of a program to increase the sea speed of commercial ships.

The Department has recently received a gift to provide for the design and construction of the additional instrumentation needed in the towing tank to test sailing yachts. This new facility will be used in the development of future racing yachts in this country, particularly those designed for international competition. Already some limited tests along this line have been conducted for a prominent designer.

Professor Kerwin has been conducting research to obtain a solution to the hydrodynamic problem of a marine propeller operating in an irregular flow field. The work is divided into two areas, the relationship between blade shape and pressure loading under steady flow conditions and the determination of periodic propeller forces in an irregular flow field.

In the Propeller Tunnel, the major research activity has been Professor Lewis' work on vibratory force reactions between ships and propeller. This work, extending over several years and supported by the Society of Naval Architects and Marine Engineers and the U.S. Navy, is nearing completion and will be summarized at the November meeting of the Society of Naval Architects and Marine Engineers.

An interesting new field of research is getting under way on the development of computer techniques in preliminary design. Professors Nicholson and Mandel developed a proposal in this area, and it is expected that support will shortly be received to begin active research. Close liaison with the project on computer-aided design of the Department of Mechanical Engineering is being maintained in this effort. It is hoped that interdisciplinary research in this field will have a long-lasting imprint on the processes of design in naval architecture and marine engineering.

Professor John B. Caldwell, a visitor in the Department for the year, has been active in research in several areas, including development of a general theory of the strength of ships' superstructures, study of structural design criteria for ships, and investigation of the use of inverse design methods in developing minimum weight ship structures. An extensive computer study on the optimization of primary hull structure based on weight and cost has recently been completed under the direction of Professor Evans; it will be presented as a paper before the annual meeting of the Society of Naval Architects and Marine Engineers in November.

Professor Frankel has conducted research on articulated ships, carrying containerization to the limit and making the container part of the hull of an ocean-going ship in order to obtain the ultimate in integration of a transportation system. He is also working on the control of ship motions as well as on complex system reliability, undertaking research into the interaction of wear and consequent failure of mechanical parts, and on the application of linear, quadratic, and dynamic programming to complex system reliability problems involving time-dependent failure rates. The results of this research may be used for optimum maintenance scheduling and definition of design parameters. He has also undertaken some research in two-phase flow with a view to obtaining the transfer function for steam generators. Results pertaining to the dynamics of the starting and end points of the evaporator region in the steam generator were obtained and will be used in subsequent analog computer studies.

MUSEUM AND TELEVISION PROGRAM

The Francis Russell Hart Nautical Museum continues to be a center of attraction for a number of visitors, and requests are numerous for loans of models and materials from the Herreshoff and Paine collections. Commitments have been made to purchase the excellent paddle steamer model *Betty Alden* and to construct models of the steamer *Great Eastern* and the steamship *Sirius*, the first to cross the Atlantic under steam power. This will enlarge the display of models that portray the development of commercial steamships, a program which was started by the late Admiral Edward L. Cochrane and Emeritus Professor Evers Burtner, the Curator of the Museum.

Interest in the America's Cup Races and the extremely fine reception given the Department's two television programs on submarines led to a request from Boston's WGBH, Channel 2, for a program on twelve-meter yachts. Professors Evans and Kerwin and Halsey Herreshoff, a graduate of the Department, participated in producing "Specification: 12 Meters" which was shown locally and over many other stations in the United States in September. *Sea Secrets,* a small publication of the International Oceanographic Foundation, has announced availability of films made from tapes of this television program, and several dozen requests have come from all parts of the country, principally from school, scout, and service organizations.

STAFF

The Department has been fortunate in having Dr. Caldwell, a member of the faculty of the Royal Naval College in Greenwich, England, as Visiting Assistant Professor during the year. He has devoted the year to teaching and research in the area of structures and has been an effective contributor to the Department's activities.

Captain William M. Nicholson, U.S.N., has been appointed Professor of Naval Construction. He succeeds Captain Edward Arentzen, who has retired from the Navy and is now serving as Administrative Officer in the Physics Department at the Institute. Captain Nicholson brings a wealth of experience to the Department from his career practicing naval architecture and marine engineering in the Navy; he has become an effective leader of Course XIII-A and an active participant in the Department's research and teaching activities. Professor Nicholson has been elected the faculty advisor for Tau Beta Pi, and he is also serving as Vice-Chairman of the New England Section of the Society of Naval Architects and Marine Engineers.

Professor Abkowitz was on leave from the Department to serve as Visiting Professor at the Technical University in Denmark during the year, having received a Fulbright award for this tour of duty. Professor Abkowitz' Graduate School responsibilities have been taken over by Professor Mandel.

Commander John R. Baylis, U.S.N., who has served as Associate Professor of Naval Architecture for three years, will leave us this year to return to duties with the Navy, having been assigned to an interesting post as Head of the Silencing Branch of the Bureau of Ships. He will be succeeded in the Department by Commander William R. Porter, who has been appointed Associate Professor of Naval Architecture.

Professor Burtner, who has served so effectively as curator of the Francis Russell Hart Museum, retires this year. The museum will be turned over to William A. Baker, designer of the *Mayflower II,* and Mrs. Baker, who has collaborated with her husband in research and writing. Mr. Baker, a graduate of the Department, is a recognized authority on ships of the seventeenth and eighteenth centuries; he is a practicing naval architect with the Bethlehem Steel Company.

The retirements of Professor Burtner and of Professor George C. Manning as Lecturer represent the termination of two long careers in the Department. Both leave many friends in the Department, throughout the Institute, and among the alumni, who respect their contributions greatly.

H. GUYFORD STEVER

Department of Nuclear Engineering

The primary concerns of the Nuclear Engineering Department are the practical applications of nuclear reactions and radiations and those aspects of physical science which contribute importantly to these applications. The nuclear reactions of greatest present importance are fission and fusion, and the Department's principal activities center around these two reactions. Major emphasis is given to fission reactors for research, power generation, space applications, and radioisotope production. The M.I.T. reactor affords an example of a fission reactor in use for teaching and research.

The fusion reactor, although not yet reduced to practice, is another major concern of the Department. Attention is focussed both on the central problem of producing and confining stably the high-energy plasma needed to carry out the fusion reaction and on efficient and economic means for recovering energy and neutrons produced in the fusion reaction.

To deal effectively with the problems of these two types of reactors, the Department follows a broad interdisciplinary approach, making use of important segments of physics, chemistry, and metallurgy and drawing on the techniques of chemical, civil, electrical, and mechanical engineering where relevant to the solution of nuclear engineering problems. Because nuclear engineering is evolving so rapidly and in directions not now completely predictable, major emphasis is placed on those aspects of physical science which will provide basic principles for nuclear engineering no matter what directions its practical applications take. Low-energy nuclear physics, neutron physics, plasma physics, electromagnetic theory, electronics, physical chemistry, and radiochemistry are aspects of physical science prominent in the Department's activities.

In attacking the problems of nuclear engineering, the Department is mindful of the two principal objectives of an institute of technology, the advancement of human knowledge through research and the education of scientists and engineers trained in dealing with novel technical problems. In this Department, as elsewhere at M.I.T., these two objectives are inseparable: students and faculty pursuing common educational objectives make vital contributions to research, and participation in research is the best way of providing students with an advanced technical education.

STUDENTS

At the start of the fall term, 117 graduate students were enrolled in the Department, seven less than a year ago. The decrease is attributed to greater competition from other U.S. universities, an increasing number of which are developing good nuclear engineering programs. Nevertheless, the fact that of 179 students awarded fellowships in nuclear science and engineering by the Atomic Energy Commission, thirty-three elected to do their work in the Nuclear Engineering Department at M.I.T. indicates the respect with which our program is viewed by students. This is almost twice the number of A.E.C. Fellows who chose the next most popular school.

The Department recommended twenty-seven students for the Master's degree, one for the Nuclear Engineer degree, and twelve for the Doctor's degree, the last a new high.

Employment opportunities for men with advanced degrees in nuclear engineering remain favorable, and our graduates are filling responsible positions in industry, government, and universities.

FACULTY

One of the most important problems in the development of practical and economic nuclear reactors is finding materials which will withstand the extremes of temperature corrosion and radiation intensity occurring in many reactors. M.I.T.'s competence in the field of nuclear materials was enhanced last year by the appointment of Dr. Massoud T. Simnad as Visiting Professor of Nuclear Materials in the Nuclear Engineering and Metallurgy Departments. Dr. Simnad was on leave for one year from his position as Assistant Chairman of the Metallurgy Department at the General Atomic Division of General Dynamics Corporation. While at M.I.T. Dr. Simnad started valuable research programs relating to the effect of reactor radiation on the mechanical properties and rate of oxidation of metals, and he stimulated student and faculty interest in nuclear materials in the

Metallurgy and Nuclear Engineering Departments. After Dr. Simnad returns to industry, instruction and research in nuclear materials will be led by Thomas O. Ziebold, who is being appointed Instructor in these two Departments. Mr. Ziebold has developed advanced nuclear fuels for the Naval Reactors Branch of the A.E.C. and is now obtaining his doctorate in metallurgy from M.I.T.

During the past year the Department was strengthened by two additions to the faculty with rank of Assistant Professor, Dr. Lawrence Lidsky and Dr. David D. Lanning. Dr. Lidsky is specializing in research and instruction on plasma physics with application to thermonuclear processes. Dr. Lanning has been appointed Assistant Director of the M.I.T. reactor; he will also play a supervisory role in a number of research projects using the reactor, particularly the lattice project.

In the coming year three men will join the faculty as Assistant Professors and Postdoctoral Fellows in Engineering. Dr. Franklyn M. Clikeman from the Physics Department of Iowa State University will participate in experimental research at the reactor; Dr. A. Edward Profio, Jr., a graduate in nuclear engineering from M.I.T., will expand the Department's program of instruction and research on accelerators and experimental plasma devices; and Armando Travelli, who is studying at Rensselaer Polytechnic Institute, will work in the field of theoretical reactor physics with emphasis on the interpretation of experiments on reactive assemblies with pulsed neutrons.

It is with great regret that we note the resignation of Professor James A. Larrimore, who served most effectively from 1960 to 1962 as Director of the Engineering Practice School at Oak Ridge, Tennessee, and in the past year made valuable contributions to our instruction in reactor physics and reactor engineering in Cambridge.

INSTRUCTION

The Department's curriculum was expanded by the addition of two new subjects of instruction. Radiation and Radioisotope Applications (22.81), introduced by Professor Gordon L. Brownell, deals with the use of radioisotopes in tracer experiments and as sources of heat and radiation. Nuclear Power Sources for Space Applications (22.27), developed by Professor Edward A. Mason, deals with the engineering development and design of nuclear rocket engines and electric power sources for space craft or satellites energized by fission reactors or radioactive heat sources. Both subjects were well received by students because of the challenging engineering problems still to be solved in these fields.

REACTOR

Under Professor Theos J. Thompson's leadership, the M.I.T. reactor has had another good year. Steady operation was maintained at a power of 2 megawatts on a twenty-four-hours-per-day, five-days-per-week schedule. A second cooling tower and additional pumps and piping which will permit increase in power to 5 megawatts have been installed. Actual operation of the reactor at this increased power may not take place until A.E.C. approval has been granted. To apply for this approval, a report describing the reactor and the proposed increase in power is being prepared, following the format prescribed in new A.E.C. regulations.

The principal projects making use of the reactor are listed in the table on the next page, which also shows the M.I.T. department or other organization responsible for each project and the source of funds. This table shows the diversity of uses being made of the reactor in fields ranging from neutron and nuclear physics to radiation effects and radioisotope production. The reactor is an extremely useful facility which is utilized in a major way by three M.I.T. departments and to a lesser extent by others. It supports thesis investigations by nearly fifty students at the same time, and makes possible a number of valuable research projects, some of which are described below.

This table also helps illustrate a discussion of the main problem associated with the reactor, financing its operating costs. Revenue from research projects is expected to decrease from around $397,000 in 1962-63 to $309,000 in 1963-64, owing primarily to cutbacks in the A.E.C.'s reactor development budget and in some research areas supported by the National Science Foundation. At the same time, the costs of operating the reactor are expected to increase from about $353,000 in 1962-63 to around $418,000 in 1963-64, owing primarily to higher wage costs and to increased charges for utilities at 5 megawatts. Thus, reactor financial performance is expected to change from a modest surplus in 1962-63, which could serve as insurance against accidental interruption of operations or as a fund for reactor improvements, to a substantial deficit in 1963-64.

At present, revenues to defray operating costs of the reactor are obtained by charging each research project for the time the project makes use of a particular facility of the reactor. In many cases these charges for reactor time are greater than all other costs for the research project. The research project supervisor is obliged to include these reactor time charges in his budget and often has difficulty in obtaining full financing for his research project because of the large

M.I.T. Reactor Projects

Project Name	*Staff supervisors*	*Organization responsible for project*	*Source of funds for project*	*Reactor use charges* 1961-62 Actual	1962-63 Est.	1963-64 Est.
Neutron spectrometers	Clifford G. Shull	Physics Department	A.E.C., N.S.F.	$104,423	$108,790	$108,000
Reactor lattice research	Irving Kaplan, Theos J. Thompson, and David D. Lanning	Nuclear Engineering Department	A.E.C.	68,605	64,025	63,000
Capture gamma ray measurements	Norman C. Rasmussen	Nuclear Engineering Department	N.S.F.	56,430	39,737	10,000
Reactor spectrometry, dosimetry, etc.	Theos J. Thompson and Norman C. Rasmussen	Nuclear Engineering Department	U.S.A.F.	39,666	43,608	36,000
Organic moderator loop	Edward A. Mason	Nuclear Engineering Department	A.E.C.	42,549	41,840	30,000
Neutron spectrometer	Clifford G. Shull	Physics Department	Lincoln Laboratory	14,945	36,730	6,000
Irradiation of gaseous hydrocarbons	Gordon L. Brownell and Edward A. Mason	Nuclear Engineering Department	McDermott Foundation	300	4,181	—
Nuclear chemistry	John W. Irvine, Jr.	Chemistry Department	A.E.C.	7,112	21,750	21,750
Radioisotope production	Gordon L. Brownell and others	Massachusetts General Hospital		7,530	6,740	6,740
Radioisotope production	—	Isoserve, Inc.		8,206	8,225	8,225
Surface reactions	Massoud T. Simnad	Nuclear Engineering Department	A.E.C.		4,000	2,000
Miscellaneous	—	—	—	10,770	17,115	17,115
Total anticipated revenue				**$360,536**	**$396,741**	**$308,830**

cost increment contributed by reactor charges. Even more serious is the fact that many potential users of the reactor are discouraged from undertaking any research at all at the reactor because of the large amount required for reactor time charges. In addition, reactor administrative personnel have to spend a large fraction of their time negotiating with research users and assisting them in obtaining contract funds to defray reactor operating charges. These difficulties would be less serious if it were possible to obtain for university reactors supporting worthwhile programs of research direct payment for operating costs from the National Science Foundation or the Atomic Energy Commission, such as these agencies now grant university accelerators. During the coming year an attempt will be made to secure direct federal support for the operating costs of the M.I.T. reactor under a plan which would replace the present system of piecemeal support through individual research contracts. At the same time, an attempt will be made to reduce some of the reactor operating costs. By these two measures it is anticipated that reactor income and expense will be brought into better balance.

EXPERIMENTAL RESEARCH

One of the principal activities making use of the reactor is the Reactor Lattice Project, directed by Professors Irving Kaplan, Thompson, and Lanning. The initial objective of this project is to arrive at a detailed understanding of the properties of reactor lattices fueled with natural or slightly enriched uranium and moderated by heavy water. Such heavy water reactors give promise of yielding more energy per ton of natural uranium and having lower nuclear fuel cycle costs than the light water reactors now being built in the United States. In this project systematic measurements are being made of the properties of a number of subcritical lattices of this type when supplied with neutrons from the thermal column of the M.I.T. reactor. Initial lattice studies have been made with natural uranium rods 1 inch in diameter at spacings of 4.5, 5, and 5.75 inches. These lattices have been used to test the accuracy of the experimental methods and to obtain new information. Investigations of lattices of 0.25-inch diameter rods containing U^{235} at a concentration of 1.03 per cent are under way. Future plans include the study of rods containing U^{235} at concentrations between 1 and 2 per cent and having diameters from 0.25 to 0.75 inch. In parallel with this experimental research, theoretical research in reactor physics is being conducted in order to provide a unified understanding of the measurements.

Professor Norman C. Rasmussen and his students have been using a bent-crystal gamma ray spectrometer developed at M.I.T. in fundamental research on nuclear energy levels and in developing a practical, non-destructive method for determining the composition of irradiated fuel discharged from nuclear reactors. One instrument of this type is being used to measure the energy of gamma rays given off when various nuclides capture neutrons from the M.I.T. reactor, to obtain precise information about nuclear energy levels. Measurements of this type are now being made on the rare earth elements dysprosium and holmium. A second instrument of this type has been used to measure the energy and intensity of gamma rays emitted during the decay of fission products in fuel discharged from the M.I.T. reactor after a known history of irradiation. This study also revealed the presence of very intense X-rays characteristic of uranium; these result from ionizations in the K shell of uranium caused by the high radiation field present in a spent fuel element. On the basis of this work it is concluded that it may be possible, by measuring X-ray and gamma-ray energies and intensities, to determine non-destructively the fission-product content and ratio of plutonium to uranium in spent reactor fuel.

Professor Mason has been directing a major research project in which an organic heat-transfer fluid is circulated through a loop in the M.I.T. reactor in order to determine the rate at which it is broken down by reactor radiation, the nature and yield of degradation products, and the changes in physical properties that occur on irradiation. From August, 1961, to October, 1962, a mixture of terphenyl isomers was irradiated at 100 psig and 610° F. A second run, at 750° F, was completed in May, 1963. These runs are the most complete and most carefully controlled experiments of this type which have ever been made. Until July, 1963, financial support for this project was provided by the A.E.C. from its budget for developing reactors both cooled and moderated by terphenyl; but this support was terminated when development of this type of reactor was drastically cut back. Future support for this work, although still supplied by the A.E.C., will come from the budget for heavy water reactors, because of interest in using terphenyl coolant in reactors moderated by heavy water. Such reactors are under active development in Canada, with development support by the U.S.A.E.C. M.I.T.'s next run will be at 750° F on a special low-melting mixture of terphenyl isomers proposed for the Canadian reactor.

With support from the A.E.C., Professor Simnad initiated two new research projects to investigate the effects of reactor radiation on materials. With Professor Herbert H. Uhlig of the Metallurgy Department, he began studies of the effect of radiation on the rate of oxidation of iron, zirconium, copper, and aluminum and on the rate of corrosion of iron and zirconium by water. With Professor Walter A. Backofen of the Metallurgy Department, Professor Simnad organized an investigation of the relationship between radiation-induced defects and embrittlement of metals. These two projects are both of considerable scientific interest and of great practical importance in connection with the behavior of materials in reactors.

During the past year the Nuclear Engineering Department took over responsibility for operating M.I.T.'s 3.5-Mev Rockefeller Van de Graaff Generator. With support from the National Science Foundation, Dr. Leon E. Beghian and Dr. Profio have been using bursts of monoenergetic neutrons of a few nanoseconds' duration to measure nonelastic cross sections and neutron transport properties of lead, bismuth, and other elements important in fast reactors. It is planned to extend this work with pulsed neutrons to subcritical fast assemblies containing U^{235}.

Dr. Profio is using pulsed neutrons from a 150-kev Cockcroft-Walton accelerator to measure neutron diffusion properties of heavy water and reactor physics properties of some of the heavy-water-moderated, partially-enriched uranium subcritical assemblies also studied by the Reactor Lattice Project.

With support from the U.S. Air Force, Professor Rasmussen and his students have developed techniques for determining trace quantities of light elements by neutron activation analysis in cases where the availability of the M.I.T. reactor with its relatively high flux is especially advantageous. Methods for detecting one part per million of boron or lithium in graphite or aluminum have been worked out, as well as a procedure for detecting microgram quantities of calcium in the presence of sodium. The latter is of particular interest to workers studying calcium in biological systems.

Use of the medical therapy facility of the M.I.T. reactor for neutron capture therapy of human patients has been suspended until basic studies of dosimetry and experimental irradiation of small animals have been completed. Professor Brownell has carried out a number of studies on radiation dosimetry of this facility. Gamma ray dose measurements have been made by means of glass rod dosimetry and more recently by means of a polyacrylamide viscometry dosimeter. Neutron spectra and resultant dose are determined by means of a neutron crystal spectrometer, threshold activation methods, and a solid state neutron spectrometer.

Professor Mason and his students are conducting a systematic study of the solvent-extraction characteristics of alkyl amines for separating fission products from uranium. This work is supported by the Oak Ridge National Laboratory, which perfected the use of these compounds for extracting uranium from its ores. At M.I.T., work on ruthenium and zirconium has been completed and investigation of niobium is getting under way.

With support from the A.E.C., Professor Manson Benedict and his students are completing an investigation of the rate of exchange of deuterium between water and dissolved hydrogen in the presence of diethyl amine, which acts as a homogeneous catalyst. If the exchange rate were rapid enough, this reaction might be used for low-cost production of heavy water. It has been found, however, that even at a pressure of 1000 psi and a temperature of 200° C, the rate is too slow for a practical process.

ENGINEERING ANALYSIS

Professor Elias P. Gyftopoulos and his students have been continuing their investigation of nuclear reactor dynamics. To this end, powerful new mathematical techniques have been introduced for the study of the boundedness and stability of nonlinear systems. These methods make possible the proof that many reactor types, whose stability could not be assessed analytically heretofore, are in fact stable.

Professors Henri Fenech, Benedict, and Mason are continuing their development of computational methods for analyzing nuclear fuel cycles and estimating the fuel-cycle component in the cost of nuclear power. A relatively simple reactor physics model which agrees well with experimental criticality data has been developed for the uranium-fueled spectral shift reactor. This is now being used to compare the fuel-cycle behavior of this reactor with that of a pressurized-water reactor, in a project with support from the A.E.C. The effects on fuel-cycle costs in a pressurized-water reactor of substitution of Zircaloy for stainless-steel cladding and of changes in uranium price scale, plutonium credit, interest charges on fuel investment, and fuel fabrication and reprocessing costs were investigated for the East Central Nuclear Group, Inc., in order to show how possible changes in future economic conditions might affect nuclear power costs.

Professor Fenech and his students are developing operations research techniques to optimize the design and operation of nuclear power systems. A dynamic programming procedure has been found to be effective in optimizing the management of nuclear fuel and control poison.

Under the direction of Professor Thompson, a group of twenty-five authors has been preparing for the A.E.C. an integrated review of the technology of nuclear reactors as related to reactor safety. The project, named SIFTOR (Safety Information for the Technology of Reactors), is intended to provide guidance for nuclear reactor designers, operators, and safety evaluation groups. A rough-draft manuscript has been prepared, with final publication of a thousand-page monograph scheduled for the summer of 1964.

Professors Kent F. Hansen, Fenech, and Mason are investigating certain engineering problems of a nuclear rocket engine, especially how best to shape the power-density distribution to obtain maximum thermal output and how to deal with transients during start-up.

Professor Gyftopoulos and his students are studying a number of aspects of the thermionic conversion of nuclear heat into electricity, with special application to space and submarine power plants. A parametric study has been made to establish the requirements, general characteristics, and principal problems of thermionic nuclear reactors for such applications. A powerful method has been developed for predicting the current-voltage characteristics of metal surfaces immersed in metal vapors as functions of temperature, crystal structure, and vapor pressure.

THERMONUCLEAR RESEARCH

Professors Rose, Thomas H. Dupree, and Lidsky are directing a comprehensive series of related investigations concerning the two major problems of a controlled thermonuclear power system: (1) stable confinement of a plasma at densities and temperatures high enough for thermonuclear reactions to proceed at a practical rate, and (2) development of economic means for injecting plasma into the reacting system and recovering in useful form the energy and neutrons produced in the thermonuclear fusion reaction. This work, administered by the Research Laboratory of Electronics, is supported by the National Science Foundation and the A.E.C.

To produce a plasma for convenient laboratory study, a hollow-cathode arc plasma generator has been developed which, although operating at a lower temperature, produces plasma displaying most of the properties of a higher-temperature plasma of thermonuclear interest. This generator has been used to study plasma diffusion rates, instabilities, and interactions with a moving magnetic field.

The practicability of an important new diagnostic tool for plasmas has been demonstrated with this type of plasma generator. This consists in measuring the Doppler shift in light scattered from an intense laser beam incident on the plasma, so that the velocity distribution of plasma particles and waves can be determined.

A new system for injecting and trapping charged particles in a magnetic mirror system, the so-called "corkscrew" injector, is being investigated theoretically and experimentally, and a facility for injecting electrons in this way is being constructed.

In collaboration with Professor Louis D. Smullin of the Electrical Engineering Department, a facility for heating a 30-liter volume of plasma to temperatures of 50 to 100 kev by electron-cyclotron resonance is being built. It is hoped that this high electron temperature will couple with the ions sufficiently well to obtain rapid ion heating.

The cryogenic, electrical, and magnetic problems of a large superconducting magnet such as will be needed for confining a thermonuclear plasma have been investigated by constructing a magnet with a field volume 20 cm in diameter and 145 cm long. Although difficulties have been experienced which prevented cooling this magnet to liquid helium temperatures, the experience has been invaluable in showing how a magnet of this type should be designed.

Professors Rose, Kaplan, and Rasmussen are conducting an experimental study and engineering analysis of the blanket which must be placed around a plasma in which deuterium and tritium are undergoing thermonuclear reactions, in order to recover the energy of 14-Mev neutrons produced in the plasma and regenerate tritium from the neutrons. A 50-energy-group, five-region neutron-diffusion computer code has been developed, with which it has been shown that a blanket of fused mixed lithium and beryllium fluorides, plus graphite moderator, should permit satisfactory energy recovery and tritium regeneration. Experimental work with 14-Mev neutrons from a Van de Graaff generator incident on this fused salt and graphite is under way to confirm these predictions.

These investigations of all phases of a thermonuclear fusion power system provide a good example of the combination of professional skills which are needed to develop a successful nuclear engineering device. The primary aim of the Nuclear Engineering Department is to give each student sufficient experience with advanced research and sufficient knowledge of the fundamentals of physics, mathematics, and engineering so that he can deal with the problems he will be faced with during his professional life, in whatever way nuclear technology may develop.

MANSON BENEDICT

Research Laboratory of Electronics

The Research Laboratory of Electronics is an interdepartmental laboratory conducting basic research in the broad fields of radio physics, plasma dynamics and communication sciences and engineering. The participation of students and faculty from eleven academic departments gives an interdisciplinary character to much of the research. There is, furthermore, a close relationship between this research and the academic program. This is evidenced by the large number of graduate and undergraduate subjects that have evolved from research in this Laboratory and by the fact that more than 1,600 thesis opportunities have been provided since the Laboratory was started. During the past year, twenty-eight doctoral, nine Engineer, thirty-three Master's, and eighty-seven Bachelor's theses were completed by students doing research in this Laboratory.

Personnel affiliated with the Research Laboratory of Electronics during the past year included 110 faculty members, 24 instructors, 16 research associates, 236 graduate students, and 98 undergraduates. A total of 21 visitors participated in research for various periods of time.

RADIO PHYSICS

The work in radio physics includes a variety of studies involving the interaction of particles and fields.

Among the technical highlights achieved this year were the radiometric measurements on the planet Venus obtained by Professor Alan H. Barrett. As an experimenter associated with the N.A.S.A. Venus probe, Professor Barrett obtained data from the vicinity of the planet through the space probe, and in collaboration with Lincoln Laboratory, similar measurements were made from the earth at the same time. Professor James W. Graham and other members of the radio astronomy group have completed the design and construction of the computer-controlled antenna mounted on the roof of the laboratory, and Dr. George Fiocco has completed the optical radar for probing the earth's atmosphere.

The work in microwave spectroscopy, under Professors Malcolm W. P. Strandberg and Robert L. Kyhl, has extended the study of electron paramagnetism in the solid state. The resonance line shape and the effect of the defect character of the paramagnetic ion in the spin-lattice relaxation were investigated. The emphasis of the group is now shifting to the study of metals.

The molecular beam studies being conducted by Professors Jerrold R. Zacharias, John G. King, and Campbell L. Searle have continued with high-precision masurements on atomic and molecular radio-frequency spectra. Improvements have been made in the design of atomic clocks, and more precise inter-comparisons are being made. In addition, these precision measurement techniques are being applied to a number of interesting research problems.

Professor K. Uno Ingard is examining relaxation phenomena in gases and solids, the interaction of sound and turbulence, and other aspects of physical acoustics. Work has also been done on instabilities in plasmas and liquid conductors and on wave propagation in plasmas.

Professors Herman A. Haus, Paul L. Penfield, and Robert P. Rafuse are investigating the noise properties of various electron devices including parametric amplifiers and microwave and optical masers.

During the past year Professor Bertram E. Warren joined the Laboratory with his work on X-ray diffraction, and Professor Clive H. Perry initiated a program on far infrared spectroscopy of solids. Professor Francis Bitter has been shifting his interests from nuclear magnetic resonance to the physics of space plasmas.

PLASMA DYNAMICS

The work in plasma dynamics ranges from basic physics to applications related to thermonuclear and magnetohydrodynamic power conversion, planetary atmospheres, electron tubes, and ion propulsion.

Professor Thomas H. Dupree has conducted theoretical studies of plasma kinetic theory and has calculated the electromagnetic radiation under a wide variety of conditions.

Professor Louis D. Smullin, Dr. George Fiocco, and Ernest Thompson, using an optical maser as a source, succeeded in observing the scattering of light by electrons. The effect was first obtained from the interaction of the light beam with a beam of electrons and later with a plasma. The technique promises to be very useful in plasma diagnostics.

The infrared interferometer, developed by Professor Sanborn C. Brown and his group, has proved to be highly important in plasma diagnostics.

Professor David R. Whitehouse and Paul Jameson have measured properties of electron heat waves in plasmas.

Professor David J. Rose and his group have assembled a sizeable magnet using superconducting materials for the coils which is expected to yield field intensities of 15,000 gauss in a volume six inches in diameter and four feet long. With a few watts input this magnet will be equivalent to a normal magnet with three-quarters of a megawatt of power.

Professor Smullin's continuing research on the beam plasma discharge has progressed to the point where nearly fully ionized plasmas with densities in excess of 10^{13} electrons/cc can be produced with an expenditure of only 10 to 20 joules of input energy. This is a new type of gaseous discharge which depends on the strong microwave oscillations that are induced by the passage of an electron beam through a plasma.

COMMUNICATION SCIENCES AND ENGINEERING

The research pertaining to various aspects of communication in living and man-made systems constitutes more than a third of the total activity in the Research Laboratory of Electronics. This portion of the laboratory is called the Center for Communication Sciences. The research includes work in linguistics, analysis and synthesis of speech and handwriting, auditory and visual perception, neuroelectric signals, sensory aids, statistical communication theory, processing and transmission of information, artificial intelligence, and computer studies.

Among the significant achievements of the past year is the development by Professor Amar G. Bose and his students of a nonlinear feedback system that has applications to regulation, control, amplification, and data recording. Analysis of this system has led to the construction of a very simple and efficient power amplifier and to the development of a d-c transformer.

Professor Jerome Y. Lettvin has evolved a theory of color vision and form perception. He has also succeeded in devising a simple electronic circuit that performs the color-matching function.

Professor Patrick D. Wall and his associates have obtained additional results from their studies of the coding of nerve signals in the skin as related to location on the body.

The Communications Biophysics Group, with Professors Walter A. Rosenblith and William M. Siebert, continues its efforts aimed at a better understanding of the communication senses, particularly hear-ing. A number of new faculty members, including Professors Thomas F. Weiss, Russell R. Pfeiffer, and Joseph L. Hall, will be active in the group next year. Professor Moise H. Goldstein, who has made contributions to the research on auditory systems, has accepted a position at the Johns Hopkins University.

Professor William T. Peake and Dr. Nelson Y.-S. Kiang have continued collaboration with the Eaton-Peabody Laboratory.

A major new program, designated Project MAC, was initiated at M.I.T. early in 1963 by the Advanced Research Projects Agency of the Department of Defense. It is aimed at the evolution of a computation system with multiple consoles to permit simultaneous access by a large number of users. The objectives of this Project include the design of new equipment, the evolution of related programming techniques, and the education of potential users. The Project, directed by Professor Robert M. Fano, has been established on an Institute-wide basis to encourage participation of faculty, students, and staff from all academic departments, laboratories, and centers. Visitors from other institutions will also participate.

In view of Professor Fano's new responsibilities, the activities of the group working on processing and transmission of information will be coordinated by Professor John M. Wozencraft. The sequential coding and decoding system designed by Professor Wozencraft in collaboration with Lincoln Laboratory has achieved high data-rate transmission over long telephone lines with very low error rates.

Professors Irving M. Jacobs, Robert G. Gallager, and Harry L. Van Trees, together with Professor Wozencraft, have examined modulation and coding techniques pertinent to space communication problems.

Professor William F. Schreiber and his students have made substantial progress in their studies of picture transmission.

Professor Samuel J. Mason's research on sensory aids includes experiments with a punched-tape-operated stenotype for tactile-kinesthetic transmission of information to a sightless subject, a servo-controlled optical probe which permits a subject to feel the edges or gradients in an optical image much as though he were tracing an embossed pattern with a stylus, an eye-movement detection system based upon skin-potential pick-up, and the use of thermal stimulation as a component in a sensory communication system involving two or more non-visual sense modalities.

During the past year Professor Kenneth N. Stevens has been on leave at the Royal Institute of Technology in Stockholm, where he has collaborated with Dr. Gunnar Fant. In his absence, Professors

John M. Heinz and Jack B. Dennis and Dr. Arthur House have continued the work in speech analysis and synthesis.

HENRY J. ZIMMERMANN

Solar Energy Research

The Godfrey L. Cabot Solar Research Fund continues to support research and study in the Departments of Architecture, Chemistry, Chemical Engineering, Civil Engineering, and Mechanical Engineering on the problems of converting the energy of the sun to the use of man by mechanical, electrical, or chemical means.

A number of fellowships were awarded during the year to graduate students whose research activities relate to the solar energy field.

GORDON S. BROWN

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE

IN RECENT YEARS I have collected reports from the individuals in charge of the various departments, sections, and centers of this school and have effected a rough consolidation in my own words. This has had the merit of providing a cohesive report and the demerit that it may have unduly reflected my personal views and emphases. From time to time, at least, a different procedure should be followed. So, after a few preliminary remarks and some highlighting, I shall let the individuals speak for themselves.

STUDENT TASTES IN ELECTIVES

For some years I have been able to report a steady increase in undergraduate enrollments in subjects taught in this School. This year we seem to have reached at least a temporary stability. The figures for 1962-63 are reported in Table I. If we compare this table with the corresponding one in last year's report, we can see that, while the overall total is essentially unchanged, there are eddy currents. Minor increases were registered in history, literature, and the totality of humanities electives and minor decreases in music and philosophy. An increase of about 3 per cent was recorded in the totality of registrations in social science, and this included large increases in psychology (28 per cent) and in political science (24 per cent) combined

School of Humanities and Social Science

Table I. Registration in Humanities, Languages, and Social Science Undergraduate Subjects, 1962-63

		Fall term		*Spring term*
Freshman core		908		880
Sophomore core		840[1]		832[1]
History	115		169	
Philosophy	323		251	
Literature	307		383	
Music	152		221	
Total humanities electives		897		1,024
Economics	613[2]		571[2]	
Political science	237		271	
Labor relations	66		78	
Psychology	297		414	
Total social science electives		1,213		1,334
Modern languages[3]		110[4]		84[4]
Visual arts[5]		76		59
Thesis		11		52
Total		4,055		4,265
Public speaking		6		8
English composition		15		8
Humanities Senior Seminar for Course XXI students		41		37
Science writing		7		7
Elementary and intermediate modern language		536		328
Grand total		4,660		4,653

[1] Includes registration in the special social science core: 173 in fall term, 178 in spring term.
[2] Includes registration in Economic Principles I (14.01) (322 in fall term, 263 in spring term) and other subjects (291 in fall term, 308 in spring term).
[3] Exclusive of 864 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. Percentage Distribution of Undergraduate Electives in Humanities, Languages, and Social Science, by Fields, 1957-58 to 1962-63*

*Omitting registrations in the underclass required core subjects 21.01, 21.02, 21.03, 21.04 (or 14.003, 14.004), and the partially required subject in Economic principles I (14.01).

	1962-63[1]	*1961-62*	*1960-61*	*1959-60*	*1958-59*	*1957-58*
Psychology	16.6 (14.6)	13.5	13.2	15.0	13.9	14.1
Literature	16.1 (14.2)	15.7	18.6	20.2	18.1	19.8
Economics	14.0 (24.4)	15.0	12.4	12.5	12.7	11.2
Philosophy	13.4 (11.8)	15.0	15.9	12.8	11.6	11.5
Political science	11.9 (10.4)	9.9	11.1	9.5	9.8	10.9
Music	8.7 (7.7)	9.2	7.8	8.3	8.9	9.7
History	6.7 (5.8)	6.5	7.0	8.4	10.5	11.1
Modern languages[2]	4.5 (4.0)	7.9	5.5	5.1	3.9	3.2
Labor relations	3.4 (3.0)	3.7	4.0	4.2	5.0	4.3
Visual arts[3]	3.2 (2.8)	3.6	4.6	4.0	5.6	4.3
Thesis	1.5 (1.3)	0.0	0.0	0.0	0.0	0.0

[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.

with a substantial decrease in economics (13 per cent) and a continuation of the gradual downward trend in labor relations. Economics continued to have the largest registration among our electives and was followed this year by psychology, literature, philosophy, political science, music, history, modern languages (upperclass electives only), labor relations, and visual arts, in that order. A large and puzzling decline (40 per cent) was recorded in the upperclass electives in modern languages, and this was paralleled by a substantial decline in the registration in elementary and intermediate modern languages (14 per cent) which may be reflected later in upperclass registrations in foreign literature.

As I have suggested before, we do encounter unforeseeable, inexplicable, and occasionally violent swings in student fashion and taste, so that most of these changes viewed from the perspective of a single year should not justify much discussion. But the substantial increases in political science and psychology merit applause, and the large decrease in modern languages should be looked into.

Another way of comparing the registrations is offered in Table II (this has been Table IV in previous reports). This gives the distribution in percentages by subjects over the past six years. I am unable to read any very interesting trends in this table, although I can wish that our excellent program in the visual arts could manage to attract at least as many students as, for example, our work in music does, and I wish more of our students were establishing a solid competence in at least one modern language.

Tables I and II each contain a specific reference to the first subject in economics (Economic Principles I), and Table II in fact contains percentages calculated with this subject included and excluded. There are historical reasons for this. Years ago many departments of the Institute, especially those outside the School of Science, included Economic Principles I as a departmental requirement for graduation. This meant that this subject was not a free elective for many students; so it was not quite fair to compare the registrations in economics with those in the other subjects, although we could never know how many students would have elected economics even if it had not been required.

It is understandable that economics should be a required subject for students who major in economics itself or in industrial management. It is harder to see why it should be considered an indispensable subject for engineers and architects where other social sciences are thought not to be, and this is particularly puzzling in architecture where social problems weigh quite as heavily as the kind of economic problems we deal with in Economic Principles I. Be that as it may, it is good to report that there has been gradual relaxation of the requirement over the years. Today this first subject in economics is required by the Schools of Architecture and Industrial Management, by three departments in the School of Engineering (i.e., Aeronautics and Astronautics, Civil Engineering, and Naval Architecture and Marine Engineering), and, of course, by our Economics Department. All together, based on the undergraduate registrations in these schools and departments, I estimate that there may be 160 required registrations in a given year out of a total this year of 1,184. The Department of Electrical Engineering does not require Economic Principles I but recommends it. Even if every student in electrical engineering took this recommendation to be mandatory, still only about 350 registrations in economics in a year would be required for this. Thus it is almost certain that economics has the largest number of free elections of any field. Consequently, I shall probably stop drawing this distinction next year.

It is of some interest and perhaps of some significance to see whether there is any correlation between the school in which a student is registered and the field in which he has elected his humanities or social science subjects. We used to have to guess at this, though we had some intuitions which the numbers now seem to justify. Now the machines make a count possible, and I find the results interesting. They are not as rigorous as I should like, because the elementary subjects in each field are elected by many students who have not chosen a major. These, listed as "unclassified" in Table v and omitted from Table iv, are numerous enough to make the school distributions shaky, especially in economics, psychology, and literature. Nonetheless, I think some generalizations are fairly obvious from the figures of the tables which show the number of registrants in each field for each school. I refrain from editorial comment save to remark that if I were responsible for advising undergraduates in any one of our schools except the School of Science, I should have some concern as to the distribution of my students' interest. It would be a different concern depending on the school. For the School of Humanities I am distressed that so few of our students seem to be interested in studying art and that not enough are establishing a solid grounding in one contemporary language. I myself think they should be required to have this competence for their first degree, but such is not our rule or indeed the apparent wish of the faculty.

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

*As registered in the second term of each academic year 1956-57 to 1962-63 (omitting freshmen)

	UNDERGRADUATES			GRADUATES				
	Social Science	*Human-ities*	*Total*	*Social Science*	*Human-ities*	*Modern Languages*	*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
1962-63[5]	65	85	150	145	—	22	167	317

[1] Course XXI initiated.
[2] Graduate degree in political science initiated.
[3] Special program in teacher training.
[4] Graduate degree in linguistics initiated.
[5] Graduate degree in psychology initiated.

Table IV. Distribution of Registrants in Undergraduate Electives by Broad Fields and by Schools in so far as They Can be Identified 1962-1963

	Humanities	*Social sciences*	*Music and art*	*Foreign literature and linguistics*
Architecture	45(30%)	51(34%)	51(34%)[1]	1(1%)
Engineering	419(24%)	1066(62%)	181(10%)	57(3%)
Humanities and Social Science[2]	299(45%)	313(47%)	25(4%)	32(4%)
Industrial Management	52(18%)	214(75%)	15(5%)	3(1%)
Science	590(41%)	556(40%)	190(13%)	88(6%)

[1] Of which all but 4 are in art and therefore at least sub-professional.

[2] The numbers for this School of course reflect the registrations of our majors. They have a heavy commitment to science subjects, too, which does not show here, but the small apparent interest in the arts and in language is nonetheless lamentable. It is interesting to compare these figures (and unfavorably) with those for the Schools of Science and of Engineeiing.

Table V. Distribution of Registrants in Undergraduate Electives by Schools and Fields (by Numbers) 1962-1963

School	*History*	*Literature*	*Music*	*Philosophy*	*Economics*	*Labor Relations*	*Political Science*	*Psychology*	*Visual Arts*	*Linguistics and Foreign Literature*
Architecture	11	21	2	13	27	—	4	20	49	1
Engineering	101	163	145	155	537	92	187	250	36	57
Humanities and Social Science	51	120	20	128	109	13	135	56	5	32
Industrial Management	10	32	10	10	64	26	68	56	5	3
Science	99	244	157	247	223	12	101	220	33	88
Unclassified	12	110	39	21	224	1	13	109	7	13
Total	284	690	373	574	1184	144	508	711	135	194

GROWTH OF THE SCHOOL

Although, as I indicated earlier, our undergraduate elective registrations were about the same as a year ago, in other respects the School continues to grow at a comfortable rate. This is shown in Table III, which lists the numbers of students majoring with us over the last eight years. It will be noticed that since 1955-56 our undergraduate majors have increased by over 150 per cent and our graduate students (practically all candidates for the Ph.D.) by 221 per cent. At the June Commencement we graduated our largest senior class (fifty-six, of which twenty-three were in social science and thirty-three in humanities). The scale and quality of our graduate operations is by now generally known and appreciated in sophisticated academic circles. Word about the undergraduate majors continues to be relayed but slowly. Few would realize, for example, that we have 40 per cent more undergraduate majors than the School of Architecture and Planning and are running a dead heat with the School of Industrial Management. On a departmental basis, the sixty-five majors in the Economics Department exceed the number of undergraduates in three departments of the School of Engineering and one in the School of Science; while the eighty-five in Humanities are more than those in three departments in Engineering and two in Science. Obviously this is still a very small portion of all undergraduates and obviously, too, we are not interested in a numbers race, and I cite these figures not to boast but to indicate that the programs have succeeded in attracting enough students. I should at once add that they are very good students.

THE DEPARTMENTAL REPORTS

The School has in general three responsibilities. Its largest is academic, comprising research coupled with graduate and undergraduate instruction. This is managed by three departments. The Department of Economics and Social Science is broken down into four sections—Economics, Industrial Relations, Political Science, and Psychology. The Department of Humanities also has sections corresponding to its fields—History, Literature, Music, and Philosophy—and a group which directs the undergraduate major program known as Course XXI. The Department of Modern Languages carries on work in elementary and intermediate foreign languages; in French, German, Italian, and Russian literature; and in linguistics, but it is not sectioned. The reports of these academic department and sections are incorporated here in the order listed above, which is alphabetical and unrelated to history or comparative size.

In addition to the research which individuals conduct under usual departmental arrangements, the School houses a large research group, the Center for International Studies, now entering its second decade of distinguished productivity. The report of the Center, which is administratively independent of the departments, follows the departmental reports.

Finally, there are non-academic activities of considerable scope in exhibitions, music, and theater which are also under the aegis of the School, and the reports of the several directors follow the report of the Center for International Studies.

JOHN E. BURCHARD

Department of Economics and Social Science

As a reflection of the variegated character of this Department, its report is broken down into those of its several constituent sections, representing the essentially separate and distinct areas of Economics, Political Science, and Psychology. In addition, a relatively brief separate report is also included for the Industrial Relations Section; for even though this unit in many respects is merely a part of the economics wing of the Department, it also has certain distinctive functions and characteristics—such as its overlapping membership with the School of Industrial Management and a special cohesiveness of the research and educational activities of its members, including the operation of its own separate elective field within the Institute's general program of undergraduate electives in the humanities and social sciences.

In view of the considerable recent expansion of personnel and the rounding out of the educational and research programs of the newer Political Science and Psychology Sections, particularly at the graduate level, increasingly serious consideration is being given within the Department to the desirability of recommending that either or both of those units be reconstituted as separate departments. It is appropriate, therefore, to take this opportunity to sketch at least briefly the background of this question.

Only a relatively few years ago, the fields of political science and psychology had merely the limited role of serving as electives in the Institute's program of general education for undergraduates. As a consequence, the staffs in these areas were small, and the subjects offered went little beyond the elementary level. Even before World War II, however, the critical decision had been made to encourage the expansion of economics beyond that level. In time that decision led to the development of a graduate program that has become one of the most distinguished in the world and to a greatly enriched content of economics instruction at the undergraduate level; the latter provided many electives available to all students and the distinctive program of a "double major" combining study in economics with some field of science or engineering. This experience with economics emphasized that excellence in education and the maintenance of a faculty of high quality require the fullest scope for the most advanced education and research to proceed side-by-side with undergraduate programs—a fact as true of the social as of the physical sciences. Not just in imitation of economics but more as an expression of the same underlying principles, the fields of political science and psychology have subsequently been launched on similar developments. Further detail is provided as to the states of progress in these other areas below, by Professors Lucian W. Pye and Hans-Lukas Teuber, the Chairmen of their respective Sections.

Naturally, the size of the Department and the physical location of its several sections also bear importantly on the question of a possible change of departmental structure. As we move into the new academic year of 1963-64, the faculty ranks alone include twenty-five full professors, ten associate professors, and eleven assistant professors; these forty-six faculty members divide into twenty-three economists, fourteen political scientists, and nine psychologists. Clearly, complements of personnel such as these rival in sheer size the corresponding ones in all but the very largest of general universities; so, from that standpoint, there is at least a *prima facie* case for organizing these fields as separate departments.

As to location, the Psychology Section is now comfortably established in its own building, appropriately located about midway between the Sloan Building and those that house other related disciplines such as biology, linguistics, and other communication sciences. The Political Science Section is at present at a considerable physical distance from the Economics Section, but this will change upon completion of the recently authorized new structure behind the Sloan Building. This contemplated move reflects in part the fact that the Economics and Political Science Sections have a closer relationship (largely through their common connection with the Center for International Studies) than either has with the Psychology Section.

Other changes, involving the undergraduate majors within the Department, are also being intensively discussed. At present, undergraduates in the Course in Economics, Politics, and Engineering or

Science (Course XIV) have the choice of specializing in economics or political science but not psychology. This reflects, of course, only the past inadequacy of staff for manning such a program in psychology, in addition to the general education subjects; for that field has long been recognized as a relevant and potentially popular one for undergraduate specialization. Now, however, we feel that the time has come when that defect can be remedied.

At the same time, we also feel there should be some mild changes of substance and some major changes of nomenclature as to the Course XIV options. At present, XIV-A carries the label of Economics, Politics, and Engineering, while XIV-B refers to Economics, Politics, and Science. For one thing, this is seriously misleading in that our majors do not specialize in both economics and political science, but rather in only one of those social sciences—in addition to their co-specialization in a field of science or engineering. For another, the addition of the psychology option would put an impossible strain on this awkward terminology.

Accordingly, we intend to propose that the three options within Course XIV (or in the separate departments if that change also takes place) be designated simply as Economics, Political Science, and Psychology. This would imply that the science or engineering content of the students' programs be taken for granted as an implication of their four years at M.I.T., without any express designation of whether their emphasis outside the department was in engineering or science.

On the substantive side, furthermore, we also propose to recommend that the currently required minimum number of subject units in science or engineering in the third and fourth years be reduced somewhat in favor of a greater amount of free electives. This would mean that a student could continue to take the same "double major" that is currently specified, if he so chose; but it would also leave him with the choice of reducing somewhat his units of science or engineering in favor of either a fuller specialization in his elected field of social science or a broader content of general education.

To some extent, this implies a modification of the former principle of the double major. This reflects our own conviction, which we hope we can justify to the administration and faculty, that a "single major" in economics, political science, or psychology now makes sense at M.I.T. On the other hand, the proposal does not imply in the slightest a desire to dissociate the study of social science here from the Institute's main strengths in science and technology; for it is precisely because of the interdisciplinary links of the M.I.T. environment that the social sciences have been able to achieve distinction here. Though sadly less appreciated at the undergraduate level than at the graduate, the M.I.T. spirit of rigorous inquiry and the mathematical and scientific background that is available here make the opportunities for rewarding study and research in the social and behavioral sciences unprecedentedly attractive.

In connection with these proposed changes in Course XIV, it is gratifying to be able to report a continued increase in the number of majors in the Department. From an average of only about forty students in the period 1955-61, there was an increase to fifty-five in 1961-62 and a further increase to sixty-five in 1962-63. While these increases are small in absolute terms and still leave us below the level that we should like to attain, the trend and the rates of expansion are encouraging.

Similarly, there has been a continued increase in the total undergraduate enrollment in subjects offered by the Department. In terms of aggregate semester registration, both fall and spring, in undergraduate subjects in economics, labor relations, political science, and psychology, the totals have moved upward from 2,323 in 1960-61 to 2,480 in 1961-62 and then to 2,547 in the year just completed. Since the numbers of our own undergraduate Course XIV majors remain small, the bulk of this registration comes from other students at the Institute who are satisfying (or more than satisfying) their junior and senior requirements in the humanities or social sciences. Furthermore, since the total registration in that category is 4,797 (as compared with 4,858 the year before), registration in the four social-science fields now stands at 53.1 per cent of that total, as compared with 51.0 per cent the year before.

This increase for the Department as a whole also involves some significant shifts among the subtotals. In particular, the registration in economics is down appreciably from 1,363 to 1,184, while more-than-offsetting increases have been recorded in political science (from 409 to 508) and psychology (from 555 to 711). In part, the decrease in economics may be transitory, because there was an abnormally large increase in that area the year before; but the change undoubtedly also reflects the removal by a number of the larger engineering departments of their requirement of at least one semester of economics. The first-semester economics subject, Economic Principles I (14.01), is now a requirement in only three engineering departments, representing in the aggregate less than 10 per cent of the undergraduate student body. Even apart from the students in those three departments, this subject continues to be elected by appreciably more than half of all undergraduates; and the field of economics as a whole continues to draw a significantly greater total enrollment than any other among the junior and senior humanities and social science electives. This year, for the first time, psychology has moved into second place among those fields, from fourth the year before. Political science remains in fifth place, behind literature and philosophy.

Following this review of matters of general departmental interest, we may now turn to the reports of the various constituent sections.

ROBERT L. BISHOP

ECONOMICS SECTION

In this, the most settled and matured portion of the department, there are fewer elements of novelty to report than in the others.

THE UNDERGRADUATE PROGRAM

The economics part of the undergraduate major in Course XIV shared about equally with the political science part in the growth in numbers of students mentioned above. Curricular changes in this area have been minor. Perhaps the most important over the past several years has been the organization and development of a thesis seminar for the economics seniors, conducted initially by a single faculty member but jointly led this past year by Associate Professor Richard S. Eckaus and Assistant Professor Robert Evans, Jr. The function of this seminar is, first of all, to give guidance to the senior-thesis writers in the selection of topics and in the methods of approach to their tasks, which is all the more important in an area such as economics where there is often a frustrating gap between data ideally desired and data practically available. Secondly, the members of the seminar, through progress reports presented to one another and to faculty critics, including members of the staff who attend only when a topic in their own field is being discussed, improve the quality of their theses and deepen their own interest in their projects.

A student-faculty committee has also been organized for the exchange of views on matters of common interest, both professional and otherwise. This venture is a promising one, but there also remains considerable scope for expanding its usefulness.

In economics as a field of the humanities and social science electives, the only changes made have been in the operation or content of certain individual subjects. In the introductory subject, 14.01, the experiment of offering two lectures plus one discussion meeting per week, launched several years ago, continues on essentially the same limited basis; and results have been such that we now plan to continue this indefinitely, side by side with other sections of the subject that will continue to be offered in the traditional form of three discussion meetings. Partly because of the desirability of scheduling 14.01 at a wide variety of hours but mainly to meet the contrasting preferences of different students, it seems wise to leave them with a choice between the two modes of presentation.

There is also a movement in both semesters of elementary economics toward term papers as a means of involving the individual student rather more personally in some aspect of the subject. This device lends itself better to the second-semester subject, 14.02, where it is becoming a standard feature for all students; but it is also being tried as a voluntary project, for the best-qualified students only, in 14.01.

During the spring semester just past, two seminars—one in game theory, one in labor relations—were offered within the Department as part of the Institute-wide program of seminars for freshmen. The total enrollment in these seminars was greater than in any other departments except electrical engineering and physics.

THE GRADUATE PROGRAM

The Ph.D. program in economics continues to thrive and to draw a gratifying quantity and quality of applicants with a broad national and international distribution. Topping slightly the count during the past several years, nineteen of the seventy-eight seniors in economics in the U. S. who were awarded National Woodrow Wilson Fellowships chose our Department as the one in which they preferred to do their graduate study. The fact that we reached almost 25 per cent of the national total might even have had some embarrassing implications, except that the number who will actually attend M.I.T. next fall will be rather less, both because we did not accept all of the fellowship winners who wanted to come and because a few (regrettably including some of the very highest quality) were subsequently lured away to other institutions which offered them more generous fellowships. Also, a continuation of the last few years' pattern of alternating first and second place in this competition with a friendly neighboring institution, this year we were only second—but only by a very slight margin and with the third-place economics department once again a good distance behind.

Despite the fact that our graduate admissions applications again reached a new all time-high (over 250), we are not contemplating any increase in the number of new graduate students in economics above the current level of between twenty-five and thirty. At the same time, however, because attrition rates have declined as the quality of students has gone up, we were forced to ask for a modest increase in our graduate-student quota. On a head-count basis, following the granting of the request, that quota now stands at 94, including those third- and fourth-year students who are registered only part-time in conjunction with their staff status as teaching or research assistants.

For all the health and strength of the Ph.D. program in economics, there remain some problems. One of the most pressing concerns the continued provision of sufficient fellowship aid, especially to second-year students, in a period when costs have risen and our former backlog of funds for departmental fellowships has greatly declined. The problem is acute in the second year because the Woodrow Wilson Fellowships cover the first year only and because assistantships as well as outside dissertation fellowships become available in the third year; the situation in economics differs from that in many fields of science and engineering in that teaching or research assistantships are not suitably available to our graduate students in their first two years.

RESEARCH AND PERSONNEL

As always, there has been an abundant outpouring of research product from the economics faculty in a form ranging from journal notes and articles to books. Among the more ambitious such publications are the following books: *The Supply and Price of Natural Gas,* by Professor Morris A. Adelman; *Introduction to Statistical Inference,* by Professor Harold A. Freeman; and *Foreign Trade and the National Economy,* by Professor Charles P. Kindleberger, who also brought out a third edition of his widely used text, *International Economics.*

In addition to research activity on an individual basis, which is typical, a growing number of projects are occupying two or more faculty members. Professor E. Cary Brown, under the sponsorship of the Brookings Institution and with the collaboration of Assistant Professor Albert K. Ando and a group of advanced graduate students, is completing a major study of countercyclical fiscal policy, with special emphasis on automatic stabilizers. In much the same area is the already completed study for the Commission on Money and Credit on lags in fiscal and monetary policy by Professors Robert M. Solow, Brown, and Ando and Dr. John H. Kareken (the latter of the University of Minnesota and a graduate alumnus of our Department). Participating members in the project of the Social Science Research Council on a quarterly econometric model of the U.S. economy include Professor Edwin Kuh (School of Industrial Management), Associate Professor Franklin M. Fisher, and Professor Brown.

Similarly, Associate Professors Eckaus and Louis Lefeber are collaborating on two projects, a pilot planning model for India and the application of models of capital theory and resource allocation to the U.S. economy. Under the sponsorship of Resources for the Future, Inc., though being prepared separately, are the major study by Professor Adelman on the world petroleum market from 1945-63 and some studies by Professor Fisher on supply and costs in the U.S. petroleum industry. As a final example, Professors Fisher, Kuh, and Solow are joining with three colleagues from Yale in the early stages of a project for a long-term growth model of the U.S. economy.

Professor Evsey D. Domar, who spent the year on leave at the Center for Advanced Study in the Behavioral Sciences at Stanford, is also working on the topic of economic growth, including an analysis of comparative growth patterns in several countries. The growth theme is also accented in Professor Everett E. Hagen's research, both completed and in progress, including an article on "How Economic Growth Begins" in the *Journal of Social Issues* and in an article by Professor Eckaus on "Education and Economic Growth" in *Economics of Higher Education,* published by the U.S. Department of Health, Education and Welfare. After publishing papers (among others) this year on "Foreign Trade and Growth," "Protected Markets and Economic Growth," "The Postwar Resurgence of the French Economy," Professor Kindleberger is now turning his attention to the effects of changes in income distribution in Western Europe on economic growth and the balances of payments.

An article on "Education for Innovation" has been published by Professor Max F. Millikan in a volume entitled *Restless Nations.* Professor Paul N. Rosenstein-Rodan, besides writing the preface to *Volume 1957 of the European Fuel and Energy Problem,* gave a paper to the United Nations Science Conference on "Determining the Need for and Planning the Use of External Resources." As a part of his usual copious output, Professor Paul A. Samuelson gave this year's Wicksell Lectures in Sweden on "Stability and Growth in the American Economy" and an address to the American Bankers' Association on "Fiscal and Financial Policies for Growth."

Department of Economics and Social Science

There were no resignations or new regular appointments in the Economics Section during 1962-63, but a number of visiting professors were with us during the year, in part as replacements for faculty on leave. Professor Albin W. Phillips of the London School of Economics gave a seminar in each term on selected advanced topics in econometrics. His appointment was made possible by a Ford Foundation grant for the support of advanced graduate-student research. George D. N. Worswick from Magdalen College, Oxford, was with us as Visiting Professor, replacing Professor Adelman who was on leave to pursue his research in Paris. As a part-time Visiting Professor, Dr. Franklin D. Holzman of Tufts University handled the undergraduate subjects normally taught by Professor Domar. Finally Dr. Edmund S. Phelps of Yale University served as a Visiting Associate Professor as a replacement for Professor Fisher who spent his year of leave conducting research in the Netherlands.

ROBERT L. BISHOP

INDUSTRIAL RELATIONS SECTION

The Industrial Relations Section has completed its twenty-sixth year at M.I.T., and its staff members continue the variety of research, teaching, and community activities which have made the Section one of the outstanding centers in this field in the United States. (This brief report does not include the activities of Section members from the School of Industrial Management.)

Work on the Inter-University Study of Labor Problems in Economic Development, in which M.I.T. joins with Harvard, University of California (Berkeley) and Princeton, continued during the past year with completion of a revised edition of *Industrialism and Industrial Man,* by Professor Charles A. Myers and co-authors from the other universities. Associate Professor Abraham J. Siegel assisted in this revision, which will be published by Oxford University Press next fall. Professor Myers was on leave during the academic year as a Fellow at the Center for Advanced Study in the Behavioral Sciences at Stanford, where he completed a new book with Professor Frederick H. Harbison of Princeton as a part of the Inter-University Study. This will be published by McGraw-Hill in the fall under the title *Education, Manpower, and Economic Growth: Strategies of Human Resource Development.* This book grows out of several years of study in a number of countries and includes a statistical analysis of human resource indicators in seventy-five countries at different stages of development. Work is also nearly completed on a series of country studies in ten Asian, African, and Latin American countries, and this second book will be published early next year.

Professor Siegel was Acting Director of the Section during Professor Myers' absence. Dr. Solomon B. Levine of the University of Illinois served as Visiting Professor and during the year completed several articles and monographs on white-collar unions, labor markets, and wage relationships in Japan. Professor Siegel gave a paper on "The Public Interest in National Labor Policy" at the annual conference on industrial relations at Michigan State University; this was subsequently published in their proceedings, *The Proper Climate for Labor Relations.* His paper on "Method and Substance in Theorizing About Worker Protest" was published as a chapter in *Aspects of Labor Economics,* a report of the National Bureau Committee for Economic Research. Professor Siegel also completed a study on the economic recovery of Nashua, New Hampshire, for the Area Redevelopment Administration of the U.S. Department of Commerce.

Professor Paul Pigors has continued to develop and refine the "incident process" which he introduced several years ago as a variation of the case method in human relations. This is widely used in executive development programs throughout the United States and abroad. Professor Pigors was elected a Fellow of the American Management Association and is in the process of completing a survey of management policies for that Association.

Professor Evans had a study on the "Economics of American Negro Slavery, 1830-60" in the volume, *Aspects of Labor Economics,* and a short study on "Wage Differentials, Excess Demand for Labor, and Inflation" in the *Review of Economics and Statistics.* He completed a study of "Industrial Location: A Model and Some Empirical Tests" for the Area Redevelopment Administration and has prepared two other manuscripts for publication in journals, one of which is entitled "The Case for Structural Unemployment." The studies by Professors Siegel and Evans on labor markets are the latest in a long line of research studies on the economics of the labor market for which the Industrial Relations Section is widely known.

The labor relations sequence in the humanities and social science undergraduate elective program continues at about the same level, but we have added a new and very popular advanced undergraduate seminar in labor economics and labor relations in which Professor Douglass V. Brown of the School of Industrial Management joined with Professors Siegel and Evans. The graduate research seminar in industrial relations, which was started in 1948, continues with unabated vigor, but some of the other graduate seminars are drawing currently as many doctoral students from the School of Industrial Management as they are from the Department of Economics. Indeed, thesis supervision and the teaching loads generally are about equally divided between students from the School of Industrial Management and the Department of Economics. This reflects the inter-school character of the Section's interests.

Several community and professional activities deserve mention. Professor Pigors spoke at a number of conferences throughout the year as did Professor Siegel. The Section was host in the spring to the annual workshop run jointly with the Personnel Managers' Club of the Greater Boston Chamber of Commerce, and a Scanlon Plan Conference is planned for next fall under the direction of Frederick Q. Lesieur. Finally, Professor Myers completed his year as fifteenth President of the Industrial Relations Research Association with a presidential address entitled "The American System of Industrial Relations: It is Exportable?" This was published in the Annual Proceedings of the Industrial Relations Research Association in May.

CHARLES A. MYERS

POLITICAL SCIENCE SECTION

The Political Science Section at M.I.T. is still guided by a spirit of experimentation and innovation. Some features of its work have achieved a high point of maturity while others are still in a period of formation. The graduate teaching program concentrates on seven fields, and during the last year the most conspicuous development occurred in two of these—defense studies and the relationship of science to government. The more established fields of communications study, political development, international relations, and comparative politics showed healthy signs of further development. The overall pattern of growth was one of bringing all fields into balance.

Although our program strives to preserve many unique and distinctive features which set it apart from customary departments of political science, we are increasingly being accepted as one of the leading training centers in the discipline. Our emphasis upon general social science methodology and the more behavioral approaches, our disregard for conventional disciplinary boundaries, and our search for quantitative measurements, which once represented pioneering gambles, are now being widely acknowledged as the pattern of the future.

It is, of course, difficult to determine the precise position a training program occupies on the national educational scene. The judgment of incoming graduate students about our program may be usefully measured by the fact that we ranked among the top few long-established graduate schools in the number of Woodrow Wilson Fellowship winners. Professional judgment of the M.I.T. political science program is to be found in the numbers of our faculty who have been engaged in national and international scholarly activities and who have been elected to distinguished positions in scholarly associations. Our faculty members have served during the year on the governing bodies of the American Political Science Association, the Association for Asian Studies, and the American Association of Public Opinion Research, on select committees of the Social Science Research Council, and on the Board of Editors of *International Organization,* the leading professional journal in the field of world organization affairs.

THE GRADUATE PROGRAM

An outstanding characteristic of the M.I.T. political science program has been a close relationship between graduate instruction and professional research. Our teaching program emerged largely from the research enterprises of the Center for International Studies, and the frontiers of research have tended to remain the dominating influence on our educational program. It is therefore appropriate in reporting on the graduate program to refer to the research activities of the faculty members.

Possibly the greatest advances of the year were in the field of defense studies under the leadership of Professor William W. Kaufmann and with the assistance of Colonel Melvin Nielsen and Dr. Arthur C. Herrington. A sequence of subjects has now been established in this field which provides systematic training for students interested in systems analysis as applied to advanced problems of national security. On the basis of this program of study, the Political Science Section was granted a number of graduate fellowships under the National Defense Education Act. It is expected that the existence of these fellowships will help to attract additional students interested in highly professional training in the increasingly technical field of defense studies. Professor Kaufmann is personally engaged in a study of the strategic concepts which have shaped the changes in United States military policy in the last two years.

A second field of significant development has been that of science and government. It is expected that our program in this field will be greatly stimulated by the association of the Political Science Section with the new M.I.T. Center for Space Research. Professor Robert C. Wood was appointed to the Technical Committee of the Center, and he has initiated a research program on the social and political dimensions of the national space effort which involves the work of several of our graduate students. Our teaching and research efforts in science and government were also significantly strengthened when Eugene B. Skolnikoff resigned from the staff of the President's Scientific Adviser to join the Section as a Research Associate.

As a result of the accomplishments of the year, we were able to come closer to our long-range goal of establishing some intellectual and operational bridges between the social and physical sciences at M.I.T. Closer faculty association has been matched by similar student interest, and during the year we initiated the first joint degree program for a student interested in combining political science with civil engineering.

The M.I.T. graduate program in political science grew out of an earlier research program in communications, and a majority of our students continue to participate in work in this field. During the last year there was a renewed surge of interest as a result of several large-scale research programs of faculty members. Associate Professor Frederick W. Frey has been conducting the first national sample survey of attitudes of villagers in an underdeveloped country in a project in Turkey. Professor Daniel Lerner has initiated a new study of elite communication in Venezuela, and the Section's work in both communications research and Latin American studies was greatly strengthened through the appointment of Dr. Frank Bonilla as Associate Professor of Political Science. Professor Ithiel de Sola Pool has begun a new research program of communications in Communist countries which has involved many of our graduate students. During the year Harold R. Isaacs was on leave for purposes of research into the images of youth in transitional societies, which will take him around the world.

Traditionally the fields of political development and comparative politics have been uniquely strong in both the Political Science Section and the Center for International Studies. We continue with vigorous programs in these fields, and the character and calibre of student work in these fields are attested to by the fact that ten of our students are presently engaged in overseas research. These students are widely distributed, according to their own interests, in Nigeria, Ivory Coast, Iran, Thailand, the Philippines, Finland, and France.

The field of political and economic development has served as a bridge to the economics side of the Department, and as in past years we have continued to have students interested in joint degrees in political science and economics. The ability of the Department to arrange such joint degrees is, indeed, one of the unique features of graduate work in political science at M.I.T.

With respect to research in the fields of development and comparative politics, the overseas work of several of the faculty has already been noted. In addition, Associate Professor Myron Weiner has been working on a study of the creation of political organizations in five different districts of India. Assistant Professor Leonard J. Fein is engaged in a study of the dynamics of Israeli politics. Professor Pye is working on a study of comparative political cultures and a theory of political development.

Our oldest teaching program at M.I.T. is in international relations, and this field continues to be the most completely organized at the undergraduate level. Graduate work in international relations has been stimulated during the year by Professor Norman J. Padelford's extensive study of United Nations financing, which has involved the use of the 7090 computer in the M.I.T. Computation Center. The research work of Associate Professor Lincoln P. Bloomfield (promoted to Professor effective July 1, 1963) in the areas of arms control and disarmament and his novel uses of political gaming exercises have provoked considerable student interest. Assistant Professor John S. Saloma, III, has been engaged in a study of the role of Congress in foreign affairs.

In summarizing the year's development in the graduate program, we can say that we have moved conspicuously closer to our objective of training highly skilled social scientists who share a wide range of skills but who also have developed their own individual styles and interests.

THE UNDERGRADUATE PROGRAM

During this year the morale and enthusiasm of the undergraduate students in political science was greatly stimulated by the efforts of Professor Saloma in organizing an association and an extensive social and intellectual program for all students concentrating in political science. At the same time the undergraduate curriculum was carefully reviewed, and a number of significant suggestions for revision were made by a committee consisting of Assistant Professors Bradbury Seasholes, Fein, and Saloma.

The Political Science Section also became more closely associated than in the past with the teaching of a sophomore social science subject. The Section is looking ahead to assuming full responsibilities for instruction in the social sciences during the first two years.

An inevitable consequence of strengthening our undergraduate program is that in time a closer association will grow between it and our graduate program. We find that our advanced undergraduates are able to perform successfully in graduate subjects. By encouraging undergraduates to take some graduate subjects we have been able to build among our undergraduates a greater sense of self-confidence, which is often peculiarly important because many of them are still reacting to the fact that they are no longer following their prior commitment to training in engineering or the physical sciences.

THE FACULTY

During the year the Section benefited greatly from the presence of three visiting professors. Dr. Shmuel N. Eisenstadt of the Hebrew University in Jerusalem served as the first Visiting Carnegie Professor of Political Development and taught subjects in political sociology and social change. Dr. Michael P. Banton of the University of Edinburgh filled the position of Sloan Professor of African Studies during the fall semester and was followed in the spring semester by Dr. Benoit Verhaegen of Lovanium University in Leopoldville. The presence of these visiting professors has stimulated the intellectual life of both faculty and students, and we are now fully convinced that a continued policy of having such new points of view each year is most desirable. We have therefore arranged in the coming year to have Dr. Bert F. Hoselitz of the University of Chicago and Dr. Francis X. Sutton of the Ford Foundation as Visiting Professors.

During the second semester Professor Weiner returned from his field work in India to assume responsibilities for teaching and research on South Asia. Professor Bonilla was on a leave of absence to direct an M.I.T. research program in Venezuela and Latin America. Professor Wood was on leave of absence during the year under a Social Science Research Council grant for research in the field of science and government. The addition of Professors Fein and Saloma greatly strengthened our teaching program.

Finally, it should be noted that planning for the Political Science Section was greatly affected by the decision that a new building is to be constructed which will bring together in close proximity all the members of the Section and the Center for International Studies. We hope this development will ensure that we realize our objective of creating a program in which graduate education and professional research go hand in hand.

LUCIAN W. PYE

PSYCHOLOGY SECTION

The previous year's report on activities of the Psychology Section described a number of steps along the road to departmental status: the initiation of a doctoral program, the planning of changes in undergraduate instruction, and the preparations for moving the research programs of the Section into an extensively reconstructed three-story laboratory building.

During the year under review, the doctoral program has seen its first nine months of operation and funds for graduate traineeships (for the first five years of the program) have been secured. The undergraduate teaching program has been intensified, with a doubling in enrollment in the introductory subject and with indications of corresponding trends for the intermediate-level subjects. The move into the new building was accomplished in November, 1962, but the equipping of the building remained a major task. Since then, a number of facilities have been financed and put into the laboratories, including the rudiments of a specialized research library, a fully equipped machine shop, the beginnings of an electronic shop, and considerable equipment for animal care and animal testing, electrophysiology and histology, and radiochemistry.

The research and teaching activities of the Section have continued to center around the three focal areas which were described in earlier reports: the work on relationships between brain and behavior (physiological and comparative psychology), studies of perception and learning (general experimental psychology), and social-developmental investigations (including work on acquisition, by children, of perceptual-motor skills, language, logic, and social values). This continued three-prong approach to research in basic behavioral science has been reflected in a triple sequence of undergraduate subjects and graduate seminars and laboratories; the work itself, with its often-costly instrumentation, has been made possible by several new grants from private and public sources. That such support could be obtained so soon after the move into the new building is probably the outstanding event of the 1962-63 period.

FACILITIES AND FUNDING

On the eve of our move into the research building we had to confess to a feeling of trepidation. The building was there, beautiful and spacious but devoid of equipment. The program planned required many facilities beyond those available in the existing quarters.

Not all of these needs have been filled, but the year under review has seen considerable advances. A first and major step was made possible by an unrestricted gift from the Rockefeller Foundation, made soon after the beginning of the 1963 calendar year and designated for the general development of the work of the Section. Nearly half a year later the Hartford Foundation announced its intention to give us additional and substantial support for three years, primarily for those aspects of the program which are concerned with effects of brain injury in children and adults.

These grants from private sources were supplemented by several federal grants, each covering a particular portion of the work of our laboratories. The Air Force Office of Scientific Research, through their Life Sciences and Behavioral Sciences Sections, provided funds for equipping the machine shop and related facilities and thus supplied items not covered by either of the private grants. Still more recently, the National Aeronautics and Space Administration announced a generous grant for three years, primarily for those parts of the program that deal with spatial orientation and other aspects of perception and sensorimotor coordination.

In spite of these welcome additions to our resources, there remain several gaps; our funds are still insufficient for some of the planned work in developmental psychology, and the specialized library is likewise in need of support.

CURRICULUM

Undergraduate Teaching. The major changes on the level of undergraduate instruction concerned the introductory subject in psychology. As we had announced last year, the subject was put into the hands of Professor Teuber who taught it through four weekly lectures. Two weekly conference sessions were added, conducted by Drs. Charles G. Gross and Peter H. Schiller who had the aid, at various times, of two or three graduate students. The response of the students to these changes in our introductory offering has been reflected in the trends of enrollment for undergraduate psychology subjects; in 1961-62 the totals were 259 and 296, respectively, for the fall and spring terms; in 1962-63 the corresponding figures were 297 and 414. During the summer of 1963, the introductory psychology subject will again be in the hands of a senior instructor; it will be taught by Dr. Herschel W. Leibowitz from Pennsylvania State College, who will be at M.I.T. as Visiting Professor.

Graduate Teaching. The graduate program in psychology which achieved Corporation approval in March, 1962, is based on the premise that education on that level should proceed with a minimum of formal instruction and a maximum of independent study. Accordingly, we have continued the pattern adopted in the previous year—a single requirement for all incoming graduate students in the form of a proseminar running through the first two terms. This proseminar, with assigned and recommended readings and classroom discussions, covers the major issues of modern psychology, be they physiological, general-experimental, or social-developmental. At the same time, however, and increasingly afterwards, each student is required to participate in laboratory work and to produce by the end of the first summer in residence an experimental paper under the guidance of one of the staff members. Subsequently the student's graduate training is essentially accomplished by means of seminars, independent laboratory work, and guided reading.

Such a tutorial style of instruction is costly and cannot be offered to large numbers of students. With the new admissions for 1963-64, the graduate student body in psychology will consist of fifteen; we do not expect to exceed a total of thirty to thirty-five in the next few years of the program. Because of the special nature of the instruction offered, we prefer to support incoming students through fellowships rather than assistantships. We were, therefore, most appreciative when the National Institute of General Medical Sciences awarded us graduate training grants amounting to a total of $373,000 for the first five years of the training program. This generous grant, in combination with other resources, permits us to support each incoming graduate student fully and equally, so that we can avoid the vexing problem of matching graduate students to existing research funds with their uneven distribution over different projects and faculty members.

PERSONNEL

The launching of a new program tends to be a period of stress, with a good deal of coming and going. We have to report several departures and a number of new arrivals. Associate Professor Ronald Melzack will return to McGill University in Montreal where he had begun his career prior to coming to the Institute; Associate Professor Davis H. Howes will move to Cambridge, England, where he plans to spend a year on a Fulbright appointment; Assistant Professor David M. Green will go to the University of Pennsylvania where he has been appointed Associate Professor of Psychology; and Associate Professor John A. Swets, who has been on an extended leave of absence from the Institute while serving with the firm of Bolt, Beranek and Newman, has decided to transfer his activities in their entirety to this consulting firm. We are grateful to these four members of the faculty for their many efforts in behalf of the undergraduate psychology program at the Institute.

We are happy to report a number of new appointments to the teaching staff in the Psychology Section. Early in the course of the academic year Visiting Professor Richard M. Held decided to accept a full professorship in experimental psychology at M.I.T. and to move his laboratory from Brandeis University to the Institute; at Brandeis he had served as Professor and Chairman of the Psychology Department. In addition, Dr. Alan Hein, currently Assistant Professor at Brandeis, is coming to the Section with the same rank to continue his close collaboration with Professor Held and to add his skills as experimental and comparative psychologist to those of the Section staff. These arrivals mark a major increase in the representation of modern studies of perception at the Institute; they thus fall into the central area of our interest—the work on perception and learning—as do the appointments reported last year of Assistant Professors Stephan L. Chorover and Wayne A. Wickelgren and Dr. Schiller as Lecturer.

In the social-developmental area, progress has been somewhat less rapid since the search for a senior appointment has not yet been successful. However, we are happy to report that Assistant Professor Herbert D. Saltzstein has decided to change his half-time affiliation with the Psychology Section into full-time status, and Dr. Solomon E. Asch of Swarthmore College has agreed to serve as Visiting Professor of Social Psychology in the Section during the fall term of 1963.

In the area of physiological psychology, several appointments have been made; in addition to that of Associate Professor Joseph Altman reported last year, there are Dr. Charles G. Gross as Assistant Professor and Dr. Helen S. Mahut as Research Associate. For a three-month period during the spring term of 1963 Dr. Maria Wyke from the National Hospital of London, England, joined us as visiting investigator.

There has, in fact, been a rather steady stream of visitors to the Section throughout the year, their stay ranging from one-day participation in colloquia and seminars to visits lasting from one to two weeks. There were all together forty-six Friday colloquia and Tuesday luncheon meetings in the Section during the academic year; ten of the speakers on these occasions came from abroad.

RETROSPECT AND PROSPECT

In looking back over the last year, we can say that our passage may have been stormy but that we have not been deflected from the course sketched out in earlier reports. We have taken chances in plunging ahead, moving into our new building and launching a graduate program before all of the funds were available to finance these efforts. Yet we have been vindicated, so far, in that the funds did come. There was turnover of the staff, and there are residual problems of staffing. But we have no regrets for having clung to the principle that psychology, just because of its multiple interests, should have a core, such as the one we tried to provide with our new program. There must be a central group of workers who can devote themselves to fundamental studies in behavioral science, irrespective of immediate applications, driven mainly by their own curiosity rather than the practical needs of the moment. There will always be more psychology at M.I.T. than our new building can encompass, but we must insist, as we did last year, that psychology at the Institute ought to be autonomous and basic, not merely ancillary to other fields, identifiable as a difficult but growing discipline, unique in the way in which it straddles the gap between the natural and the social sciences.

HANS-LUKAS TEUBER

Department of Humanities

During the spring term of the recent academic year the Department of Humanities undertook an extensive review of its curriculum, with particular emphasis on the freshman-sophomore sequence. A special committee of ten, under the leadership of Associate Professor E. Neal Hartley, bore the major burden of this study, which was initiated at the same time that Professor Jerrold R. Zacharias' Committee on Curriculum Content Planning started its discussions of the humanities component of the underclass curriculum. Professor Hartley's group, like the Zacharias Committee, was especially concerned with the relative merits of studies in general education and studies in single disciplines during the freshman and sophomore years. Members of Professor Hartley's committee submitted a series of specific proposals for new subjects and programs at a conference with the Chairmen of the Humanities Sections early in May, and out of these deliberations have come a set of rather basic revisions affecting the first four subjects of the eight-subject requirement in Humanities and Social Science.

The Department will therefore recommend the following changes, to take effect in September, 1964. Although the freshmen requirement will continue to be committed to the principles of general education, directed toward the character and elaboration of basic values in the Western tradition, (1) the second term will hereafter permit limited options, to staff and students alike, of subjects dealing with several modes or stages in the development of that tradition. (2) In the sophomore year a student will be required to take one subject concerned with the analysis of contemporary society, and (3) a second subject, either in literature or philosophy, from a separate list of disciplinary studies for sophomores. Described in another way, the content of the first year will be interdisciplinary and addressed to certain cultural antecedents of modern civilization. The content of the second year will rely upon different modes of analysis and will be relatively less historical in perspective. (4) The loss of the current sequence in general education from the sophomore year will be recovered, at least in part, by the introduction of a few special subjects in humanities, elective for seniors only. The planning of these changes in detail is expected to take place during the fall term of 1963.

Few members of the Department of Humanities have been more consistently involved in the design of the underclass curriculum for the past decade, and few more successful in combining effective teaching with distinguished scholarship, than Professor Alfred D. Chandler, Jr. Professor Chandler has resigned from his post at M.I.T. to accept an appointment at Johns Hopkins University, where he will be a member of the Department of History and Chief Editor of the papers and letters of General Dwight D. Eisenhower, a project expected to continue for the next decade. We look upon his resignation with acute regret.

It is more comforting to be able to report the return of Professor Howard R. Bartlett from India, where he has been a special consultant at the Birla College of Engineering at Pilani. Professor Bartlett will be on leave of absence during the coming year but will be associated with us in the planning of curricular revision. Also returning from leave, in Europe, will be Associate Professor Lynwood S. Bryant, who will be a full-time member of the humanities faculty after leaving his post at the M.I.T. Press; and Associate Professor Robert S. Woodbury, who has been conducting research in the history of technology in Denmark on a Guggenheim Fellowship and who was promoted to Professor effective July 1, 1963. Assistant Professors William H. Youngren, Barry B. Spacks, Emmet J. Larkin, and Gordon M. Jensen had leaves during the year under the auspices of the Old Dominion Fund.

Professor Giorgio D. de Santillana has received a grant of $20,000 from the Twentieth Century Fund with which to support current research in pre-classical cosmologies in the Ancient Near East. Awards for research leave in 1963-64 under the Old Dominion Fund have been made to Assistant Professors Harold C. Kirker and Louis Kampf and to Ira A. Glazier, Albert R. Gurney, Jr., Samuel J. Todes, and William B. Watson; Messrs. Gurney, Todes, and Watson were promoted to Assistant Professors effective July 1, 1963. Associate Professor Harald A. T. O. Reiche has received a Guggenheim Fellowship for research on anthropomorphism in Greek philosophy and early Christian theology, which he will continue next year in Athens.

RICHARD M. DOUGLAS

HISTORY SECTION

Most of the energies of members of the History Section were concentrated on the freshman and sophomore core subjects. Of the twenty-four full-time members of the Section this year, twenty-two taught in the core, Professors de Santillana and Chandler being the exceptions. The number of junior-senior subjects offered was less than that in the other sections because of the explicit policy to avoid proliferation. At the same time the Section was able to achieve its goal of permitting each of the younger men above the rank of instructor to teach one subject of his own, while senior men teach two subjects of their own as well as a section of the core.

At its first meeting in the fall, the Section urged the Chairman to explore possible graduate programs in history at M.I.T. The Chairman then proposed a program which combined the history of science, technology, and industry and economic history and concentrated on their interrelationship. Because of the priority given by the Department to obtaining approval of the philosophy program and because of pending personnel changes, no further action was taken. At the last meeting of the Section a committee consisting of Institute Professor Cyril S. Smith, Professor de Santillana, and Assistant Professor Frederic L. Holmes was appointed to make a revised and more detailed proposal to the Section in the fall.

PERSONNEL

Besides teaching, members of the Section were also busy in their scholarly pursuits. Professor Woodbury spent a year in Denmark, as has been mentioned. Nearby was Owen P. Stearns, an instructor in the

Department, who was a visiting lecturer in American history and literature in Denmark with funds provided under the Fulbright Act. In July, 1962, Professor Thomas H. D. Mahoney lectured on "Burke and the American Revolution" to the history faculty of the University of Cambridge; Professor Mahoney during the year also served as a consultant to the Peace Corps project of Boston College and became Chairman of the Organizing Committee of the North Atlantic Historical Association. Professor Cyril Smith received several honors, including the James Douglas Medal, highest award of the American Institute of Mining, Metallurgical, and Petroleum Engineers. He was elected President of the Society for the History of Technology and gave the first "invited lecture on outstanding research" to the American Society for Testing Materials. Professor Smith also visited Iran at the request of the United States Department of State to discuss the metallurgical examination of archeological artifacts with Iranian archeologists and to study the simple technology still being carried out in small Iranian towns. Professor Reiche acted as a consultant to *Life* Magazine's seven-installment series on "The Miracle of Greece." Assistant Professor Thomas W. Perry's book, *Public Opinion, Propaganda, and Politics in Eighteenth Century England: A Study of the Jew Bill of 1753*, was published by the Harvard University Press as one of the Harvard Historical Monograph Series. Mr. Glazier attended the Second International Economic History Conference at Aix-en-Provence in September, 1962, as a Discussant. Professor Douglas read a paper at the New England Renaissance Conference in May and served on committees of Educational Services, Inc., and the Newton School System for the revision of social science curricula. Professor Chandler read papers at the meetings of the American Historical Association, the Midwestern History Conference, and the Mississippi Valley Historical Association.

ALFRED D. CHANDLER, JR.

LITERATURE SECTION

With an enrollment of 690 in its twenty subjects, the Literature Section continued to offer instruction to more students than any other section in the Department of Humanities; but because of the steady increase of enrollment in the subjects offered by the Philosophy Section, the difference in numbers was small this year. Of the eighty-five students in Course XXI, thirty-one recorded literature as their humanities major.

The Section somewhat revamped the curriculum in literature which is to be listed in the Institute's 1963-64 catalogue, revising and renumbering several subjects to make a more logical sequence. Three new literature subjects were added: Chaucer; Nineteenth-Century: Post-Romantics and Early Moderns; and Nineteenth-Century American Literature, the first two to be offered in alternation with subjects already in the curriculum.

SECTIONAL ACTIVITIES

Professor William C. Greene gave a series of five public lectures during the fall semester on the general subject "The Choices of Criticism."

Professor Roy Lamson, in addition to working on the M.I.T. Committee which is assisting the University of Oklahoma City, served the University of Rochester's Honors Program as an examiner in Renaissance Literature and Milton.

Joseph D. Everingham directed ten plays at M.I.T. this year, ranging from an adaptation of Kafka's *The Trial,* performed by the Dramashop, to Synge's *The Tinkers' Wedding,* performed at one of four workshop evenings. This year the catalogue of offerings by the Literature Section included for the first time theater arts subjects under Mr. Everingham's direction, in which enrolled students worked directly with actual productions and received credit for their participation. Mr. Everingham will continue and extend this work in the future as a member of the faculty, to which he was appointed effective in July, 1963, as Associate Professor.

Associate Professor Robert R. Rathbone continued the cooperative program of teaching technical writing in subjects offered by Courses I, II, III, VI, XIII, and XVI. He also responded to a request from the University of Minnesota to help devise a program in the teaching of technical writing at that University's College of Engineering.

Professors Norman N. Holland, Spacks, and Gurney continued their work on a large series of "programmed" literature textbooks to be published by Harcourt, Brace and World, Inc., for use in the secondary schools. Their expectation is that these texts will lead to improvement in the study of literature by making it possible for the student to learn how to read critically no matter what the skill or competence of his instructor.

Professor Holland read papers before the Division on Esthetics of the American Psychological Association and the Society of Cinematologists; he also became a member of the Board of Supervisors of the English Institute and Editor of the *Journal of the Society of Cinematologists.*

Professor Spacks gave a reading at Birmingham University, England, from a novel in progress.

Mr. Gurney's *The Politician,* a series of interrelated dramas about American politics produced by the Lincoln Filene Center for Citizenship and Public Affairs of Tufts University and *21" Classroom,* was presented on WGBH-TV in November and April.

Norman Pettit's doctoral dissertation on "The Image of the Heart in Early Puritanism: A Study in Religious Introspection" received the George Washington Egleston Prize at Yale University.

Professor Benjamin H. DeMott came to us from Amherst to teach the subjects normally offered by Professor Carvel Collins, who spent the year as a member of the Committee on Curriculum Content Planning.

Professor Collins received a grant from the American Philosophical Society to support preparation of a biographical and critical volume on William Faulkner to be published by Atlantic—Little, Brown.

Robert Graves, the British poet and novelist, was a visitor in the Section during two weeks of the Spring Term while he was in residence at M.I.T. as Arthur D. Little Lecturer. His lecture, "Nine Hundred Iron Chariots," contained a summary of his conclusions about similarities and contrasts in the creative processes of scientists and poets.

CARVEL COLLINS

MUSIC SECTION

Our music subjects had an enrollment of 373 students during the year. Our staff situation was improved somewhat by making Assistant Professor Victor H. Mattfeld available on a full-time basis and by adding the part-time services of a teaching assistant. The subject in the Opera was reinstated, and the sections were held to manageable proportions. Lack of sufficient classroom and library space remain problems to be solved, we hope in the near future.

Looking at the music program as a whole, it seems obvious that the curricular side has been hampered by the need for expansion of both staff and equipment. The interest in specialization and graduate work in the humanities is bound to obscure the fact that music is one of the few remaining fields which tries to and can succeed in "educating the whole man." This ideal can be achieved on all levels—from freshmen to graduates and even to staff members. The only requirement is an ample and first-class staff. One need not offer graduate subjects to assemble a first-rate staff of musicians, for musicians find sufficient satisfaction in their work as composers and performers outside the classroom. However, our music courses are too limited in variety, and since music is not a part of the core curriculum we do not meet students early enough. While we are restudying so many elements of the M.I.T. program, an inquiry into the role of music in the M.I.T. curriculum is also in order.

KLAUS LIEPMANN

PHILOSOPHY SECTION

During the year under review, academic work in philosophy has developed more than in any previous year in the history of the Institute.

PERSONNEL

New appointments were notable. Dr. James F. Thomson of Corpus Christi College, Oxford, was appointed Professor of Philosophy effective July 1, 1963; his appointment adds to the Section's strength in logic and epistemology and will mark the beginning of work in the philosophy of mind. Dr. Philippa R. Foot, also from Oxford and one of the most distinguished moral philosophers of our time, will be here as Visiting Professor of Philosophy for the year 1963-64. Dr. Jerry A. Fodor is returning to the Institute after a year at the University of Illinois' Institute of Communications Research, and Dr. Jerrold J. Katz, already at M.I.T. as a Fellow in the Research Laboratory of Electronics, has also formally been added to the Philosophy Section; both begin appointments as Assistant Professors in July, 1963. Though young, each has already established an enviable reputation in the philosophy of language, and they will strengthen the Section's close collaboration with the Institute's program in linguistics, while Professor Thomson's interests in the philosophy of mind and Professor Fodor's in psycho-linguistics will constitute bridges from philosophy to the Institute's Psychology Section.

These four appointments bring the faculty in philosophy to a total of ten. This is a respectable number, but more important is the variety of interests represented in the section and the level at which these interests are pursued. With Professor Hilary Putnam in the philosophy of mathematics, Assistant Professor Abner E. Shimony (promoted to Associate Professor effective July 1, 1963) in the philosophy of physics, Professor Thomson in the philosophy of psychology, and Professors Fodor and Katz in the philosophy of language, and with the strong assistance of Professor de Santillana in the history of science, the group constitutes one of the strongest centers in the philosophy of science anywhere in the world. This might be expected at M.I.T. The happy fact is that the accumulation of strength in this sector has not been at the expense of diversity and balance. All the aforementioned people have philosophical interests which exceed those in the philosophy of science proper. Professor Foot is pre-eminent in the field of moral philosophy; Hubert L. Dreyfus and Samuel J. Todes (both promoted to Assistant Professor effective July 1, 1963) represent the continental, phenomenological-existentialist wing of contemporary philosophy as effectively as do any other pair of philosophers in the country; and Associate Professor Irving Singer is engaged in new departures in the philosophy of literature. By the twin criteria of breadth and depth, it is an impressive group.

PROPOSALS FOR A GRADUATE PROGRAM

With the gathering of these men, thought of graduate work was certain to arise. Impetus for it has come not only from the philosophers themselves but from other groups at the Institute, primarily the linguists and psychologists who foresee that the introduction of a strong graduate program in philosophy could be of help to them, and from various philosophers across the country who have written to ask if their students might come here for graduate study. Early this spring the Section presented to the Committee on Graduate School Policy a proposal for a graduate program in philosophy. That Committee recommended that the proposal be explored, and an *ad hoc* committee consisting of three faculty members at the Institute (Professors Robert M. Solow, Harold S. Mickley, and Murray Gell-Mann), three philosophers from outside the Institute (Professors Willard V. Quine of Harvard University, William K. Frankena of the University of Michigan, and Norwood Hanson of Indiana University), and Dean Harold L. Hazen was appointed for the purpose. It made several important recommendations which were incorporated into the proposal, after which the Committee on Graduate School Policy recommended that it be accepted. Accordingly, at the last regular faculty meeting of the year the proposal was presented to the faculty which took it under advisement with its vote scheduled for the first meeting next fall.

It is hoped and expected that the vote will be favorable. If it is, a principal concern will be to see that the graduate program develops in ways which strengthen the undergraduate program in humanities rather than detract from it. The Section is alert to this need and looks forward to full participation in the revised humanities program which is projected.

HUSTON C. SMITH

COURSE XXI

Course XXI began its sixth year in September, 1962, with the largest enrollment in its history; a total of eighty-five students from three classes were working in the combined program in Humanities and Science or Humanities and Engineering. The table below indicates the fields in which students in Course XXI elected to take their science or engineering component:

Architecture	2
Chemical engineering	1
Chemistry	7
Electrical engineering	11
Geology	3
Industrial management	1
Life sciences	22
Mathematics	23
Mechanical engineering	1
Physics	12
Undesignated	2

As was the case during the past two years, most students followed a division of half their work in science or engineering and half in humanities. Five elected a division of 60 per cent in science or engineering against 40 per cent in humanities; a majority of these students also took overloads in humanities, especially in foreign languages but also in social science, psychology, and visual arts. The advantage of curricular flexibility, one considerable source of strength in Course XXI, was again successfully put to use by those who recently completed the program.

The Humanities Senior Seminar in the fall term of 1962 was conducted on the theme "Romanticism and Revolution," a study of history, literature and philosophy during the period 1789-1848 in England, France, and Germany. Dr. Howard Mumford Jones of Harvard was the Visiting Carnegie Professor, and he collaborated effectively with Professor Roy Lamson in the design of the Seminar. Based on the experience of the students in their first three years, the Seminar was developed around a significant period of time, focusing on a continuing theme of such nature as to permit individual students to pursue their special interests from varying perspectives. The entire Seminar met in conference for a two-hour meeting at the beginning of each week and again in smaller discussion groups in mid-week under the direction of a member of the humanities staff. During the second term of the Senior Seminar, students also devoted their time to the preparation of bibliography and the writing of theses. Between early March and the end of April, each member of the Seminar presented an oral report on the progress of his research before an audience of his thesis director, other members of the staff, and his colleagues. The purpose of these presentations was to permit critical assessment of the structure and the direction of the research. The range of topics and fields is represented by the following thesis titles: *Higher Criticism of the Old Testament; Joyce's Ulysses as Comedy; Plato, Epicurus and the Early Aristotle; The Idealism of Machiavelli; Ritual Murder in the Plays of Jean Genet; Structural Changes in Modern Physics and Music; Three-Valued Logic and Some Anomalies in Quantum Mechanics; The Appeal to Natural Law in American Constitutional Crises.*

During the past year the Course XXI Society sponsored nine meetings and seminars independent of the formal program of the Course. Two of these meetings were held at Endicott House, one in October and one in April, each organized as a colloquium in which members of the Humanities Department were joined by members of the Institute faculty in science. The October colloquium, directed to the question "What Makes Good Art?," included Professors Greene, Singer, and Liepmann and Associate Professor Jerome Y. Lettvin (Physiology). The April meeting, concerned with "Conceivability in Philosophy and Science," included Professors Putnam, Huston Smith, Shimony, and Felix M. H. Villars (Physics). Other meetings of the Course XXI Society dealt with papers on "Literary Value: a Psychoanalytic Approach" by Professor Holland; "Recent Work in Progress in the History of Early Astronomy" by Professor William D. Stahlman of the University of Wisconsin; "The Dilemma of Contemporary Architecture" (two lectures) by Dean John E. Burchard; "Some Philosophic Implications of Our Sense of Balance" by Mr. Todes; "An Anthropological Discussion of Nativistic Movements" by Dr. Anne Marie Shimony, Assistant Professor of Sociology and Anthropology at Wellesley College; and "Cinema as Art and Technology" by Robert Gessner, Professor of Cinema and Television at New York University. The Course XXI Society has served as an especially important adjunct of the formal curricular program and has provided a unique occasion for cross-disciplinary discussions at a high level. At the annual Course XXI banquet in May, Professor Elting E. Morison (Industrial History) presented a paper on "Poetry and Politics" which was followed by comment and response by Mr. Graves, then visiting as the Arthur D. Little Lecturer. An incomplete indication of the future careers or vocational choices now indicated by members of Course XXI in the Class of 1963 indicates the following: three to industry, five to graduate study in science, seven to graduate study in the humanities, two to medical school, one to preparatory school teaching, one to professional work in oceanography, and one to the Peace Corps. Five of these students have received fellowships, including a Woodrow Wilson grant to Kenneth S. Friedman, who will enter Harvard University after completing his Course XXI program in philosophy and physics.

ROY LAMSON

Department of Modern Languages

The most striking fact about the Department of Modern Languages within the last year has been the continued rapid development of graduate work. We accepted eight new graduate students in the fall of 1962, and seven of last year's eight returned. Graduate subjects, only eleven of which were offered last year to 142 registrants, increased to seventeen this year, with 202 registrations. This rate of growth will not continue beyond next year, when we expect to award our first degrees. From then on it is planned to hold the number of graduate students to between twenty-five and thirty, at least for the next few years.

Total enrollments in language and literary subjects remain about the same, with a total of 2065 registered in 29 subjects. About half of this registration is made up of graduate students.

CURRICULUM

The language and literature subjects offered for undergraduates by the Department changed during the year only by the addition of one new subject: Goethe's *Faust*, taught in German. Fifteen students registered.

New graduate subjects included a Seminar in Linguistics, Structure of Russian, Mathematical Backgrounds for Communication Sciences, Mathematical Models in Linguistics, Typology of Grammars, and Linguistic Change.

FACULTY

We were fortunate this year in having Dr. Jerzy Kurylowicz of the University of Crakow as Visiting Professor for the fall term; he taught Indo-European Morphology. As Guests of the Institute we had Professor John J. Gumperz of the University of California (Berkeley) and Miss Thyllis Williams, formerly of Itek Corporation.

Professor Jan Miel came from Goucher to teach French literature and the humanities in French, replacing Dr. Stephen Gendzier who resigned to go to Brandeis.

LANGUAGE LABORATORY

The Language Laboratory provides remote-operated, two-channel tape recorders for each of thirty students; it has been heavily used for the three years since its installation. This year the Laboratory was open for students and classes a total of forty-four hours a week in the fall term, with an average attendance of twenty per hour. At the end of January the equipment of the Laboratory was completely overhauled, restoring it to practically new condition in time for the second semester. Our experience with the Laboratory proves that students do much better oral work if they practice regularly, listening to recordings in the voice of a native speaker, recording their own voices, and then playing the two back for comparison.

The location of the Language Laboratory, in Building 20, remote from the usual student activities and particularly inaccessible on week ends when most of the outside doors are locked, is a major deterrent to its full use. Since its function is similar to that of a classroom, the Laboratory should have some more central location, preferably nearer the departmental offices.

GRADUATE STUDENT AND STAFF LOUNGE

Another departmental need which is becoming acute as the number of graduate students increases is for a comfortable room where graduate students and staff may meet informally. The social, intellectual, and morale value of such a facility has been shown in many other departments.

RESEARCH

Members of the Department have continued their research in theoretical and descriptive linguistics. Professors Noam A. Chomsky and Morris Halle are in the process of writing a book on their research of the past several years on phonological theory and its application to English. The central problem to which this work has been devoted is that of accounting for the physical form of an utterance in terms of its deeper syntactic features on the basis of a general characterization of constraints on form and interconnection of grammatical rules. Professor Halle has also applied these general hypotheses to the study of Russian and Latvian sound structure and to historical phonology.

Professor Chomsky has also been engaged in a reformulation of syntactic theory to deal with a variety of new empirical observations that have resulted from recent descriptive work and in the study of mathematical models incorporating certain of the features of generative grammars.

Assistant Professor Edward S. Klima has continued his work on syntactic and semantic description of several Indo-European languages and on comparative Indo-European syntax. Dr. G. Hubert Matthews (promoted to Associate Professor effective July 1, 1963) has completed a very extensive transformational grammar of Hidatsa and has continued his work on comparative syntax and on analysis-through-synthesis algorithms for interpretation of sentence structure. He has also proved several new results relating to automata-theoretic characterization of certain types of formal grammars.

Professor William F. Bottiglia is continuing to concentrate on Voltaire. In collaboration with David M. Perlmutter he has just completed a volume on Voltaire's private library in Leningrad. Also, because of the warm reception accorded his full-length study entitled *Voltaire's "Candide": Analysis of a Classic* (1959), he has been asked to prepare a second, revised edition. This is now in progress. Finally, he is well advanced in the composition of a third work which will bear the title, *Voltaire's Prose Dialogues.*

Assistant Professor Alexander L. Lipson and Mr. Perlmutter have been working this year on programmed instruction of Russian in conjunction with the Harvard University Committee on Programmed Instruction. Professor Lipson has been programming parts of a first-year Russian grammar and using them with volunteers from our beginning subjects. The results have been encouraging. Mr. Perlmutter has been doing similar work, also with good results, on programming our Russian reading class for Ph.D. candidates. It is hoped that by next year most of the grammar necessary for a reading knowledge of scientific Russian can be taught in programmed form.

CONGRESS OF LINGUISTS

M.I.T. was co-host with Harvard to the Ninth International Congress of Linguists from August 26 to 31, 1962. Professor William N. Locke was Secretary General, and Professor Halle was Secretary. It was the first of this series of quinquennial congresses ever held in the U.S., and the largest, with a registration of over 900, some 300 of whom came from overseas. It is a tribute to the stature of our youthful linguistics group that the Institute should have been chosen as co-sponsor of this UNESCO-affiliated congress.

GRADUATE LANGUAGE REQUIREMENTS

An important change in the language requirement for the doctor's degree voted this spring by the Graduate Policy Committee will have an effect on the work of the faculty which can not yet be estimated.

Previously, each doctoral candidate had to prove to the Department of Modern Languages that he could read (and translate into English) technical material in his field. A new option has been added which permits a student with substantial competence in reading and speaking a foreign language in which his department determines that there is a large amount of technical material to offer this in place of a reading knowledge of two languages. Students will be expected to prove their competence by carrying on a conversation in the foreign language concerning both general topics and their special fields. These new oral examinations may involve considerable staff time in addition to the written examinations for reading knowledge which the Department will continue to give. It will be welcomed, however, since in our view depth in any one of the leading contemporary languages is far more desirable than superficiality in two, or even in seven.

WILLIAM N. LOCKE

Center for International Studies

Since the major function of the Center for International Studies is research rather than teaching, this report differs from those submitted by other parts of the School. This distinction should not, however, be taken to mean that the Center is not an active participant in M.I.T.'s academic program. Virtually every member of the Center's senior staff contributes to the Institute's undergraduate and graduate teaching programs in economics and political science. The classes in economic development, one of the fields of specialization in the economics doctoral program, are taught by members of the Center. The Ph.D. program in political science, which stresses such fields as comparative development, international communication, and American foreign and defense policies, is particularly closely related to the Center's work. Special mention should be made of the development this year of a new series of graduate courses on defense problems and policies, a field in which the Center intends to initiate a substantial program of research.

Among other Center contributions to M.I.T.'s academic program are the opportunities offered for graduate student participation in research projects. The Center has also raised substantial fellowship funds for graduate students working on problems of the underdeveloped countries. In addition, grants to the Center and the Political Science Section have made it possible to invite scholars from other institutions to M.I.T. for varying periods of time for both research and teaching.

Perhaps the outstanding feature of the past year was the initiation of an unusually large amount of new research, which has broadened the scope of our research program in various ways. For example, it has seemed inappropriate to us that a group strongly interested in comparative economic and political studies of underdeveloped countries should have no research commitments in Latin America. We are therefore pleased that suitable opportunities have now arisen. A field study was begun this winter on communism in Latin America as part of a larger project on the international Communist movement, and work began in the spring on a set of social and political studies in Venezuela. The Latin American studies and other new projects are strengthening the comparative aspects of our research, with related studies now underway in the Center's four main areas of interest—economic and political development, international communication, communism, and American military and foreign policy.

STUDIES IN ECONOMIC AND POLITICAL DEVELOPMENT

Research on development planning has been an important aspect of several of the Center's recent studies in economics. Professor Hagen has edited this year a series of case studies on the varied planning experiences of eight countries, focusing on the evolution of planning processes and the machinery for carrying out planned goals in each country. These studies, together with comments and several chapters on planning by Professor Hagen, will be published this fall in a book entitled *Planning Economic Development*. Dr. Edward P. Holland has completed the report on his investigation of the use of the simulation technique to study the complex dynamic processes and problems of an economic system in the early stages of development. The book will be published this fall by the M.I.T. Press. Professors Eckaus and Lefeber have recently begun a study of planning methods, their objectives being to improve the analytical sophistication of the methods employed and to develop practical means of utilizing high-speed computational techniques.

Since 1952 the Center has been engaged in a research program relating to the economic development of India. The work, which is under the direction of Professor Rosenstein-Rodan, is being carried out in cooperation with a number of Indian research institutions and with the government Planning Commission. Studies this year have concerned planning procedures, especially the mathematical formulation of alternative planning models for analysis by high-speed computers; public finance; pricing policy; and interindustry relations.

Many of the essays prepared earlier in connection with the formulation of India's Third Five Year Plan have been edited by Professor Rosenstein-Rodan and will be published in two volumes, *Capital Formation and Economic Development* and *Pricing and Fiscal Policies: A Study in Method.* Professor Lefeber has begun a separate project to develop a long-term transportation plan for the Indian economy.

The political dimension of Indian development has been under study by Professor Weiner, who returned to M.I.T. in January after eighteen months of field research in India on the Congress Party. He studied various aspects of the Party's activities in five districts with different social, political, and economic environments. Other work in the area of political development includes the first stage of a comparative study planned by Professor Pye with the aim of improving our understanding of present and potential development patterns in different types of societies. Professor Pye will be utilizing some of the theoretical concepts and research techniques developed in his recent study on Burma (*Politics, Personality, and Nation Building: Burma's Search for Identity*) as a basis for comparative analysis of several transitional political systems. He plans to focus his attention first on Communist China in an attempt to analyze certain critical sets of attitudes which determine the responses of the Chinese Communist leaders to their environment.

As mentioned above, the Center has also extended the comparative basis of its research on development problems by including studies in Latin American countries. Work started this spring on a socio-political study intended to locate points of conflict and possible bases for consensus among a wide range of groups at different levels in Venezuelan Society.

In this study the Center is collaborating with the Centro de Estudios del Desarrollo (CENDES) of the Universidad Central de Venezuela as part of a research and training program planned by CENDES with the support of the Ford Foundation.

Another aspect of development planning with which the Center is concerned is the relation between economic development and technological change. Professor Eckaus in the past year has been investigating the relation of education and training to technology and economic growth, with specific attention to the educational and training requirements of Italian industry and admissions policies in Indian universities. Other activities in this field have been undertaken in connection with a project of the Advanced Technology Laboratories of the General Electric Company concerning rural electrification in underdeveloped countries. The Center's main contribution to the study has been to examine various facets of the economics of power production and utilization in villages.

The Center's four-year study of African economic and political development formally ended a year ago, but members of the project have continued writing up the results of their field research. Arnold Rivkin, former director of the research team, last summer completed the manuscript for *The African Presence in World Affairs,* which deals with the related problems of economic growth and political stability in the new African states. Other studies undertaken during the course of the project concern the economic and political problems of the Congo Republic, the influence of political change on economic policy in Nigeria and in the Federation of Rhodesia and Nyasaland, and economic growth in Africa south of the Sahara in the 1950's. Dr. Archibald C. Callaway returned to Nigeria last summer to complete his study of private capital formation in Nigeria and to continue his previous work on the problem of unemployed youth. Through interviews and other means he is investigating the various economic and social questions arising from the mass unemployment of school leavers.

STUDIES IN INTERNATIONAL COMMUNICATION

The current year has brought the completion of several studies in the field of international communication as well as the inauguration of considerable new work. One study to be concluded is the work of Professor Pool with Professor Raymond A. Bauer of Harvard University on the role of international information in the formation of American foreign trade policy. The results of their study, based on interviews with 900 heads of American corporations and some 500 journalists, lobbyists, congressmen, and opinion leaders were published this spring as *American Business and Public Policy: The Politics of Foreign Trade.* Work has also been completed on the Center's investigation of the impact of educational television on the attitudes and behavior of its audience. The results of this study undertaken by Professor Pool in cooperation with station WGBH in Boston will be published in *The People Look at Educational Television,* a volume which also reports on a series of studies carried out simultaneously in other cities under the direction of Professor Wilbur Schramm of Stanford University. Another new book, *The New World of Negro Americans,* incorporates the material obtained by Mr. Isaacs in interviews with leading Negro communicators, writers, scholars, educators, and public figures. It traces some of the links between the ending of the white supremacy system in Asia and Africa and its quickening decline in the United States and goes on to examine the effects of this change on certain key aspects of Negro group identity. Last spring Mr. Isaacs set off for a year of research, primarily in Asia, on the effects of political change on patterns of group identity in other countries.

A new research program is under way on various communication problems relevant to national security. One goal of this research, which is under Professor Pool's direction, is to improve Western ability to communicate with Communist societies, particularly the Soviet Union and China. Since this first requires a better understanding of the communication systems within these societies, an effort will be made to learn more about the roles of the mass media, the party, rumor, and American statements and other foreign news in a system approximating the demographic, geographic, and social characteristics of one or more Communist countries.

Other research efforts within the international communication program relate to comparative international surveys in Europe and Latin America. Professor Daniel Lerner has continued his investigation of the evolution of elite attitudes in France, Germany, and Great Britain toward the unification of Europe on the political, economic, and military levels. Three Center members have been involved in an innovative "national sample" survey of villagers in Turkey sponsored jointly by the Agency for International Development and the Turkish government. Professor Frey was Chief of the U.S. Consultant Party, which also included Professors Lerner and Pool. Finally, there should be mentioned again the survey research begun last spring in Venezuela which is attempting to investigate the basic attitudes of key groups in the society. Responsible for this research are Professors Lerner, Frey, and Bonilla.

STUDIES ON COMMUNISM

The Soviet Union and communism remain a major focus of the Center's research. Dr. William E. Griffith's study of the 1953-56 thaw in East Europe will be published during the next year. An outgrowth of this study, *Albania and the Sino-Soviet Rift,* an extensively documented analysis of Albania's role in the international Communist dispute, was published by the M.I.T. Press last winter. As part of a new research project on the international Communist movement, Dr. Griffith completed work on a second volume of documents and analysis of the Sino-Soviet controversy covering the period between February, 1962, and the summer of 1963. Other studies are being carried out on certain Communist parties in Western and Eastern Europe and in underdeveloped countries in Latin America and Asia. Their emphasis is on the interaction between domestic and external factors as an influence on each party's policy and organization and on its relations with other parties, especially the Soviet and Chinese parties. Assistant Professor Donald L. M. Blackmer is studying the international Communist labor movement, particularly the effect of polycentrist tendencies on the World Federation of Trade Unions.

Before his death in February, Herbert Ritvo had been analyzing the role of the Soviet Communist Party in the decade since the Nineteenth Party Congress in October, 1952. Several parts of his study have appeared as journal articles. *The New Soviet Society*, published by *The New Leader* in December, 1962, contains a translation of the final text of the Third Program of the Soviet Communist Party with an introduction and detailed commentary by Mr. Ritvo.

Alexander G. Korol has completed his study of the resources, manpower, and organization of the Soviet research and development establishment. The results of his research will be published by the National Science Foundation.

STUDIES ON AMERICAN MILITARY AND FOREIGN POLICY

The Center's continuing interest in American foreign policy is currently reflected in studies on defense policy and arms control. The new program of graduate subjects on defense problems and policies developed by Professor Kaufmann has been mentioned above. During the past year Professor Bloomfield has been directing a number of studies on arms control and disarmament.

One study concerns the role of international military force, both under actual contemporary circumstances and under certain hypothetical conditions of general disarmament. One result of this study was a symposium to which specialists in different disciplines contributed their views on various military, economic, political, and psychological aspects of international force, published as a special issue of *International Organization* (Spring, 1963). Another approach to the study of arms control was a series of four three-day gaming exercises in which between twenty and thirty academic experts and government officials participated. These political exercises attempted to simulate hypothetical crises in situations involving international military force and in some cases elements of disarmament.

Work has begun on two other aspects of the arms control problem. One study is examining the problem in the light of Soviet external policies and strategies and of Soviet domestic organization. The other is investigating the possibilities, limitations, and implications of various arms control arrangements, both regional and international, for developing areas in Africa, the Middle East, and Latin America.

MAX F. MILLIKAN

Extracurricular Activities

DRAMA

The program in drama for the academic year 1962-63 consisted mainly of two productions of full-length plays: Thornton Wilder's farce-comedy *The Matchmaker* in December and the first performances of a new adaptation of Franz Kafka's famous novel *The Trial* in April. Mr. Everingham adapted the Kafka novel and also directed the play with his design and technical assistant, Mrs. Helen Brumby.

In addition to the major productions, four evenings of workshop productions entirely produced by students took place during the year and were open free to the M.I.T. student body, who were invited to participate in an onstage critique of the evening's plays with the actors, student directors, designers, and technicians immediately following the performances.

The workshop evenings began in October with a one-act play by the new English writer Harold Pinter entitled *The Dumb Waiter* presented along with Jean Giraudoux' *Song of Songs*. Two Irish plays, J. M. Synge's *The Tinkers' Wedding* and W. B. Yeats' verse drama *The Cat and the Moon* comprised the second evening, with Michel de Ghelderode's *Escurial* coupled with Tennessee Williams' *Twenty-Seven Wagon Loads of Cotton* as the third. In March, Dramashop presented the young American playwright Jack Richardson's two plays entitled *Gallows Humor* as the final offering. All four evenings played to capacity houses.

The drama program continues to expand each year, with an active participative group of 150 and an audience mailing list of over 1,000 students.

JOSEPH D. EVERINGHAM

EXHIBITION PROGRAM

The Museum Committee has continued its exhibition program in the Hayden Gallery with the objective of making conveniently available to students, faculty, and visitors the works of significant contemporary artists. With sympathetic administrative support, these exhibitions have now obtained a commendable stature and a place of value in the greater Boston museum program.

Exhibitions for 1962-63 included one-man shows of paintings by Kenzo Okada, Robert Motherwell, and Conger Metcalf and of sculpture by Dimitri Hadzi. For Messrs. Motherwell and Hadzi it was their most inclusive U.S. exhibition. Catalogs prepared for these major shows include sufficient photographic coverage of each man's work to be a useful future reference for students, and requests suggest that they are also valued by museums. Gallery attendance continues to grow at a modest but reassuring rate.

For the second year a Christmas Print Sale, sponsored jointly with the Art Committee in the Gallery, was a great success and indicated the interest that students and faculty have in good graphic art.

Through the generosity of Mr. and Mrs. Samuel Marx, the Art Committee was able to commission during the year a major sculpture by Dimitri Hadzi. Located on the Hayden Library entrance plaza adjacent to the Gallery, "Elmo III" was unveiled with a suitable ceremony on May 13; the retrospective exhibition of Hadzi's work which was the culmination of this year's program was assembled from U.S. and European collections in honor of the important occasion.

The Committee wishes to acknowledge with most sincere appreciation the friendly and essential support it has received from museums and galleries and from many friends and private collectors.

HERBERT L. BECKWITH

MUSIC

Extracurricular activities constitute a very large part of the M.I.T. community's participation in musical affairs. The musical performances of the 1962-63 season were notable for their variety and for the quality of their artistry.

The Humanities Series, arranged by Associate Professor Gregory Tucker, concentrated on the chamber music of Mozart, Schubert, and Brahms; there were two performances by the New York String Sextet and appearances of the Fine Arts Quartet of Chicago, the Claremont String Quartet, and the Juilliard String Quartet (with which Professor Tucker was soloist). The afternoon concerts in the Music Library, also arranged by Professor Tucker, were presented by Ruben Varga, the Boston Bassoon Ensemble, the Woodwind Quintet of Indiana, Mr. and Mrs. Zsigmondy, and Orrea Pernel, with Professor Tucker as occasional soloist.

Anna Russell appeared under the Guest Artist Series sponsored by the Choral Society; the Musica Sacra Group, directed by Professor Mattfeld, presented a program of ancient Christmas music in the Little Theater; and the M.I.T. Baton Society sponsored appearances by Josh

White, Professor Tucker and assisting artists, and a number of student events. Of particular interest was a special concert, by Professor Tucker and assisting artists, of music by Janacek and Stravinsky in honor of the latter's eightieth birthday.

Heinz Wunderlich of Hamburg, Professor E. Power Biggs of Harvard assisted by Joseph Silverstein (Concertmaster) and Louis Speyer (English horn) of the Boston Symphony Orchestra, André Marchal of Paris, and Michael Schneider of Berlin presented concerts on the Kresge Auditorium organ. Concerts and recitals were given on the Chapel organ by Fenner Douglass of Oberlin College; John Fesperman of Old North Church; Margaret Mueller of Salem College; Frank Bozyan of Yale University; Richard Carlson of Fort Wayne, Indiana; Thomas Foster of Danvers, Massachusetts; Myrtle Regier of Mt. Holyoke College; Harriette Slack Richardson of Springfield, Vermont; Professor Mattfeld, and a number of M.I.T. students.

Under John D. Corley's direction, the M.I.T. Symphony Orchestra pioneered important new music. A concert on December 1 included the familiar Saint-Saens' *Symphony Number 3* with Alexander J. Borrevik '64 as organist and the world premiere of *Symphony Number 1* by Nikos Hontzeas, a young Greek composer whose brother is a Research Associate in the Department of Chemistry. A combined concert with the Amherst-Smith Orchestras on March 10 featured the first Boston performance of the *Festival Prelude for Organ and Orchestra* (Op. 61) by Richard Strauss; the off-stage corps of trumpeters required for this composition was supplied by the Concert Band and Brass Choir.

The Concert Band, also under Mr. Corley's direction, presented compositions by Thomas Beversdorf, Vittorio Giannini, Peter Seeger, and Alexander Tcherepnin; and at a concert on the Smith College campus in April the Band presented the first performance of a large and complex work by Professor Edwin London of Smith, *Three Symphonic Movements*, dedicated to the Band and its conductor. The Band's mid-year tour included concerts in Pittsburgh, Johnstown, and Harrisburg, Pennsylvania, and in March the group appeared before the annual meeting of the Massachusetts Music Educators Association in Springfield.

The M.I.T. Glee Club under Professor Klaus Liepmann's direction presented Bach's *Cantata Number 179* with the Radcliffe Chorus and Poulenc's *Gloria* and Bach's *Cantata Number 4* with the Smith College Glee Club.

The Choral Society, having returned from its third European tour in 1962, gave Fritz Büchtger's *Christmas Oratorio* its American premiere with the composer conducting and later sang Handel's *Messiah* under Professor Liepmann, director. During the 1962 summer tour the group presented American music by Copland and Ives and works by Schütz, Purcell, Bach, Mozart, and Bruckner in Norwich, Cambridge, London, Paris, Cologne, Berlin, and Munich. Highlights of the tour were a broadcast for the B.B.C.'s Third Program and two concerts at the Free University of Berlin with the Berlin Philharmonic Orchestra. A noteworthy event on this tour was the Berlin première of Purcell's *King Arthur* in the Academy of Music.

In another notable musical event, the Baton Society presented the M.I.T. Symphony Orchestra and the ballet group of the Boston Conservatory of Music and the Boston Dance Theater in a highly successful program on the Kresge stage which included Walter Piston's *Incredible Flutist.*

The season reached its climax in the Second M.I.T. Spring Festival of Music, at which the Symphony Orchestra and Concert Band performed music by Schönberg and Piston with Miss Janet K. Stober '64 as soloist in Lalo's *Symphonie Espagnole.* The Choral Society presented Bach's *B Minor Mass,* and the Glee Club, with the Choir of Douglass College, sang Haydn's *The Seasons.*

KLAUS LIEPMANN

General Comments

It may be appropriate to end this report with comments on a few of the matters discussed in the preceding separate reports.

CURRICULAR CHANGES

It will be apparent from the reports of Professors Bishop, Pye, Teuber, Douglas, and Liepmann that the School is throbbing with discussion about undergraduate curricular revision and that some of the proposals are drastic. This is consonant with the climate of the Institute as a whole, epitomized by the current studies of the major committee under the chairmanship of Professor Zacharias. This is entirely beneficial. Even if large changes do not in the end occur, such discussions have the effect of revitalizing what is being done. My personal view is that major changes should occur and I find the proposals of the Zacharias Committee exciting and convincing without any major exception. I see nothing in them adverse to the special interests of this School and much that will be beneficial.

In all such discussions one may meet extreme views while the final propositions are evolving. They come from many quarters within and without the faculty. One needs to be wary of adopting the extreme positions. For example, some of our friends, examining the great success of our highly technical linguistics program, have concluded that all our humanities programs should find similar ways to join with technological advances; and if they cannot, should be abandoned as fields of scholarship and perhaps even of teaching. This is surely a distorted view of what the humanities are and what they can contribute to education at M.I.T., and I know no one on our faculty who would agree with such a conclusion. Indeed, those who have been most successful at effecting such alliances would be the first to deny that everything should be patterned on alliances. We are not going to remove history, literature, philosophy, and the arts from the experience available to M.I.T. students whether or not they can be "computerized."

A somewhat analogous view seems to be held by some, though certainly not all, of the engineering faculty, that our programs in humanities and the social sciences should all be examined with respect to their practical and contemporary utility. They seem to feel that since close analogues from history are dangerous, studies in many of the humanities are irrelevant to any problem of the modern world, especially as the humanists and even many of the social scientists are not as reliable as prophets and predictors as scientists and engineers deem themselves to be (and sometimes have been). This is too long a subject to be debated here. One would first have to examine the meaning of "utility." One could remark, for instance, that while a clear understanding of the history of a tribe, a race, or a nation might not predict their future, a good many operational mistakes in the field might be avoided by engineers who had a sense of the history and culture of the people they were trying to "upgrade" into the industrial twentieth century. I do not regard this view of the "practical" as prevalent enough to constitute a threat to a proper program in the humanities and social sciences, but it cannot be ignored.

At the other extreme, there used to be a fairly common view among our colleagues that the humanities and social sciences constituted some kind of a counterpoint to the life, if not the profession, of an engineer, added up to something that increased cultural sophistication and therefore happiness. From this they drew the conclusion that students should roam freely among nonprofessional electives. It is not much of a caricature to say that some felt that eight terms would be best spent divided into eight parts of, say, music, literature, art, history, psychology, economics, political science, and philosophy. In practice in bygone days one department used to insist that if a student entered with, say, two years of high-school German, he should then not be allowed to augment his German but rather be required to study another foreign language in order to achieve "breadth." Of course, the result in fact was that the student had competence in neither language and what he had learned only in part evaporated as he matured. This view of the humanities and social sciences as a charming smörgasbord is fortunately not very prevalent now, but whenever it is voiced it should be refuted.

A reaction against such a view may become violent enough to suggest that all survey courses and core curricula are inevitably superficial and that every student should be required to do "deep digging" in one field, perhaps down to the level of a genuine minor. I have no objection to this view in principle except to remark that it needs to be applied warily. It may in principle be better to study a single work or a single writer in depth than to study a variety of works and authors superficially, but one needs to remember that not all surveys, all cores, all treatments of several works and authors are *ipso facto* superficial though many have been, and that not all deep digging in the humanities at least may be productive for other professionals, especially as it may tend to develop in technical directions. And when it comes to single works, it is absurd to claim that it does not matter what the work is, even if one's interest were to be purely technical. We cannot so limit our interest in literature. The smaller the range of exposure we offer our students, the more important it becomes that the microscope be focused on a work of importance. In literature we have the world of time to draw on; and it is no criticism of our own age to say what can be said of almost any time, that it has not produced many towering works of literature. It seems beyond argument that no recent writer offers work that can be so completely rewarding and so rich in variety as is afforded, say, by the Bible, the great Greek tragic and epic poets, Aristotle, Plato, Dante, Shakespeare, Chaucer, Milton, perhaps Goethe, and a handful of others. We should not dig our deep wells only in the shallow soils of the present, and we must not till the past to the exclusion of the present. This is the dilemma of deep digging.

It also does matter enormously who is directing the spadework. A whole semester, even a year, might be devoted to a study of the cathedral of Amiens. In the hands of the right man it would open up a range of historical experiences, of the movement of people, of the change in social views, of the meaning of symbols, of the growth and evolution of engineering structure, of fable, or art, of theology, of philosophy, and become a major experience in the life of any student. Another teacher, equally informed about this same great building, could make the whole year into a dreary wasteland. This is the problem of concentration, and it cannot be ducked.

Concentration is more attractive to most of us in theory because each of us knows more about some area than we do of another, because we can increase our knowledge in that area compatibly with our general advance in scholarly reputation, and because we think we can teach it with less effort and with more sureness of foot than we can teach any common core which inevitably will contain some matter we do not know very well. This may turn out to be a *fata morgana.* It may work out easily when we are dealing with students who are to become specialists in our own areas; but if our treatment is to be responsible general education, each of us, sitting with his pet work and his microscope on the end of his preferred log, must ask how important his work really is for a young man who will meet but few pet works and how responsible he is for bringing to his students all the vast fringe which lies outside the field of view of his microscope. If he faces the question squarely, he may conclude that deep digging is not really an easier way.

But given the proper amount of precaution and conscience, it may still be the more productive way. Our faculty is not in full agreement on this point, and we may expect to see compromises and combinations with more specialization and selective distribution than we have had in the past. This should be welcomed so long as we are careful that the specialization does not extend to self-defeating limits. This is the crux of what has always been and always will be the central problem of the nonprofessional parts of any curriculum—and, in truth, at least at the undergraduate level it probably applies to the professional parts as well.

DEPARTMENTAL STRUCTURE

Professor Bishop indicates that changes are clearly in the wind, at least in psychology and political science, by which these activities might emerge as independent departments. These are the most fully matured of the specialist sections, but comparable if less pressing stirrings may develop in other fields. Over the past fifteen years of enormous growth, which I intend to summarize in my final report a year from now, the small degree of departmentalization in this school has been highly beneficial. But it is no longer so useful as it was; indeed in some situations—of which psychology offers perhaps the best example—it becomes absurd for a faculty, say, of distinguished economists to attempt any judgment of policy in psychology; similar difficulties may arise elsewhere.

We have here a fairly immediate problem involving psychology and political science and a longer-range one involving other sections. There is surely a chance that the first fissions will set off others and these should therefore occur in accordance with a plan. It seems clear to me that this plan should be designed by my successor, who will have to live with it and make it work. Accordingly, I would hope that, pressing as are the desires of the psychologists and the political scientists, they could reconcile themselves to a delay of one more year so that my successor can be a party to and, indeed, the developer of the new School structure.

On the larger issue of whether the School should be divided into two, one for humanities and one for social sciences, I am clear that unless major changes are simultaneously made in the overall institutional structure of M.I.T., it would be premature to make such a separation, harmful to both groups but probably especially harmful to the humanities. Our School has a substantial advantage, not merely intangible, in being the third largest school in the Institute by a considerable margin, and it would be foolish to throw this away by making our activities the function of the two smallest schools. At the level of graduate education and perhaps with our own undergraduate majors, two schools might suffer no disadvantages, though I do not see what advantages they might gain. But our responsibility—and it is a very large one—to some 3,300 undergraduates in other schools would become more difficult to discharge. I have no sympathy with the view sometimes held that since the dean of a school like ours must in the end be either a humanist or a social scientist, the discipline which he represents will be bound to gain at the expense of the other. This underrates the ultimate fairness of mind and judicial attitude which it is reasonable to expect any dean must cultivate even to the extent of suppressing his instincts. He may always have to act as a brake on highly energetic and ambitious groups and as a prod to groups which are insufficiently energetic and ambitious, but where these groups will appear and develop is not really predictable. Indeed, if I were an anxious professor I would like my dean to feel that his specialized knowledge was remote from my own. To seek built-in sympathy on the part of a dean is a bad reason for splitting a school; and I can see no other reason to recommend it at this moment in time.

GRADUATE PROGRAM IN PHILOSOPHY

Professor Huston Smith has discussed the proposed graduate program in philosophy clearly and in enough detail. I would merely like to add that this program has my full support. I believe its adoption to be in the best interests of the Department of Humanities and of the Institute, and I hope the faculty will so find when the matter comes to vote in the autumn.

COURSES XIV AND XXI

We can continue to be proud of the quality of these curricula and of their growth. We must persist in publicizing them, for very few people outside M.I.T. seem to realize that we do in fact have a substantial undergraduate major program in the humanities and the social sciences. Professor Bishop's comment on proposals for a change of name and of balance as between the social and natural sciences should be studied carefully. As for Course XXI, we should realize how dependent it is upon a very few departments of the Institute. For instance, of the 85 students this year, 88 per cent had their majors in one of only five Courses: Mathematics 27 per cent, Life Sciences 26 per cent, Physics 14 per cent, Electrical Engineering 13 per cent and Chemistry 8 per cent. Or, looked at another way, with the exception of the Department of Electrical Engineering the responses of the School of Engineering to the opportunities of Course XXI have been negligible. The success of Course XXI has been largely due to students from the School of Science, who accounted for 80 per cent of all the double majors; Engineering provided 15 per cent, of which 13 per cent was from Electrical Engineering alone; Architecture provided 2 per cent; Industrial Management 1 per cent; and 2 per cent were unclassified. This and other evidence leads me to feel that if bridges between worlds need to be built, one of the shortest spans in the end will be between the sciences and the humanities.

NEW BUILDING AND LIBRARY

Professors Bishop and Pye have mentioned the new building soon to be constructed behind the Sloan Building. This is a joint project of the School of Industrial Management and the School of Humanities, financed from a variety of sources. It will house a new and much larger Dewey Library which will serve both Schools with our main collections of material in economics, political science, management, and labor relations. It will also accommodate, together with the present Sloan Building, the faculties and graduate students in the same fields, and in the Center for International Studies. Thus we will finally again have all the social sciences together except for the experimental psychologists, and they will be in close proximity.

When these moves are made, facilities will be released in the Hayden Building so that the Departments of Humanities and Modern Languages will be freed from the long constricting coils of inadequate space. Considerable modifications in Building 14 ought to be made at that time, and a detailed study of this, at the level of programming and architectural drawings, should be undertaken now, including studies of possible enlargement of the building.

A major difficulty for the Department of Humanities will not be solved by this move alone. This concerns its library facilities. The Hayden Library building was designed to be the center of library administration for all the Institute and to provide a central reference collection and the libraries of the humanities and social sciences. Subsequent moves have brought the Science Library into the building, where it occupies two-fifths of the Library space originally intended for this School; and yet is not well located for the needs of science and is also terribly overcrowded. Growing reference requirements now monopolize more than half of the one remaining floor of general library space (the north room is too small to serve for anything more than reserve books or a very specialized collection). The economics collection has, it is true, moved to the Sloan Building. But the needs of history, literature, philosophy, and modern languages are not met at all in the space available, which daily becomes less.

Our collections in these fields have inadequacies, but budgetary provisions have been made to improve them substantially. Even if the works are acquired, however, it is becoming less and less possible to shelve them efficiently; while the conditions which confront any intending user are discouraging—including controls, an awkward and long stair trip, and a split collection when he reaches the room. I have no doubt whatever that the Departments of Humanities and Modern Languages are less well served by the Library than any other departments of the Institute and that the disparity is becoming greater despite the infusion of budgetary funds for collections. The Library administration might be able to take a somewhat more generous view of the needs of these departments and their students, but it cannot go very far within the limits of the present walls. The problem can be solved only by the creation of a substantial and useful and properly located library for the sciences and the return to the humanities of the space now occupied by science. When this is done (and science needs it as much as we) and a first-class humanities library is established *on the ground floor,* our problem should be solved for quite a number of years. Until this is done, however, we are living in a time of crisis which deepens daily and which is already unbearable. I am not in the habit of crying "Wolf!" in these reports, and it is inappropriate for me to speculate here on the needs of the Science Library, but I am convinced there is no other problem currently facing the School of Humanities which is so bitter and so urgent as this one.

MUSIC AND DRAMA

Professor Liepmann has suggested a revision of the curriculum in music and an extension of the subject offerings. I am not in full agreement with this proposition. Music is in fact very large at the Institute now, well supported financially, and well known outside M.I.T. due to the splendid performances conducted by Professors Liepmann and Tucker and Mr. Corley, all under the vigorous direction of Professor Liepmann. He and we have much to be proud of, including not only the well-known spectacular things such as the Choral Society's foreign tours, the Spring Festival, and the Humanities Series but also such fine and less publicized events as the five o'clock chamber music concerts in the library directed by Professor Tucker.

But it does not seem to follow from this that drastic increases in the total activity, either extracurricular or curricular, are necessary. The number of registrants in the more advanced subjects does not seem to predict a great demand for more variety. Our problem is rather to maintain our present standards and to push them gently upward as we can.

This is especially true since we should be putting more funds behind the excellent drama program conducted by Mr. Everingham and into the arts program of which I shall write later. Mr. Everingham rightly feels that he has a good, if modest, program and that it would be extravagant to spend a lot more money on it within the present physical facilities which are normally limited to the Little Theater in Kresge and some cramped dressing rooms and offices in the same area. So far as the various performing arts are concerned, our greatest need is not for larger and better concert halls—Kresge Auditorium serves well for most musical events and its capacity is seldom fully taxed save on occasions of Boston Symphony Orchestra performances or spectacular drawing cards such as Aldous Huxley's lectures. I have no doubt that we need a new and much better theater and workshop. So does the Cambridge and Boston community. It is a project towards which we ought to direct considerable energies, beginning now.

In saying this I by no means wish to imply any desire to "contain" music at M.I.T. More than fifteen years ago we made a decision that we could not at that moment and with our then-resources develop both music and the fine arts adequately. We chose for the moment to concentrate on music. The wisdom of this choice is apparent in the achievements of Professor Liepmann and his team. Now the time has come to bring the drama and the fine arts to parity, not by diminishing music but by augmenting the others. The choice between them will need to be exercised only as they are opposing claimants for the *same* new funds.

THE VISUAL ARTS

The visual arts program does not come within the jurisdiction of this School save with respect to the exhibition program, the budget for which has been in my hands for some years. So it is inappropriate for me, at least in this report, to say much about the present situation except to indicate that it is overdue for enlargement. M.I.T. does not offer enough work in the arts, either in studio, history, or criticism. We do not attract enough students to the subjects which we do offer. The gallery in Hayden has served us well and is still attractive and well located, but it is too small for many purposes. The exhibitions put on by Professor Beckwith and Miss Jean C. Bullitt have been distinguished and original and have become part of the life of the larger community, but there are not enough of them. We do not have enough good works of art on the campus in places where they can really be encountered. The whole program needs enrichment and enlargement —and quite a lot more money. In this as in music and drama the extracurricular experiences are quite as important as—perhaps more important than—the curricular and certainly can affect more students.

During the last few years a fine outside art committee has been established, presently under the chairmanship of Jeptha H. Wade, III, '45. This committee has been instrumental in acquiring a number of art works which have been strategically located and has made highly important recommendations on a number of major points. It was this committee which commissioned *Elmo III* by Dimitri Hadzi, referred to by Professor Beckwith in his report.

The symbolic importance of this installation on the terrace of Hayden can hardly be overestimated. But it also says to me every time I walk by it that the time has come for a giant step in the arts at M.I.T. It is probably not a step that can be taken by any one school alone, for the School of Humanities has an interest in the arts that is quite different from those of the School of Architecture. I think we need a building as a Center for the Visual Arts and should seek to have one. But such a building, real or imagined, must have two doors, equally inviting. Through one should pass the makers of art and through the other those who discuss and observe it. Perhaps inside they might find a common meeting ground; though this is not easy, for artists and architects tend to think they would be better off without the "polished pretenses of historians," as one well-known architect put it recently. But the meeting ground might be there, and it is certain that of my two metaphorical doors neither should bear the inscription that stood over the gate leading to Dante's city of woe.

A FORWARD STEP

There are some of us who believe that a serious competence in at least one contemporary foreign language is one of the hallmarks of a truly educated man. Such an understanding has, of course, the practical advantage of making one at ease in one's professional literature, of helping one to carry on a business transaction or just to get about more comfortably, since it is a fact that many fewer educated and uneducated foreigners handle English well than Englishmen and Americans presume. But there are also larger values, cultural, aesthetic and civic—the better understanding of, say, General de Gaulle or Konrad Adenauer as a product of a people who use (and enjoy) the language they do. Those who feel this way wish American universities and colleges generally had an entrance requirement in foreign languages and even more that there were a graduation requirement of competence in at least one language. But this sort of requirement is missing in almost all our institutions, including the leading ones. It is rather an absurdity that having made no language requirement for the undergraduate degree, and usually none for admission to a graduate school, we then all turn around and require from our Ph.D.'s a reading knowledge in two other languages. The theory, of course, is sound —that a scholar must be able to work in literature that is not translated; the practice is shabby in that usually the requirements can be met by laboriously working through the language of one's special field with a dictionary at the elbow. It is pretty certain that people who read with such pain will do little such reading later and that they will soon forget what little foreign language they know. On the other hand, there is a level of competence in a foreign language which, having been reached, is not eroded easily. This is what we should seek to inculcate. Those of use who feel this way are encouraged by the recent action of the Committee on Graduate School Policy reported by Professor Locke, which permits a student to substitute substantial competence in reading and speaking one foreign language, consequential to his field, for the minimum requirement in two. It is not a large step, but it is distinctly in the right direction.

TRAVEL

During the year I had the privilege of assisting in the School of Industrial Management's seminar program in India and incidental to this voyage lectured in Lebanon, Iran, and Pakistan and traveled in the Hunza Valley of the Karakorums and later in Greece, Turkey, Spain, and England, collecting more architectural slide material. In November I was privileged to lecture in the *Aula Magna* "George S. Messersmith" under the auspices of the Instituto Mexicano-Norteamericano de Relaciones Culturales, A.C.

VALE!

The preceding reports have recorded all the staff changes in the School save one, which I must report with mingled regrets and pleasure. For several years, Arthur L. Singer, Jr., has worked as the intelligent and efficient aid to a number of us, particularly to Professor Millikan as Executive Officer of the Center for International Studies and to Dean Howard W. Johnson and me as Assistant Dean of our respective Schools, concurrently. Everything he did, he did well and we shall miss him a great deal. But our disappointment is more than tempered by the knowledge that he left us at the end of the academic year to assume a more influential role as Executive Associate of the Carnegie Corporation of New York. I know he will be equally effective in his new role. Perhaps it is only fitting that we should in this way repay the Carnegie Corporation for the steady support it has given our School in so many of our enterprises!

JOHN E. BURCHARD

SCHOOL OF INDUSTRIAL MANAGEMENT

RESEARCH ON THE PROCESS and problems of management is a force of increasing power in American enterprise. Management remains an art, where the quality of business judgment, combined with courage and a resolute spirit, distinguishes success from failure. But increasingly business judgment is being informed by a growing body of research-based knowledge. Powerful tools of mathematics and statistics, coupled with the capacities of the computer, are multiplying the range of alternatives available for management decision. Problems are being solved in production and distribution, market analysis, asset management, in the very dynamics of industrial systems. Economics is contributing substantially to analysis and measurement of capability and performance. The study of history is illuminating processes of innovation and business strategy. The behavioral sciences are displacing the folklore of leadership with new understanding of individual motivation and incentive, of group goals and attitudes derived from the rigorous testing of ideas.

This work, both basic and applied, is gaining momentum in the universities, in industry, and in government, with important encouragement from the foundations. The effects of this growing body of research-based knowledge on the education and development of managers of the future cannot be predicted with certainty. It seems clear, however, that managers whose judgment is buttressed by new knowledge have the probabilities of success in their favor.

The past and the promise of management research impose on the schools of management a multiple duty to the industrial community. They must lead in challenging old ideas, in conceiving and testing new ones; they must train men for teaching and research in management; and they must convey to managers, both of this generation and the next, the significance for management of new and relevant knowledge.

Management Research at M.I.T.

The School of Industrial Management has been fortunate to develop in M.I.T.'s research-oriented environment dominated by a rigor of method, a readiness to experiment, and an excitement of discovery. As President Stratton said in his address marking the success of the Second Century Fund, "The total body of (our) research is large indeed; but it is a life-giving force to the institution. It is not something apart from teaching but is completely bound up with the whole process of education."

For the School, the work of the year just ended reflects this interaction of research and education. It was a year of new emphasis and increased momentum in the research of our faculty and student body. It was a time of review and re-orientation of the curriculum on several levels, with the more effective treatment of new analyses and new approaches a principal objective. In summarizing the year, it may be useful to look first at the direction of our research.

MANAGEMENT OF RESEARCH AND DEVELOPMENT

Last year my report noted the grant from the National Aeronautics and Space Administration for research into the organization and management of large-scale technology-based enterprises. Under the general direction of Professor Donald G. Marquis, the studies under way and planned for the future are being focused on the broad problem of understanding and improving the effectiveness of research and development activities relative to their goals. Major attention is being devoted to approaches to the evaluation of research performance. The work of Professor Marquis and Professor Edward B. Roberts, now Associate Director of this study known as the Organization Research Project, is directed to theoretical and empirical analysis of performance by projects and by laboratories. Studies directed by several faculty members are being made within various research organizations of such relevant factors as competence and motivation, information and communication, interpersonal relations, and the relationship between work organization and spatial arrangements. Simultaneously, the project has stressed educational aspects, with extensive graduate student involvement in the research and in seminars growing out of it.

The Organization Research Project has marked promise and gains momentum steadily. Its focus on the management of research and development is appropriate to the interest of our faculty and of the Institute as a whole. Additionally, members of the School's faculty will also participate in the general framework of the Center for Space Research, now being developed at M.I.T.

RESEARCH IN BUSINESS FINANCE

During the year the Ford Foundation granted funds to the School to spur research and more effective teaching in the fields of business finance and industrial relations. The grant in support of research in finance is especially timely, for it will significantly advance the research efforts of our faculty in their two major areas of interest—capital investment and financial decision-making under uncertainty. The particular research activities of the faculty illustrate these interests. Notable are the concern of Professor Franco Modigliani with the cost of capital and market valuation; his study of the determinants of consumption, saving and accumulation of assets; and his research in the area of monetary theory and monetary policy. Professor Daniel M. Holland continues his study of the effect of taxation on personal effort and rewards, with particular attention to groups whose decisions appear to be important to economic growth. Professor Edwin Kuh has completed his book, *Capital Stock Growth: A Micro-Econometric Approach,* and continues his work on the cyclical distribution of income. Professor Paul H. Cootner's studies have been on the problem of financial decision-making under conditions of risk and uncertainty. These four members of the faculty summarized their recent work in a symposium on financial decisions held this spring.

INDUSTRIAL RELATIONS RESEARCH

The grant in support of industrial relations aids research with a broader base than the term normally connotes. It includes relationships among all people within an organization as well as among organizations. Here the principal emphasis is upon the factors producing change, reactions to change, and means of accommodation to change.

We will be interested here, for example, in the solutions to problems of employee displacement due to automation, to problems of manpower renewal and development within radically changing technical environments, and to problems of communication and accommodation in change situations. In the traditional areas such as union-management relations and line-staff relationships, the focus will be on the nature of problems in an environment characterized by rapid technological advance, by increasing activity on the part of government, and by changing "social expectations." Work in this area is being carried on jointly by Professor Douglass V. Brown and other members of the faculty of the School of Industrial Management and by members of the Industrial Relations Section of the Department of Economics and Social Science, headed by Professor Charles A. Myers.

RESEARCH IN ORGANIZATIONAL BEHAVIOR

Our faculty in organizational studies, headed by Professor Douglas M. McGregor, grows steadily stronger and now numbers nine full-time men. Under a policy which encourages its members to pursue their individual behavioral science research interests in organizational phenomena, a wide range of research is under way. One cluster of projects involving members of this faculty has already been reported on in connection with the Organization Research Project. It is important to note here as well, however, Professor McGregor's own study of the planning, strategy, and consequences of a major organization change in a large utility; Professor Warren G. Bennis' work in the analysis of the strategy and consequences of a major business effectiveness program; and his plans, in collaboration with the M.I.T. Civil Engineering Department, for studying the social consequences of computer installation in a Latin American country. Professor Edgar H. Schein continues his promising study of organizational influences on attitudes and values, a research program which is illuminating our understanding of early career development in managers. Professor David E. Berlew is examining managerial "coping strategies" under career stress. Professor William M. Evan has begun studies of the consequences of various strategies for dealing with conflict within and between organizations, and Professor Peer O. Soelberg is furthering his analysis of individual decision-making and complex information processing. Professor Leo B. Moore continues his study of the decision-making process at the senior executive level.

Much of this research is still in process and as yet unpublished. Its potential is great, and I anticipate significant contributions from it.

THE QUANTITATIVE AREAS

It is difficult to apply the term "quantitative" with meaning to any single group of researches, since the application of measurement, analysis, and testing is a traditional area of strength across the whole reach of the School. Some of the work already mentioned may be so classified. But I use the heading to describe such advances as the following. Professor Martin Greenberger is devoting substantial effort as a member of M.I.T.'s Technical Committee for the Development of the Multiple Access Computer. I note with pleasure the appearance of Professor Geoffrey P. E. Clarkson's *The Theory of Consumer Demand: A Critical Appraisal* and his continuing work on the theory of decision-making behavior. Professor John D. C. Little has developed efficient methods for solving certain types of programming problems which are of general interest. Professor Lionello A. Lombardi has completed his basic design of the "incremental computer" and its language. Professor Gordon M. Kaufman, who took a leading part in developing and teaching the new two-term sequence in Mathematics for Industrial Management, has continued his work in applied statistical decision theory and his simulation studies. Professor Ronald A. Howard, whose work bridges the Department of Electrical Engineering and this School, has carried on his research in probabilistic systems models and automatic instruction systems.

Industrial dynamics, a field in which the School has pioneered and which I have described in detail in previous reports, continues as a significant field of study for us. Professor Jay W. Forrester and his associates have advanced their research in growth dynamics, a line of inquiry showing promise of practical new insights into causes of growth problems in new companies.

RESEARCH IN APPLIED FIELDS

I would not wish, in this selection and summary of research under way, to imply neglect of other active areas. In marketing, much study has been given to the systems interrelationships of market forces, with conclusions incorporated into a game for teaching and further research. I wish to note, in this field as well, the publication of Professor Henry J. Claycamp's monograph, *The Composition of Consumer Savings Portfolios.* In production, or management of operations, the development of a simulation of production problems has been an important focus of attention. Noteworthy, also, is the field study of Professors Edward H. Bowman and William F. Pounds of decision-making at the operations level. In the area of management information and controls, much work is under way on the impact of mathematics and the computer on the whole process of planning and control in organizations, with special attention to effects on goals and structure. In the field of international business, James C. Abegglen and Hiroshi Mannari have completed their study on careers of modern Japanese business leaders. Professors Carroll L. Wilson and J. Daniel Nyhart have initiated an important study of development banking which should be extremely useful to managers and policy makers interested in economic development.

In another area, Professors William L. Letwin and William P. Travis have completed manuscripts of forthcoming publications—Professor Letwin on *The Origins of Scientific Economics: English Economic Thought, 1660-1776* and Professor Travis on *The Theory of Trade and Protection.*

GRADUATE STUDENT RESEARCH

The research activities of the School cannot be described in full without mention of the major contributions being made by our graduate students, whether as research assistants working under the guidance of the faculty or as independent workers in thesis preparation. The quality of thesis research increases steadily. Eleven Master's theses were nominated for the Brooks Prize, and the award was made to Charles H. Greer for his thesis entitled *A Gaming Approach to Management Education.* The *Industrial Management Review,* whose editors this year were Charles H. Greer, Emery G. Olcott, and Gillett Welles, III, is steadily developing as a publication of value in recording research results and highlighting topics of interest to the business community.

The Curriculum

I stressed, in the opening paragraphs of this report, the interaction of research and education and the focus of the year just ended on the introduction of new knowledge into the curriculum. It will be useful to record the nature of these changes.

THE MASTER'S PROGRAM

A principal objective of our study of the Master's curriculum in the past year was to improve further its quantitative content, taking greater advantage of the strength of our faculty and taking explicit cognizance of the mathematical tools and the managerial applications of the computer as a component of the curriculum. Central to this change is a new required first-year subject in Managerial Models, integrating material previously taught in other subjects such as mathematical programming, Markov processes, forecasting, simulation, and non-analytical problem solving applications to topics such as inventory control, budgeting, and project scheduling. This subject thus contains elements of analysis that are common to accounting, production, marketing, and finance. These areas, as well as those covered in the two-term subject in Mathematics for Industrial Management introduced in 1963, will be closely linked with the new Managerial Models subject. While this represents a more orderly alignment of our quantitative work, it does not signal a shift of emphasis. The studies of economics, organizational behavior, and the environment of the firm, as well as the business problem areas, continue to be key elements of the curriculum, and we expect them to strengthen, if anything, in the planning to be undertaken next year.

These structural changes, effective in the fall of 1963, will give new integration to our Master's degree program, a program that continues to attract able young men in increasing numbers and provides them a quality of management education for which there appears an increasing demand by American industry. Eighty-nine men were awarded degrees in this program in 1963, and nearly one hundred more will register in the fall of 1963, selected from among more than 350 who applied.

SLOAN FELLOWSHIP PROGRAM

During 1963 the Sloan Fellowship Program observed its twenty-fifth anniversary as a competitive, nation-wide fellowship supported by the Alfred P. Sloan Foundation. This has been, in many ways, a pioneering program in the development of industrial executives, and it continues, in such ventures as its European Management Visit, to break new ground in executive education.

This year a committee chaired by Professor Stanley M. Jacks has given each aspect of the program careful study—its objectives and place in the School, its duration and degree status, the selection of Sloan Fellows and the size of the Sloan group, and their curriculum. This review has reaffirmed the Sloan Fellowship Program as a full year in length offering an opportunity for the Master of Science in Industrial Management to the Sloan Fellows who meet the requirements, and it has resulted in a number of curricular changes

The principal revisions in course structure, which begin to be implemented in the summer of 1963, are in the quantitative studies, organization studies, and the humanities. A continuation of the sensitivity training laboratory is planned, followed by the preparatory program in economics, an expanded subject on management information and control and a full term on quantitative approaches to management problems.

Building on this base a new subject, Operations Management, will be introduced into the fall term to include, as new topics, computer applications and management information systems. An experiment in the programmed teaching of basic accounting was begun in 1963 with the newly selected Sloan Fellows completing an experimental programmed teaching text prior to their arrival at the Institute.

The new sequence in Organization Studies provides for a two-term subject in organizational behavior. The emphasis on humanities in the Sloan Program expressed now through the subject Readings in Power and Responsibility will be increased by extending this work over two terms. Two recent innovations should be noted: the Seminar in the Arts and Sciences, which brings the Sloan Fellows into contact with distinguished scientists, artists, and scholars in the Cambridge community; and the extended mid-year period of thesis research and preparation.

The Sloan Fellowship Program, given its position of leadership and responsibility in the executive development field, must continue to experiment with the new and then consolidate its achievements. The emphasis this past year has been on program review and curriculum revision. But some basic facts about the program must be added. Forty-two Sloan Fellows received the Master of Science degree at M.I.T.'s graduation exercises in June, and forty-six Sloan Fellows, the largest number in history, five of them from companies sponsoring Sloan Fellows for the first time, began their year of study with the summer term.

UNDERGRADUATE SYSTEMS CURRICULUM

A third major area of curriculum review concerns the undergraduate program. Undergraduate education in management has continued to have a useful role at M.I.T. It affords an opportunity for the engineer—and prospective manager—to learn some of the fundamentals of management, and it provides an undergraduate degree offering a combination of M.I.T.'s basic preparation for science and engineering with formal work in management. This year 138 students were enrolled in this program, known in M.I.T.'s traditional nomenclature as Course xv, and 48 seniors have received their Bachelor of Science degrees. The Industrial Management Association award for the outstanding thesis of the year was given to Robert E. Lindquist, Jr., who wrote on *A Simulation of New Haven Railroad Yard and Freight Train Operations.*

During 1963 a small-scale experiment in this curriculum has been devised by a faculty committee of which the prime mover was Professor Forrester. This experiment carries the title of the "Undergraduate Systems Curriculum." Its primary objective is to instill in a student fundamental insights into the industrial system and the way it behaves as a result of system practices, structure, and interactions. Our hope is to develop a student who is able to look beyond the symptomatic behavior of the work system into the causes that interact to produce the behavior. He will then be positioned to make more effective managerial decisions. The experiment will begin with students at the start of the junior year and will run two years to the S.B. degree. A research core of the curriculum will consist of a series of projects in the creation and study of models of dynamic systems. A series of study units will be developed for each of the principal concepts which the student is expected to understand. Some of these will relate to the functional areas of management, others to the basic principles of the dynamic behavior in systems. Twelve students have been selected to begin the program in the fall of 1963. It is expected to continue at least over a five-year period, and all of us in the School are greatly interested in its outcome.

OTHER CURRICULUM CHANGES

Curriculum changes affecting the undergraduate, graduate, and Sloan programs have not been confined to the major studies discussed above. It has been a year of general re-examination as subjects have been realigned and new subjects added to take advantage of new faculty strength, new research inputs, and better integration of the course structure.

The organization studies curriculum, for example, was re-organized by Professor McGregor and his colleagues to provide a related series of behavioral science studies emphasizing underlying theory and applied fields and utilizing the various special competences of the faculty.

Marked changes have also been made in the subjects dealing with management information and control, all of them aimed at giving more emphasis to the decision-making aspects of measurement and information. The emphasis in these studies, under the leadership of Professor Zenon S. Zannetos, is on the necessity, theory, and design of such information and control systems; the design of organizational structures; and the methods of generation as well as the types of information that are necessary for economic and decision-making models. To transmit the results of some of the research for management use, a Special

Summer Program on Management Information and Controls was organized for the first time this year. Conducted by Professor Zannetos and Professor James C. Emery, it covered many of the more important current topics in this area of central interest to management.

In finance, the group headed by Professor Holland and greatly strengthened by the addition of Professor Modigliani, and the return of Professor Kuh from a year of study abroad, has revised and expanded its curriculum with new materials and new subjects which reflect the special competences and research interests of the faculty.

In marketing, Professors Ross M. Cunningham and Arnold E. Amstutz and their colleagues have tested a new subject which emphasizes a systems approach using each of the elements of marketing as part of an integrated system of relationships and treating what is known about every element in the marketing environment in an explicit and quantified form. Work has progressed in the refinement and sophistication of the M.I.T. Marketing Game, substantially increasing its usefulness as a component of the curriculum. Professor Billy E. Goetz, Professor Bowman, and their associates have redesigned the sequence of subjects in the management of operations to take advantage of the new mathematics and management science sequence. Only a few years ago, the work of this group began a new approach to the study of production management that has had its effect on business schools throughout the country. Now, with a better analysis base secure, we are preparing to move more heavily to problems of process and practice in management operations.

All these improvements in curriculum go on more or less continuously, but this year an accelerated pace reflects both the increase in strength of the faculty and new discoveries in their fields.

TUTORIALS IN AMERICAN POLITICAL ECONOMY

To improve the graduate student's ability to organize and express his ideas effectively, Professor Elting E. Morison, with the cooperation of a number of the faculty, has organized a series of tutorials as a part of the required first-year subject, American Political Economy. Each week during the term the students were required to write a paper related to the course and individually to review with a faculty member its essential ideas and their organization and presentation. The reaction of both the graduate students and the faculty to this tutorial relationship has been a good one. It remains to find the time in a crowded calendar to continue this important process.

THE DOCTORAL PROGRAM

The emphasis in the preceding paragraphs has been on programs under active review. At the same time, note should be taken of the School's doctoral program, launched in 1960, which is making its impact upon the School in many useful ways. Thirty-five doctoral candidates are now registered; thirteen more will be admitted in September from among 87 applicants for admission. Two men received the Ph.D. in Industrial Management in June. The work of a number of others is sufficiently far advanced so that they are able to accept faculty appointments at M.I.T. and elsewhere while completing their thesis requirements for the degree. This program has provided, certainly, a new dimension to the School. The stimulus of bright young men studying the problems of management with considerable insight and enthusiasm is a source of satisfaction to us all. Needless to say, there is substantial beneficial impact on the research activities in the entire School.

PROGRAM FOR SENIOR EXECUTIVES

Our Program for Senior Executives, along with the Sloan Fellowship Program under the direction of Dr. Peter P. Gil, continues to attract—and in increasing numbers—high-caliber men at senior levels of responsibility. This ten-week program, which this year completed its fifteenth session, gives strength to the School through the fruitful interchange between experienced managers and a management faculty. At the same time, it appears to be serving a useful purpose for those companies—and their executives—who value M.I.T.'s emphasis on the fundamentals underlying management decisions and the opportunity for close acquaintance and substantial faculty contact that the small group of twenty to twenty-five provides. Observers of the spectacular increase in "executive development" programs across the country in the past few years have been fond of saying recently that "the bloom is off the rose" in this field. It seems fairer to say that the weaker varieties of roses are dying off. With good cultivation and some pruning, the hardy ones continue to bloom well indeed. That, at least, has been our experience in the M.I.T. programs. The fact is, of course, that education in mid-career is becoming a necessity in a rapidly changing world. This past year we have seen the beginnings of the extension of this principle to the field of engineering, with the School of Engineering's program for Advanced Engineering Study sponsored by the Sloan Foundation. We expect to extend every support to this new program, and we predict that this new variety of mid-career education will bloom with attractiveness and authority.

GREATER BOSTON EXECUTIVE PROGRAM

The Greater Boston Executive Program in Business Management, an activity of the School of explicit service to the Massachusetts business community, has now completed its sixth year. Interest in this program, both on the part of the participating companies and their executives, remains high. Conducted for fifteen full-day sessions during the spring term each year, the program now has close to 150 energetic alumni whose enthusiasm for continuing their learning beyond the classroom is manifest in their desire each year to return for refresher sessions with members of the program faculty and for renewed contact with their colleagues in the program.

International Programs

I turn now to further developments within the School itself. The international management scene has beckoned to us and occupied an important, if small, segment of our effort over the past three years. We have been at it long enough to know that this activity will become increasingly important for us. The fact is that the development of all countries—more or less developed—will depend in large part on the quality of management, both public and private, involved in the enterprise of those countries. Our School is being singled out as a source for ideas and resources in several areas of the world. We can expect this to continue.

THE ADVANCED MANAGEMENT PROGRAM IN INDIA

In India, the work of the School has continued to meet with a favorable response. At the request of the All-India Management Association and the Ford Foundation, a faculty team led by Associate Dean John M. Wynne and including Dean John E. Burchard and Professors Letwin, Myers, Thomas M. Hill, and Wilson conducted in Kashmir the Third Advanced Management Program for the most senior executives of Indian firms. Another team, led by Dean Johnson and Professors Brown, Bowman, Hill, and Max F. Millikan, together with members of the Indian Institute of Management faculty, conducted the fourth session in the summer of 1963. The response to this program has been highly rewarding to the faculty who have contributed to it, and it is seen as an important symbol of the potentialities of management education within India. We hope that the Programs can continue under the auspices of the Indian Institute of Management at Calcutta in the future, with support from the M.I.T. base.

INDIAN INSTITUTE OF MANAGEMENT AT CALCUTTA

On a larger scale, the collaboration of the School with the Government of India in the formation of the Indian Institute of Management at Calcutta is bearing fruit. Two short executive development programs were held during the year: the Indian Institute, with help from Professor Gerald B. Tallman, conducted a four-week seminar for executives in Indian firms on planning marketing strategy; and later in the year Professors Hill and Emery conducted a similar seminar on financial planning and control. The two American faculty members at the Calcutta Institute under M.I.T. auspices will be increased in mid-1963 to five under the leadership of Dean Wynne, who replaces Professor Hill on his return to M.I.T. in October, 1963. Great credit must go to Professor Hill for his work there. An Indian faculty of very high quality has been attracted by the bright hopes of the Institute, and it has every prospect of making a substantial contribution to the development of enterprise in India if the present major barrier—inadequacy of physical plant—can be removed.

We will miss the valuable contribution here of Dean Wynne during his term in Calcutta, but his going there reflects the serious interest that the School attaches to the success of the Indian Institute of Management.

M.I.T. FELLOWS IN AFRICA

The M.I.T. Fellows in Africa continue in a significant way to aid the development of the new nations where they are assigned. This program, conceived by Professor Wilson and effectively organized with the help of his associate, Professor Nyhart, has successfully met an explicit need of the countries participating and has even more importantly been a trail-blazer in a new pattern of international cooperation. Sixteen men were in Africa during 1963; six of these will return to the United States in the summer of 1963 at the conclusion of their two-year tours, and nine will begin fresh two-year assignments. Most of those who returned during 1963 were given appointments as Research Associates in the School to review and write on their experiences. This has been a unique venture for the School and a useful one to the African nations where the M.I.T. Fellows have served. The important lesson of this program has been, it seems to me, that able young men, suitably prepared, can make substantial contributions to enterprise and economic development if they are properly placed and supported. It may soon be time to move the application of this lesson to other areas of the world and to other problems of management.

School of Industrial Management

New Physical Facilities

For the past few years, these annual reports have stated the needs, increasingly urgent, for expanded facilities for the School. The most pressing of these have been for a much expanded library, more student and faculty research space, more seminar rooms, and, in another category, some adequate living accommodations for our graduate students. *All of these are now to be realized.* It has been an exercise in forbearance in this review to delay reporting until at this point our progress on this important aspect of the School's development. At the same time, however, it is appropriate to report such progress in the context of our principal goals—education and research for management.

We will break ground before the end of 1963 for a new four-story building to be situated to the rear of the Sloan Building. Separate from the Sloan Building but associated with it, this new structure will house a two-floor library devoted to the management and social science collections of M.I.T.; its two floors of office and seminar space will give us for the first time adequate research and study space for students in management, economics, political science, international studies, and related fields, making possible more effective collaboration between the social sciences and management. This excellent addition to M.I.T. will be possible as a result of a gift from Alfred P. Sloan, Jr., a grant from the National Science Foundation, and a major gift from an as-yet anonymous donor. Plans are not yet complete, but the forecast for the facilities is a good one; we will spare no effort to make this an outstanding extension to education at M.I.T.

At the same time, we expect to complete plans for a large tower residence for married graduate students, to be built also to the rear of the Sloan Building. This facility will serve M.I.T. as a much-needed expansion for housing for our students. It will also bring facilities, now sorely lacking, for M.I.T.'s guests and special students. This structure, harmonizing with the Sloan Building and the management and social science building already described, will be financed in part by federal mortgage funds and in part by an additional gift of an anonymous donor.

While completion is still two years away, the vision of these two buildings will sustain us—faculty and students—during the crowding that presses upon the entire School now.

Staff Changes

It gives me great pleasure to report the promotions to the full rank of Professor of Industrial Management of Warren G. Bennis and Thomas M. Hill.

Our work in business finance, outlined earlier in this report, will be advanced during the coming year by the presence of Professor Roland I. Robinson from Michigan State University. He will be with us as Visiting Professor of Finance during the year's research leave of Professor Modigliani on a Ford Foundation Faculty Fellowship. Added strength in this area will come also from the appointment of Dr. H. Martin Weingartner of the University of Chicago, whose thesis won a 1962 Ford Foundation Dissertation Award, as Associate Professor of Finance. Dr. Donald E. Farrar, winner of a Ford Foundation Dissertation Award in 1961, will join us as Assistant Professor of Finance. At the same time I note with regret the resignations of Assistant Professors John D. Bossons, who goes to Carnegie Institute of Technology, and Myles M. Dryden, who leaves for the University of Edinburgh.

Dr. James J. Linn comes to M.I.T. from the University of California and will be associated as Assistant Professor with our work in management information and control. However, Professor Robert L. Dixon of the University of Michigan is terminating his productive association with us in the same area as Visiting Professor of Industrial Management.

Three men are ending their work as Lecturers in the School: James C. Abegglen, John P. Eberhard, and Robert K. Greenleaf. Their presence and service here will be missed. I am pleased, however, to announce the association with the School, in the capacity of Lecturer, of Richard S. Morse, Chairman of Cryonetics Corporation, who will continue his subject on Organization and Management of New Enterprises introduced in the spring of this year; Richard Beckhard of Richard Beckhard Associates; and Frank J. Carr of Westinghouse Corporation, who will lecture in the area of management of operations during the absence next year of Professor Bowman. I am also pleased to report that Harold J. Szold, partner in Lehman Brothers, will share his extensive experience with our graduate students as a Lecturer.

Two new appointments in which we take a special pride because they are products of our own doctoral program are those of William H. White as Assistant Professor of Finance and Charles H. Kriebel as Instructor.

Designated as the first Alfred P. Sloan Faculty Fellows are Dr. Sidney R. Maxwell of Brunel College, London, and Dr. William T.

Newell of the University of Washington, who will be in residence at M.I.T. during the forthcoming year.

Dr. Edward L. Bowles, whose contributions to the School and to the Institute over the years have been invaluable, became Professor of Industrial Management, Emeritus. Our students will continue to draw on his wide knowledge and varied experience in his continued association with the School.

I regret to report the death this past year of Charles Huntington Porter, Professor Emeritus of Business and Engineering Administration. Professor Porter was appointed to the M.I.T. faculty in 1927 and served until his retirement in June, 1949.

We have been especially saddened by the sudden loss of our good friend and colleague, Professor Houlder Hudgins, who died in July, 1963. Professor Hudgins was appointed to the faculty of the School in 1955, and his untimely death will be keenly felt by all of us—faculty and students alike.

Administration of the School

The following changes in the internal administration of the School reflect the completion of assignments well done by senior faculty members and the appointment of others of our colleagues to these key assignments.

Professor Jacks replaces Professor Marquis as chairman of the Graduate Committee. Professor Zannetos becomes chairman of the Undergraduate Committee, and Professor Bennis has been designated chairman of the Doctoral Committee in the absence of Professor Bowman.

Constantine B. Simonides becomes Assistant to the Dean in addition to his highly useful work as Assistant Director of International Programs.

I am sorry to record the departure of Arthur L. Singer, Jr., who has served the School well over the past year and a half as Assistant Dean; he leaves to join the staff of the Carnegie Corporation. I note also the departure of J. Bruce Neighbor after three years of effective work as Assistant Director of Executive Development Programs. He will be succeeded by Miss Priscilla A. Karb, formerly Director of the Non-Resident Term and Placement at Bennington College.

Staff Activities and Awards

The full scope of the enterprises of an active faculty is not reflected fully in an account of their teaching and research. I take pride in the list of professional honors and activities of members of the School listed at the back of this book and draw attention, in addition, to the following contributions:

Meriting special mention is the choice of Professor Forrester's book, *Industrial Dynamics,* by the Academy of Management for one of the five McKinsey Foundation Awards given books "of greatest value to executives;" one leading management journal has said that *Industrial Dynamics* may be ranked by future generations as one of the management classics "pioneering the measurement of interactions between factors which determine the growth and stability of business systems."

Three members of the faculty received Ford Foundation Faculty Doctoral Dissertation Fellowships for the forthcoming academic year: Professors Donald C. Carroll and Soelberg and Mr. Otto H. Poensgen.

Professor Holland continues to serve as a member of the Treasury —Internal Revenue Service Committee on Statistics, advising the Commissioner of Internal Revenue.

Professor Kuh was a consultant to the Council of Economic Advisors on the construction of a multi-sector growth model. He continues as a member of the Social Science Research Council Econometric Project and next year will be principal investigator.

Professor Morison delivered a series of three papers at the California Institute of Technology on *Three Uneasy Relationships:* The Muse and I, Men and Machinery, and Poetry and Politics.

Professor David Durand spent the year on leave completing work on his book on *An Introduction to Statistical Control.*

Professor Howard is a member of the Education Committee of the Operations Research Society of America and was a visiting scholar at Stanford University in April of this year.

Professor Bowman was Chairman of the Cleveland meetings of the Operations Research Society.

Professor Berlew participated in the selection and training of the ACCION volunteers for service in Venezuela.

Professor Evan served as Chairman of the sessions on the sociology of law at the Fifth World Congress on Sociology in Washington, D. C.

The Advisory Council of the School

The School continues to be greatly strengthened by the counsel, advice, and support of its Advisory Council, chaired by Alfred P. Sloan, Jr. The past year saw the completion of the terms of several distinguished members of this Council: Albert Bradley, Director and former Chairman of the Board of General Motors Corporation and Trustee of the Alfred P. Sloan Foundation; Wayne J. Holman, Jr., Chairman of the Board of Chicopee Manufacturing Corporation; Frederick R. Kappel, Chairman of the American Telephone and Telegraph Company; David A. Shepard, Executive Vice President of Standard Oil Company (New Jersey); Robert C. Sprague, Chairman and Treasurer of the Sprague Electric Company; Thomas J. Watson, Jr., Chairman of International Business Machines Corporation; and James E. Webb, Administrator of the National Aeronautics and Space Administration.

At the same time, I am glad to announce the appointment to the Council of Edward Pennell Brooks, Dean Emeritus of the School of Industrial Management; George M. Bunker, President of the Martin Marietta Corporation; Louis W. Cabot, President of the Cabot Corporation; Everett Case, President of the Alfred P. Sloan Foundation; Elisha Gray II, Chairman of the Whirlpool Corporation; Grover M. Hermann, Chairman of the Board of the Martin Marietta Corporation; Hoyt P. Steele, Manager of the Government Relations Service of General Electric Company; William S. Wheeler, Jr., Vice President and General Manager—Military Electronics of Motorola, Inc.; and Joseph C. Wilson, President of Xerox Corporation.

Summary

The stress of this report has been on management research and the impact of new knowledge on the curriculum. This is no new emphasis. Research has always been central to the School's objectives, and past reports have recorded our progress. However, this has been a year of rising tempo, of acceleration and intensification of effort—a change more to be sensed than observed. But it manifests itself in added financial support being offered, in the growing quality of students drawn to the School, in a heightened sense of excitement in new ideas, in special seminars, in new courses and new course materials, and in an expanding stream of contributions to the literature of management.

In an educational institution, research must never be at the expense of concern with the students themselves or their education for enterprise management. Imbalance is dangerous, and we must always guard against an excess of emphasis on research to the detriment of our educational objective. Our students are a great source of strength and stimulus. Their quality increases steadily. Through the Graduate Management Society and the Industrial Management Association they contribute substantially to their own professional development. The premium for their services rises each year, and the demand for their skills increases steadily. Measurement of the value of an educational effort is always difficult, but we do take pride in the account our students give of themselves as they move into industry.

We have much to be grateful for and to be proud of in reviewing our balance sheet at the end of this particular year. I hope it will not seem inappropriate if I say that we have further needs, of course. We need more adequate fellowship and loan assistance for students, increased research support in certain fields of study. There are academic areas in need of greater strength. The forecast for meeting these needs is good, however. With the constant support of the Institute and its leaders, with the manifest interest of the business community and others, and with the continuing encouragement of Alfred P. Sloan, Jr., and the Sloan Foundation, I have great confidence in the future of the School of Industrial Management.

HOWARD W. JOHNSON

SCHOOL OF SCIENCE

THE DETAILS OF ACTIVITIES in the School of Science during the past year are covered by the reports of the individual department and laboratory heads, which form the main body of this discussion. In preparing an integrating introduction, I am taking this as an appropriate time to discuss briefly changes in the School which have occurred during the second and third decades of its existence. The completion of twenty-one years in so central an observation post as the deanship is likely to tempt one to re-assess long-term trends.

It was in 1932 that M.I.T. took the step of becoming a university containing discrete but closely-connected schools, the number of which has now grown to five. During its first decade the School of Science faced and solved many problems arising from its transformation from a group of service departments charged with deepening and broadening the education of engineers, to an entity having more basic responsibilities in the production of scholars in its own disciplines.

By 1942 the School had become a finger, perhaps the index finger if the analogies are not pressed too closely, on a hand which may be taken as symbolizing the organizational structure of the new M.I.T. This metaphor, emphasizing unity in diversity, seems not too inappropriate, for although the various schools lead scholarly existences which are essentially autonomous, in a major portion of their educational activities they are firmly joined under a common administrative structure. The growth of the School of Science must be evaluated, therefore, not as that of an independent entity but as an important part of a rapidly growing institution faced with many new assignments, to each of which the School is expected to make some contribution in greater or less degree.

Because 1942 was a year in which many Institute faculty members, including the new dean, were giving major attention to problems of national defense, and because the war years saw many dislocations in student enrollment and other activities, 1938-39 is here chosen as a more appropriate year than 1942 to use with 1962-63 in making statistical comparisons.

Growth in the School between these years has responded to three principal factors: (1) the increasing excellence of preparation of entering students, which has permitted attainment of new levels of quality in the output of graduates and in their numbers; (2) the enlargement of M.I.T.'s activities made possible by three successful campaigns for capital financial support; and (3) increased support by the federal government of fundamental research through contracts and grants and in other ways.

Greatest in magnitude of these developments have been those involving the expansion of basic research, reflecting the accelerated pace of science and technology throughout the world and especially in America. It has been conservatively estimated that such research activities in this country have increased almost tenfold since 1939. As a university whose principal activities reflect the status and needs of science and its applications, M.I.T. has naturally shared strongly in this growth and been directly affected by it. Expenditures for what may be termed academic research activities at the Institute, as distinguished from its operation of large research laboratories on behalf of the government, have increased about 100-fold in the period under consideration.

In the School of Science the growth of academic research activities has been approximately 150-fold since 1938-39. This particular increase reflects the marked emphasis on fundamentals which was initiated when Dr. Karl T. Compton assumed the presidency of the Institute in 1930 and the growing public appreciation of the fact that all technology and engineering rests on basic science.

INDICATORS OF GROWTH

The total number of faculty of various ranks in the School of Science has changed from 84 in 1938-39 to 221 in 1962-63. The number of undergraduate students specializing in science has grown from 266 to 898. This has reflected an increasing interest in science on the part of university students, much of it the result of accomplishments by scientists during the war, some of it due to confusion by laymen of scientific with technological developments.

A notable trend of the period was the increasing number of students desiring to major in scientific curricula as compared with other curricula offered by the Institute. In 1938 11.9 per cent of the entering class chose scientific disciplines as major subjects, while in 1962-63 57.7 per cent of the 1,446 initially admitted freshmen indicated one of the science disciplines as a first choice. Accompanying this change was an eventual shift from certain engineering curricula to physics as the elected major of the greatest number of beginning students. In 1962-63 the number of second-, third-, fourth-, and fifth-year science majors was 33.7 per cent of the enrollment for those classes; in 1938-39 it was 15.2 per cent.

Of special interest is the increasing enrollment in mathematics subjects, which has grown from 1,453 in 1938-39 to 3,920 in 1962-63. In addition, this Course is now third in number of undergraduate majors in the Institute, after physics and electrical engineering.

Table I shows the number of roll cards in science subjects for the various departments in the years 1938-39 and 1962-63. This table also gives the numbers of undergraduate majors, of graduate enrollment, and of recipients of the degrees of S.B., S.M., Sc.D., and Ph.D. The growth in the number of bachelor's degrees is 220 per cent, while that in the production of doctorates is 117 per cent. This increase in output of science graduates occurred despite the fact that undergraduate enrollment at the Institute increased only about 50 per cent during the period, being 2,401 in 1938-39 and 3,553 in 1962-63.

During the same period Graduate School quotas have been permitted to increase fairly regularly throughout the Institute. The growth in the School of Science has here paralleled that elsewhere in the Institute, being about 4.5-fold.

The faculties of the respective science departments have grown as shown in Table II, which lists the number of faculty in various ranks. Instructors, Teaching Assistants, and Research Assistants as of the two years are also compared.

INCREASE IN RESEARCH ACTIVITIES

As measured by annual expenditures, research activities at the In-

Table I. Enrollment and Degrees Granted in The School of Science

Department	ENROLLMENT						DEGREES AWARDED BY CALENDAR YEAR					
	*Total roll cards**		*Second-, third-, and fourth-year majors*		*Graduate majors*		*S.B.*		*S.M.*		*Ph.D. and Sc.D*	
	1938-39	*1962-63*	*1938-39*	*1962-63*	*1938-39*	*1962-63*	*1939*	*1962*	*1939*	*1962*	*1939*	*1962*
Biology	561	943	43†	75	33†	91	6	27	3	1	1	9
Chemistry	4148	4059	82	100	87	222	25	14	—	5	33	38
General Science	—	—	30	—	—	—	13	—	—	—	—	—
Geology and Geophysics	267	412	20	28	19	73	4	10	2	7	4	8
Mathematics	2645	6462	9	290	13	150	2	67	1	4	3	15
Meteorology	—	215	—	—	—	45	—	—	—	7	—	1
Nutrition and Food Science	—	296	—	—	—	58	—	4	—	3	—	2
Physics	3271	6611	82	405	59	299	17	92	5	9	7	31
Totals	10,892	18,998	266	898	211	938	67	214	11	36	48	104

* These figures do not include thesis and are as of the end of the terms.
† Includes Course VII-A, Biophysics and Biological Engineering.

Table II. Changes in Size of Faculties in School of Science

Department	*Professorial rank**		*Instructors*		*Teaching Assistants†*		*Research Associates*		*Research Assistants*	
	1938-39	*1962-63*	*1938-39*	*1962-63*	*1938-39*	*1962-63*	*1938-39*	*1962-63*	*1938-39*	*1962-63*
Biology	11	22	2	2	—	—	4	36	1	1
Chemistry	28	35	8	—	—	77	10	47	10[1]	52
Geology and Geophysics	8	22	—	1	—	8	2	3	4[2]	33
Mathematics	12	39	6	21	5	36	—	3	—	24
Meteorology§	—	12	—	—	—	1	—	3	—	—
Nutrition and Food Science	—	22	—	3	—	—	—	24	—	27
Physics	25	69	5	7	3	45	5	2	12[3]	112
Totals	84	221	21	34	8	167	21	118	27	249

* Includes assistant, associate, and emeriti professors but not visiting or absent.
† Does not include teaching fellows.
§ Included in Aeronautical Engineering in 1938-39.
[1] Includes 9 research fellows.
[2] Includes 1 research fellow.
[3] Includes 5 research fellows.

stitute have increased 100-fold during the period under consideration, although a more realistic estimate of activity would show a somewhat smaller growth. Formal teaching activities in terms of student involvement have about doubled. The trend of these ratios might be expected, if continued, to lead to considerable unbalance. The very excellence of research activity, while it contributes greatly to the over-all educational program of the Institute and gives students increased motivation and a sense of participating in the front-line activities of science, does tend to produce expansion of other activities at the expense of the more formal aspects of academic instruction. Fortunately, specific efforts are now being made, in the School of Science as elsewhere, to redress this balance.

Familiar to all college administrators is the fact that nothing tends to deplete institutional finances so rapidly as large gifts or grants for new activities. These, even in the form of government contracts with their vaunted "overhead," inevitably cost a university money. Their action is like that of the aspirator pump of the chemist—the more water is passed through it, the more it sucks in from the side—in the financial case from institutional coffers. As the university grows richer in research support it finds available space diminishing. Funds needed for the upkeep of purely academic buildings are usurped by the upkeep costs on new buildings largely devoted to research. The result is that funds for the upkeep of teaching laboratories and for replacement of worn and obsolete teaching equipment and machine tools for shops which provide apparatus for student laboratories are increasingly difficult to come by. A slow deterioration in teaching is then likely to set in which can be rectified only by specific attention to the support of educational activities as such. It is heartening to see an increase of such activities as those of the Science Teaching Center, now directed by Professor Jerrold R. Zacharias, and of the faculty Committee on Curricula and the Committee on Educational Policy.

THE PROTECTION OF FREEDOM IN RESEARCH

Many warnings are in the air regarding the dangers of government interference, through financial control, with the directions taken by research activities in America. At M.I.T. the level of faculty and student research in the departmental and interdepartmental laboratories, an intrinsic part of our educational system, does indeed depend strongly on government support. Nevertheless, each project is directed entirely by the faculty member who has suggested it, and the course the research takes is the one he determines.

In 1939 a professor usually considered himself fortunate if as much as $10,000 was available for the annual support of his research program. Such funds as could be found were usually provided by grants from foundations or from industry. Today it is not unusual for the same faculty member to have available ten times as much support, placed at his disposal by government agencies on the recommendation of committees made up of peers in his own discipline.

I have detected no attempt on the part of governmental sponsors to influence the direction research projects should take. It has been argued that the effect could be a more subtle, even unconscious, directing of the course of events through selection of certain types of projects over others. To guard against the possibility of influence through such selective support, the Institute is building up a special fund to aid in financing projects whose faculty sponsors may have difficulty in attracting outside support for a time, whether because they are entering fields not attractive to grants committees, are not yet sufficiently well-known in the field of their activities, or for other reasons. Because this fund would be easy to dissipate, it is being husbanded most carefully; but its existence gives us valuable security in feeling that the Institute will stand firm in defense of academic freedom in the directions research may take. I know of no meritorious research projects which now suffer for lack of support. This is not to say, of course, that there is no lack of funds needed for the further expansion of research.

Basic scholarly investigation has also been protected by the very clear line which has been drawn by the Institute administration between the research activities of faculty members and those of such government-supported institutions as the Lincoln Laboratory, Instrumentation Laboratory, and other Institute-operated entities having specific missions of research and development. Many of these, too, involve research of a very basic nature, and the Institute community benefits greatly by the scholarly exchange which their presence makes possible. Activities in them are the province, however, of staffs especially selected for the purpose, while the academic research activities of the Institute, carried on by its faculty and students, are an integral part of its educational program.

SPACE AND FACILITIES

During the period under consideration the net floor space assigned to School of Science activities has grown vastly. Nevertheless, despite this generous expansion, the activities of the School are in some ways even more handicapped by lack of space than they were in 1939.

The Physics Department offers a case in point. Greatly in need of new space since a doubling in size caused overflow from the Eastman Building, the Department found its situation improved to some degree when the Compton Building was completed in 1957. This building is now completely filled, however, by the activities of the Research Laboratory of Electronics, the Laboratory for Nuclear Science, and the Computation Center. Although many research activities of a number of members of the Physics faculty are carried out in these laboratories, psychological problems connected with the unity of the Department are seen likely to arise as a result. The interdepartmental laboratories are of inestimable value in promoting interdisciplinary cooperation, but when groups begin to identify themselves predominantly with a series of laboratories, the unity of the Department as an entity slowly but inevitably crumbles. It seems important, therefore, that insofar as possible departments be provided with buildings of their own which are integrated components of a closely-knit complex and, while physically connected with buildings housing contiguous disciplines, maintain an identity of their own.

Thus the Physics Department, having trebled in size since 1939, now needs a new building having its own designation.

The Department of Chemistry is one of the few in the School which has been provided with very little new space during the period, and plans are now being made to obtain a new chemistry building. This is being designed for location in the Eastman Court, and we hope that its construction can be started in the near future.

Mathematics, with the highest percentage enrollment and faculty growth of any science department, has benefitted by a 600 per cent increase in floor area but needs additional office and classroom space very badly. Detailed analysis shows that 11,000 net square feet of added space are needed as soon as possible, while another 9,000 square feet net will be needed within the next decade.

The life science departments—originally represented only by biology and now by biology and nutrition and food science—have been greatly expanded during the period, not so much as a result of the demands of student enrollment as because of the challenge and opportunity foreseen in their scientific and technological atmosphere. Now more than doubled in faculty size, the life science departments rank among the foremost in the country. They fill new space as rapidly as it can be provided. Formerly housed in very limited quarters in Building 10, in 1952 they occupied the fine new Dorrance Building

In the near future their space is to be more than doubled by expansion into the new Life Sciences Building, construction of which is to begin shortly.

The earth sciences were in 1946 moved into enlarged quarters in Building 24 and are soon to move into the beautiful Green Building. This will house the Center for the Earth Sciences, consisting of the Departments of Geology and Geophysics and of Meteorology, with the work in oceanography and in space science associated with both. In 1939 meteorology was a department of the School of Engineering. The transfer in 1956 to closer association with other earth science activities has proved most wise.

LIBRARIES

Although much attention has been given to library problems at the Institute, those of the School of Science cannot yet be considered solved. Shifting concepts of library operation between one extreme, in which all the books are housed in a great central library accessible to all, and the other extreme, in which they are housed in numerous departmental libraries more accessible to those who use them most often, cause emphasis on different policies at different times. The arrangement in force in 1939, in which physics, chemistry, and mathematics books were housed in the Eastman Library, centrally located for them, was excellent until its space became overcrowded. The trend toward centralization which resulted in moving the Science Library to the fine new Hayden Library Building was somewhat less satisfactory to the science departments because of decreased accessibility and led them to set up small, informal book depots in their own space. Many of these have now achieved recognition and support and are being enlarged. No entirely satisfactory solution is in sight, but one involving a certain amount of duplication of books seems inevitable if the specialized needs of the departments and the general needs of the entire Institute are to be met at the same time.

Another library problem which needs attention is the crowding which results because students use library facilities for studying even during periods when consultation of library books is not involved. Study rooms giving students quiet places to work between classes would be of great benefit and would relieve much of the overcrowding in the main and department libraries.

PROLONGATION OF GRADUATE STUDY

A problem of graduate study which is being given much attention is the increased length of time required by graduate students working for the doctor's degree for completing their thesis work. The average length of time between the S.B. and Ph.D. in physics, for example, has increased from 3.5 years in 1939 to 4.8 years in 1963, and there has been a similar but somewhat smaller increase in most other science departments. This has resulted in some cases in a diminished output of graduates while graduate enrollments were actually climbing. This apparent loss of efficiency has complex causes, but it is probably related to the increased availability of good support in graduate assistantships, scholarships, and fellowships with resulting reduction in pressures for early completion of graduate work.

Steps are now being taken to insure that prolonged enrollment in the Graduate School will not result in unnecessary continuation in posts needed for the support of new candidates.

RESPONSIBILITIES OF FACULTY MEMBERS

Since the beginnings of the School of Science it has been a stated policy that a faculty member should be able to devote approximately half his time to research, while half should be available for teaching and other duties. This has been interpreted as meaning that a professor could be called upon, if active in research, for the equivalent of approximately six hours of lecture and recitation work per week per term in addition to preparation time and time spent in the direction of the research activities of graduate students. This figure still stands, although of late increasing pressures for its reduction have arisen as a result of increased demand for scholarly teachers of university caliber. Considerable flexibility has always been permitted department heads in arranging faculty teaching loads; and this has become increasingly essential in recent years because of the large number of time-consuming, attention-requiring details that have arisen as the Institute has grown larger, science has grown more complex, and the numbers of students, faculty, committees, and public responsibilities have increased.

INCREASED OPPORTUNITIES FOR BREADTH OF FACULTY EXPERIENCE

The sabbatical year has always been a most useful device for promoting mental refreshment and stimulation and increasing scholarly interchange. The modified form of this used at M.I.T. in the "educational leave" has served a most useful purpose. Up to 10 per cent of a given department faculty may be on educational leave at any one time, and in most of the science departments full advantage has been taken of such opportunities. In addition, faculty members have profited greatly by exchange arrangements and by enlarged opportunities for travel. Government sponsorship has made possible increased attendance at national and international conferences and is doing much to broaden scientific horizons and to help our faculty members keep abreast of developments in their respective fields.

FACULTY SALARIES

Although faculty salary rates before World War I averaged only about one-fourth of current figures, the purchasing power of income after taxes was somewhat greater then. Only now are top salaries in the leading academic institutions beginning to catch up in the United States, to the point where a faculty family can maintain the approximate relative social position which was the academic standard in the early years of the century. The situation, greatly helped by today's improved professional opportunities in non-academic activities, is being ameliorated further by necessary response to the law of supply and demand and the greatly increased need for capable college professors. This has resulted in a very competitive situation in which many anomalies occur. The ability of M.I.T. to attract and hold strong faculty members has resulted from our possession of top administrators who have succeeded in keeping our salary scales well up among those of leading institutions. To this must be added the attraction of finding assembled in one institution so great and diverse a body of scientific and technological workers whose degree of mutual cooperation is unsurpassed.

Although M.I.T. has more than completed its first hundred years, it is still in a period of rapid growth and combines the vigor and enthusiasm of youth with some of its problems. The psychology of the unified Institute faculty can no longer be what it was when the president could know everyone personally and could participate in all university functions. Yet there are numerous advantages in our close coupling of the individual schools which are likely to be lost when they are forced to become more autonomous. That the School of Science has fared so well during its third-of-a-century of existence is the result in great degree of the able and detailed support and surveillance of three outstanding presidents of the Institute and the close collaboration of the deans of the various Schools.

GEORGE R. HARRISON

Department of Biology

The enrollment of students in the Department of Biology continues to increase at all levels from undergraduate to postdoctoral. Students from other parts of the Institute are becoming more and more interested in the life sciences and are electing undergraduate subjects in biology for broadening and extending their educational experiences. The resulting rapid growth in the teaching activities of the Department has placed a major strain on its facilities, and in particular the teaching laboratories have become overcrowded. This situation will be only partially alleviated by the new life sciences building, which is designed primarily for research.

CURRICULUM

A considerable demand has developed for an introductory subject in biology which would be available to all students at M.I.T. above the freshman level. At the same time this subject would be suited to preparing students who are majoring in the life sciences for advanced work leading eventually to M.D. or Ph.D. degrees.

In the fall of 1963 such a subject in General Biology will be taught by Professors Cyrus Levinthal, Charles E. Holt III, Tom D. Humphreys II, and Patrick D. Wall. This subject will attempt to present general biology at a high level for students who are well prepared for an introduction to molecular and systems biology. Special emphasis will be placed upon the simplest organisms as well as on the most highly evolved. This subject will be followed by a new General Biology Laboratory taught by Professors Jerome Y. Lettvin and Holt, which will utilize the research approach to modern quantitative biology.

The genetics program of the Department is being revised by Professor Maurice S. Fox to emphasize molecular instead of classical genetics. Since molecular genetics is based primarily upon research with microorganisms it is planned to combine the laboratory work in genetics and microbiology into a single subject entitled Microbial Genetics Laboratory. This subject will be supervised by Professor Robert M. Dowben who will be assisted by the genetics and microbiology staffs. The equipping of this laboratory has been made possible by a generous matching grant from the National Science Foundation backed by funds from M.I.T.

The subject in Developmental Biology has been revised to make it almost solely an experimental laboratory. During the spring term of 1963 the students developed experiments which were filmed in collaboration with Educational Services, Inc. These films will be available for teaching at M.I.T. and also for use at other institutions.

SYMPOSIA

During the past year the Department of Biology has sponsored five symposia: Professor Vernon M. Ingram's symposium was devoted to chemical genetics and medical aspects of hemoglobin; Professors Eugene Bell and Levinthal directed a symposium on biophysics and developmental biology; Professor Kurt S. Lion and Dr. Albert O. Seeler conducted a one-week symposium for medical researchers on recent applications of instrumentation to medicine; Professor Dowben, at the request of the National Institutes of Health, conducted a symposium on muscular dystrophy; and Professors Salvador Luria and Phillips W. Robbins presented a discussion of the chemistry, immunology, and genetics of the bacterial cell membrane.

PERSONNEL

During the coming year Professor Gene M. Brown will be on leave to carry on research in cell biology at the California Institute of Technology. Professor Luria has been awarded a Guggenheim Fellowship for a year of research at the Pasteur Institute, and will also be on leave.

New additions to the faculty are Dr. Robert M. Dowben, Visiting Associate Professor of Microbiology, who will teach the microbial genetics laboratory and pursue research on enzyme control mechanisms related to muscular dystrophy; and Dr. Tom D. Humphreys II, who has been appointed Assistant Professor of Biology to take charge of the developmental biology laboratory. Dr. Humphreys will carry on a research program on the growth and regeneration of sponges.

RESEARCH

During the past year much of the research in the Department of Biology has been concerned with the general problem of the biosynthesis of proteins in the ribosome and the genetic and chemical mechanisms for the control of protein structure and function. Many of these studies have been carried on with tissue cells, bacteria, and viruses by Professors Luria, Levinthal, Boris Magasanik, Fox, and Holt, who have investigated the role of inducing agents, substrate inhibitors, operator genes, DNA, and RNA with reference to enzyme production and control. Professors Alexander Rich and Cecil E. Hall have studied the biosynthesis of hemoglobin in the reticulocyte of the bone marrow. They have found that the ribosome in which hemoglobin synthesis occurs is not a single structure, but is made up of five subunits each called a ribosome; the total assembly they have named the polysome. Attached to each ribosome is a thread of messenger-RNA which carries the genetic code which is the blueprint for the hemoglobin molecule. Each ribosome is able to read this code and synthesize a hemoglobin polypeptide starting at the amino end of the chain and continuing without interruption to the carboxyl end. Professor Ingram has found that occasional mistakes (genetic defects) in the code result in the wrong amino acid being placed in a particular position in the hemoglobin molecule. For example, in sickle-cell anemia, glutamic acid is replaced by valine. Professor Ingram has summarized this work in his Jesup Lectures now published in a book entitled *The Hemoglobins in Genetics and Evolution.* Other aspects of protein biosynthesis have been studied in polio and other viruses by Professor James Darnell.

Much of the work in biochemistry carried on by Professors John M. Buchanan, Brown, Bernard S. Gould, Robbins, and Irwin W. Sizer has dealt with the biosynthesis of vitamins and their role in enzyme systems. Special attention has been devoted to folic acid, ascorbic acid, and pyridoxal phosphate. These investigations are leading to an understanding of how the living cell can synthesize vitamins and use them as the catalytic site of enzyme molecules.

Connective tissue with special reference to collagen continues to occupy the attention of Institute Professor Francis O. Schmitt and Professor Gould. The former has been particularly concerned with the manner in which fibrils are held together in living systems, while the latter has studied the successive steps of collagen biosynthesis in healing wounds.

Studies in neurophysiology have been carried on in collaboration with the Center for Communications Sciences. Professor Wall has investigated the junction between sensory fibers and the central nervous system at the level of the spinal cord and has discovered a new mechanism for inhibition of nerve impulses in the cord. Professor Lettvin has concentrated his attention on the eye and its connections with the brain. From this study has come a new theory of color vision which has made it possible for Professor Lettvin to construct an extremely simple but powerful model which can distinguish hue, saturation, and intensity of light together with some aspects of the form of the stimulus.

In the field of developmental biology, Professors Bell and Humphreys have been studying feather formation at the molecular level in chick embryos as well as considering factors concerned with tissue organization, using disassociated cells of sponges.

Professor David F. Waugh has been investigating the kinetics of the blood coagulation system using purified preparations of fibrinogen and fibrin. He has been comparing this system with milk coagulation using protein components isolated from milk by means of the ultracentrifuge.

IRWIN W. SIZER

Department of Chemistry

There were thirty-five undergraduate majors in chemistry who received the Bachelor of Science degree in June, 1963. Of this group, thirty-one will enter various universities as candidates for the doctoral degree; two will attend business school, one after active duty in the Army and the other before active duty in the Navy; and two have accepted employment in the chemical industry.

During the year forty-one candidates for advanced degrees in chemistry completed the Ph.D. degree and five the S.M. degree. These men and women, as well as members of the group of approximately 75 postdoctoral research fellows and research associates in the Department who completed their appointments during the year, have accepted a wide variety of positions in universities, the chemical industry, and research institutes.

CURRICULUM

The faculty of the Department has approved changes in the undergraduate curriculum to be made effective in September, 1963. In the regular chemistry curriculum, the language requirement will be increased to one year of a foreign language (from one semester), and the minimum registration for a senior thesis will be lowered to 12 units (from 30). This change produces a net increase in elective time of 10 units. Also, a new curriculum in chemical physics has been approved in which the specific course requirements in chemistry are reduced, requirements in physics and mathematics are increased, and the elective time is increased. Elective time in this curriculum amounts to 50 units, and the electives must include one subject involving laboratory work. Other requirements are the same as those of the regular chemistry curriculum.

PERSONNEL

On June 30, 1963, Professor Leicester F. Hamilton reached the mandatory retirement age of 70, and on July 1, 1963 Professor Glenn A. Berchtold became Executive Officer. Professor Hamilton will undertake special administrative assignments during the coming year. Professor Berchtold will continue to teach the graduate subject in the instrumental techniques of research in organic chemistry (5.53) and will also continue to direct the research in organic chemistry of a group of graduate students, seniors, and postdoctoral men.

Professor Charles D. Coryell was on educational leave during the second semester and summer of 1963, during which time he was a Fulbright Lecturer of the Faculté des Sciences à Paris at the Institut du Radium. During his leave of absence his research program at M.I.T. continued with help in administration from a group of postdoctoral men and Professors John W. Irvine, Jr., and Glen E. Gordon.

Professor Gordon spent the summer of 1963 in research in the field of nuclear chemistry at the Oak Ridge National Laboratories.

Professor Lawrence J. Heidt was on educational leave during the academic year and held a Guggenheim Fellowship during the fall term at the University of Tokyo in Japan and during the spring term at the University of Sydney in Australia. His year was spent in research on the elucidation of the charge and energy transfer processes involved in both organic and inorganic systems of potential use for solar energy conversion.

Dr. George M. Whitesides joined the Department in the summer of 1963 as Assistant Professor of Organic Chemistry. He received the Ph.D. degree from the California Institute of Technology where his research on organometallic compounds and nuclear magnetic resonance was done with Professor John D. Roberts, formerly of this Department.

Dr. David M. Hercules became Assistant Professor of Analytical Chemistry in the summer of 1963. He received the Ph.D. degree at M.I.T. in 1957 with Professor Lockhart B. Rogers and has held faculty appointments at Lehigh University and Juniata College.

Dr. Ian M. Mills of the University, Reading, England, became Visiting Associate Professor of Physical Chemistry at M.I.T. in the summer of 1963. His field is molecular spectroscopy.

Among outstanding awards presented to members of the Department were the Baekeland Award of the New Jersey Section, American Chemical Society, to Professor Albert E. Cotton and the Fisher Award of the American Chemical Society to Professor David M. Hume. Other professional honors and activities are listed at the back of this volume.

FACILITIES

The new laboratories for research in nuclear chemistry in the building adjacent to the M.I.T. nuclear reactor were completed in the spring of 1963, and the research groups associated with Professors Coryell and Gordon, as well as these members of our faculty, moved to the new laboratories. Additional space thus became available on the fourth floor of Building 6 for research in inorganic chemistry by the groups associated with Professors Cotton, Irvine, and Dietmar Seyferth.

During the spring and summer of 1963, research space was remodeled in the basement of Building 2 as offices and research laboratories in physical chemistry and mass spectrometry. The research groups associated with Professors Klaus Biemann, James L. Kinsey, Irwin Oppenheim, and Walter R. Thorson are occupying this space.

Planning for a new building for chemistry that is needed to correct overcrowding and permit moderate expansion during the next ten years continued during the academic year.

RESEARCH

Professor Isadore Amdur and his research group have been continuing their investigations of intermolecular forces as determined from elastic scattering of high-energy molecular beams. A redetermination of the interaction potential between two helium atoms has confirmed a significant discrepancy between the best experimental values and the best theoretical values at internuclear separations of the order of 0.5 Å. The reason for the discrepancy is the basis of continuing experimental and theoretical work. Studies of the mutual diffusion of gases using radioactive tracers have revealed differences in the intermolecular potentials of systems containing different hydrogen isotopes. Among the systems studied were He-T_2 and He-TH, TH-T_2, TH-D_2 and TH-H_2. The differences arise from quantum effects in the collision dynamics of these light particle systems and from differences in the asymmetry of the intermolecular potentials of the hydrogen isotopes.

Professor Cope and his research group have completely resolved *trans*-cycloöctene into its optical isomers. This compound has molecular asymmetry of a new type and is the first *trans* cyclic olefin to be resolved. The resolution was accomplished by fractional crystallization of diasteriomeric forms of *trans*-dichloro(*trans*-cycloöctene)(α-methylbenzylamine)platinum(II), in which the amine was either the pure positively or negatively rotating isomer. Decomposition of the two pure complexes separately gave positively and negatively rotating *trans*-cycloöctene with a high specific rotation of about ±450°. This new method of resolution involving formation of a pi complex between an olefin and platinum bound to an optically active amine is being extended to other unsaturated compounds.

Professor Cotton has extended his studies of structure and bonding in inorganic compounds along several lines. X-ray crystallographic investigations have clarified several questions: how benzene rings are bonded to transition metal atoms; how the amino acid, histidine, binds metal ions; and how nitrate ions may often be bound to metal ions through two, rather than one, oxygen atom. This work has also revealed the existence of a new type of polynuclear complex anion, $[Re_3Cl_{12}]^{3-}$. The bonding in this and several previously known polynuclear species, which have been designated metal atom cluster compounds, have been investigated by the molecular orbital method, and it has been shown that the strong metal-metal interactions can be well understood in this way. Other studies, using spectroscopic and magnetic measurements, have dealt with metal-ligand bonding and the electronic energy levels in polyatomic conjugated ligands such as β-diketonate and β-phosphonylketonate anions.

Professor Frederick D. Greene II and Dr. Kerry W. Bowers have been investigating electron spin resonance phenomena of organic compounds in ether-alkali metal mixtures at low temperatures. Of special interest is the formation of the cyclopropane radical anion, affording a well-resolved seven-line spectrum of binomial intensity with an unusually narrow line separation of 2.33 gauss. These findings provide a new method for the examination of strained hydrocarbons and imply a variety of points of theoretical and experimental interest that are under active investigation.

Professor Hume and his students have been exploring the potentialities of novel excitation sources in emission spectroscopy. The use of a radio-frequency plasma torch in conjunction with an ultrasonic atomizer system has made it possible to work with very dilute solutions of difficultly excitable elements with a convenience comparable to that of conventional flame photometry. Plasma excitation in a nitrogen medium provides comparative freedom from the interferences due to compound formation observed in chemical flames and affords very high sensitivity. The technique offers particular promise in applications to systems of biological interest.

Professor William R. Moore and his students have continued studies of the reactions of carbenoid species. Treatment of 1,1-dibromocyclopropanes with alkyllithium reagents results in the generation of cyclopropylidenes, carbenes in which the carbenoid carbon atom is part of a three-membered ring. In many cases these intermediates undergo essentially instantaneous valence isomerization to yield allenes. However, in certain systems, in which the allene linkage would be severely strained, the cyclopropylidenes can undergo reactions typical of simpler carbenes. For example, trapping experiments with olefins have given spiropentanes. Of particular interest are the intramolecular insertion reactions shown by certain of these cyclopropylidenes. A number of very highly-strained compounds have been formed, including derivatives of bicyclobutane and bicyclo[2.1.0]pentane. The formation of bicyclobutanes by this method appears to be fairly general. Current studies are concerned with defining the mechanisms and scope of these reactions and developing the chemistry of the resultant novel highly-strained compounds.

Professor Oppenheim and his co-workers have obtained statistical mechanical expressions for relaxation times measured by nuclear magnetic resonance techniques. There is excellent agreement between theory and experiment for the entire range of fluid densities. A modified Langevin equation has been derived which describes relaxation in configuration space. The equation is considerably simpler than the original Langevin equation and yields similar results in most cases of physical interest. A new theory of transport in liquids has been developed, utilizing results of neutron diffraction experiments, which indicates that molecules in a liquid exhibit two types of motion which can be roughly described as oscillatory and jump. A theory of the kinetics of helix-coil transitions has been developed, and comparison with experiment is being pursued.

Professor David P. Shoemaker and members of his research group have completed crystal structure studies by neutron and X-ray diffraction on zinc and cadmium cyanides, redetermining and refining these structures and showing them to be disordered with respect to CN orientation. The crystal structure of a complex intermetallic compound, δ-MoNi, with 54 atoms in a unit cell of low symmetry, was determined by X-ray diffraction and refined, and the E phase of Ti-Ni-Si was shown to have a structure closely related to that of $PbCl_2$. An X-ray study of the calcium salt of 1,2-cycloöctatetraene-dicarboxylic acid revealed the conformation of the carboxylate groups in relation to the ring.

ARTHUR C. COPE

Department of Geology and Geophysics

During the year good progress was made in developing an integrated program of undergraduate and graduate education and research in the geosciences and oceanography. Working in close cooperation with the Department of Meteorology and with the Woods Hole Oceanographic Institution, we devoted much attention to the complete program in the earth sciences that will become possible when the Center for the Earth Sciences occupies the Green Building.

ENROLLMENT AND DEGREES

The enrollment of seniors was unusually high, with thirteen receiving bachelor's degrees. But undergraduate enrollment was again low for the second- and third-year classes (seven and five majors, respectively). A similar situation prevailed throughout the United States and Canada. Graduate enrollment reached an all-time high of seventy-two; six master's and seventeen doctor's degrees were awarded, the latter number being the largest ever awarded in a single year by our Department. Undergraduate enrollment is expected to remain at a low figure, and graduate enrollment will drop next year to about sixty, chiefly because of the unusually large number of graduate degrees granted this year.

As in recent years, our freshman electives in astronomy and earth science continued to attract a fair proportion of the freshman class (about 8 per cent) despite an increase in the number of electives from which freshmen could choose. Our introductory subjects in oceanography had the largest registration since they were introduced five years ago, indicating increased interest in that earth science among M.I.T. students. We expect student registration in oceanographic subjects to continue to increase.

DEPARTMENTAL ACTIVITIES

In 1961, at the close of the fourteenth M.I.T. Summer School of Geology held at Crystal Cliffs, Nova Scotia, it was decided to discontinue the School because of low sophomore registration. Instead, our undergraduates of the Class of 1965 had their required summer field training in 1962 at the Indiana University Field Station near Caldwell, Montana, or at the Woods Hole Oceanographic Institution.

For the twelfth summer we participated in the Student Cooperative Program of Geophysical Service, Inc., of Dallas, Texas. The program, as in previous years, was organized and managed by Dr. Cecil H. Green, Honorary Chairman of the Company and a member of the M.I.T. Corporation. Twenty-three students from twenty U.S. and two Canadian colleges participated in the Program. It began in Dallas with a four-day orientation period during which the students heard some forty lectures by leading geologists, geochemists, and geophysicists from industrial organizations, government agencies, and educational institutions; Professor Raymond Hide of the Department of Geology and Geophysics and Professor Edward M. Hofstetter of the Department of Electrical Engineering gave lectures in this series.

CURRICULUM, CONFERENCES, AND SYMPOSIA

Interest continued high in oceanography, with the largest registration we have ever had in undergraduate subjects in this field, and our graduate group was one of the two or three largest in the country. For the second year we conducted a one-day conference for local and Washington oceanographers at which graduate students presented the results of their research projects. Representatives from federal agencies requested that we make this conference an annual affair. An experimental luncheon seminar in oceanography was held each Thursday and proved effective in bringing together students and staff members interested in the oceans; it will be continued next year.

Professor Hide and several of his departmental colleagues participated actively in the affairs of the COMPASS group, an informal interdepartmental committee concerned with future graduate study and research in the planetary and space sciences. Professor Hide acted as chairman of the group and directed its activities, including a weekly seminar that was well attended. Discussion continued as to how the earth sciences are to be coupled with planetary and space science. A booklet on "Planetary and Space Science at M.I.T." was prepared, and copies were distributed widely throughout the United States and Canada. The response to this book indicated much interest in this rapidly expanding new area of science.

PERSONNEL

Dr. William S. von Arx, for many years Physical Oceanographer on the staff of the Woods Hole Oceanographic Institution, was appointed Professor of Oceanography and will join our staff on a full-time basis in July, 1963. He has been a part-time Professor of Oceanography in the Department since 1956.

Dr. John W. Kanwisher, Biophysicist on the staff of the Woods Hole Oceanographic Institution, joined our staff as a part-time Assistant Professor of Oceanography. His appointment adds to our strength in oceanography and makes it possible for some of our graduate students to do research in biophysical oceanography under his supervision. He will also offer a series of lectures on oceanographic problems.

Professor John W. Winchester was on leave to serve as Visiting Fulbright Professor in Nuclear Chemistry at the National Tsing Hua University of Taiwan. During his year in Taiwan he offered lectures and laboratory work in nuclear chemistry at both the National Tsing Hua University (Hsinchu) and Taiwan University (Taipeh) and conducted research on the new nuclear reactor of the former's Institute of Nuclear Science.

Professor Louis H. Ahrens, Chairman of the Department of Geochemistry at the University of Cape Town, spent six months in the Department as Visiting Professor. He gave two series of lectures, conducted a number of special seminars, and investigated the distribution of elements in igneous rocks.

Dr. Joseph L. Gillson, retired Chief Geologist of the DuPont Company, continued a second year as the William Otis Crosby Lecturer in Geology. He conducted a lecture-laboratory study of mineral deposits, drawing on the Lindgren Collection of ore minerals, and also carried on personal study of some of the ore suites.

Professor Ely Mencher accompanied five undergraduates to the Indiana University Geologic Field Station in Montana, where he and they participated in a field course under the direction of Indiana's Professor Judson Mead. Professor Mencher also directed the field work of six seniors who carried on thesis investigations in the Maine woods.

Professor Martin J. Buerger spent January in India under the auspices of the U.S. State Department. During the month he visited sixteen colleges, universities, and government research centers and gave lectures on crystallography at ten of them. He also delivered lectures to the Faculty of Science in Chula Long Korn University in Bangkok and to the Crystallographic Society of Japan.

Professor Thomas Cantwell spent September in Australia, where he delivered a number of lectures and conducted a series of demonstrations involving the use of induced polarization and resistivity methods of geophysical exploration. These activities were sponsored by the Bureau of Mines of South Australia and were widely publicized. The lectures are to be published and distributed by the Bureau.

RESEARCH

The year was one of greatly increased research activity by both staff and students. The program included experimental and theoretical investigations of the physical nature, chemical composition, and geological age and history of the earth's crust and mantle. A major program in the hydrodynamics of rotating fluids and another in oceanography were underway during the year, and a program involving experiments in the mechanics of rock deformation was started.

Professor Buerger and his students continued investigations of a number of natural minerals, using X-ray diffraction with a precession camera and a single crystal diffractometer and treating the data on the I.B.M. 7090 computer. Automation of the single-crystal diffractometer was completed in the spring and will reduce the time for data acquisition by a factor of five. The outstanding research result of the year was solution of the structure of chalcocite (Cu_2S). This structure, which has been under intermittent study for more than twenty-five years, proved to be unusual in having the copper atoms in three different coordinations.

Professor William F. Brace spent the summer in a preliminary field study of some folds in the Western Alps and then continued to investigate experimentally the applicability of Griffith Theory to fracture of rocks. He also studied further the elastic properties of rock at low confining pressures and started an investigation of the effects of pressure on electrical resistance.

The Cabot Spectrographic Laboratory under the direction of Professor William H. Dennen continued to provide services to several other M.I.T. laboratories while allowing an increased number of graduate students and guests to conduct their own investigations. Continued research on common quartz produced three noteworthy results: (1) the microscopic impurities, which are detectable by spectroscopic analysis, can be used to determine the kind of rock from which the quartz was derived; (2) quartz from different environments blackens to different degrees when subjected to X-radiation; and (3) study of microscopically clear quartz may provide deeper insight into the pressure-temperature conditions of rock formation.

In our Geochronology Laboratory Professors Patrick M. Hurley, Harold W. Fairbairn, and William H. Pinson and a large group of graduate students, using an array of mass spectrometers and supporting chemical facilities, continued investigations of variations in radiogenic isotopes in minerals and rocks, both ancient and recent, and in meteorites and tektites. Extensive studies of Western granites were conducted during the year, and preliminary investigations of deep-sea sediment cores from the Puerto Rico Trench were started. Professor Pinson and Dr. Charles C. Schnetzler investigated the Rb/Sr ratios in stony meteorites and showed that: (1) the different types are all of the same age, namely $4.45 \pm 0.09 \times 10^9$ years; (2) the Rb/Sr age agrees closely with Patterson's Pb age for meteorites and the earth; (3) the decay constant for Rb^{87} as measured by Flynn and Glendenin is confirmed; and (4) the primordial Sr^{87}/Sr^{86} ratio is 0.698 ± 0.001. Their similar work on tektites demonstrated that the several geographical groups of tektites formed from planetary silicate crustal material which was differentiated 225 ± 100 million years ago. The radiogenic Sr^{87} content of all tektites varies sympathetically with their parent-to-daughter ratios. This homogeneity of tektite ages strongly negates hypotheses of origin that require random fusion of terrestrial materials by meteoritic impact and suggests an extraterrestrial origin. If the tektites were splashed from the moon by random meteoritic impact, then the moon's surface must be fairly homogeneous and must have been differentiated within the last 300 million years.

The experimental program in the hydrodynamics of rotating fluids initiated a year ago by Professor Hide was well established during the past year. The objective of this work is to understand the basic hydrodynamical processes occurring in both mechanically and thermally driven flow of highly-rotating fluids, since this will be a necessary first step in the elucidation of fluid dynamical phenomena in geophysics and planetary physics (e.g., origin of planetary magnetic fields and circulation of planetary atmospheres). Several experimental and associated theoretical investigations are now in progress, including studies of boundary layers, flow stability, turbulence, heat transfer, and wave motion. Related theoretical work is also in progress in the Department of Mathematics and the Department of Meteorology. Professor Hide and his associates have applied their work on Taylor columns and Rossby waves in a compressible medium to the problem of interpreting observations of certain unusual phenomena in the atmosphere of the planet Jupiter, and thus they have made a start on a systematic study of the hydrodynamics of Jupiter's atmosphere.

Professor Harry Hughes continued measurements of conductivity of minerals and rocks and coupled these with theoretical work in thermodynamics and the physics of solids to gain better understanding of the nature and composition of the earth's mantle and core.

Professors Theodore R. Madden and Cantwell completed a review of the various aspects of the induced polarization prospecting method, including representative conductivity models, electromagnetic coupling, and interpretation problems. They also completed their study of on-site detection of underground explosion sites by means of electrical measurements. Theoretical and laboratory studies showed that the fluid flows associated with the after-effects of an explosion could under certain conditions set up detectable electric signals at the earth's surface. Such signals were actually observed for about a month after explosion *Aardvark*, and the 1500-foot depth of the explosion could be determined from these signals. Measurements of the conductivity of the earth's crust were continued, including use of natural electromagnetic fields for shallower conductivity structures. Some good quantitative results were obtained from analysis of magnetic station data from six-month and 13½-day magnetic fluctuations; these are important in casting further light on the electrical conductivity of the upper mantle. Professor Madden and his students continued study of the resonance character of the audio-electromagnetic signals due to the earth-ionosphere cavity. The influence of the magnetic field on the propagation properties of the ionosphere were shown to explain most of the observed features of the resonant modes.

Professor Mencher, besides instructing in field geology at the Indiana University Field Station, directed a program of field investigations of middle paleozoic rocks in Maine in which he and his thesis students cooperated closely with the United States Geological Survey and the Maine Geological Survey.

Professor Stephen M. Simpson, Jr., continued his study of ways for discriminating between seismic records from nuclear blasts and those of natural earthquakes, including research on the statistical structure of microseismic noise, multi-dimensional filter theory, decision theory, and computer techniques. These studies were conducted as part of the VELA UNIFORM project.

The program of oceanographic research started a year ago with support from the Office of Naval Research, has already been expanded and diversified, and more graduate student assistants have been added to the project. As in the past, much of the research depended on close cooperation with staff members of the Woods Hole Oceanographic Institution. Although Professor Robert R. Shrock served as director of the project, the actual supervision of much of the research program was carried out by Professors Dayton E. Carritt, Harold E. Edgerton, and John B. Hersey. Among the problems investigated were the following: (1) experimental and theoretical study of longshore currents on a plane beach; (2) development of a device for measuring underwater turbidity; (3) study of sound scatter from the water-sediment interface at the ocean bottom; (4) investigation of acoustic wave trains in the ocean; (5) bottom sediment probing by

12 kilocycle sound pulses reflected from shallow-water bottom sediment layers; (6) research on Ca^{48} fractionation in sea water; (7) studies of fractionation of halogens at the air-sea interface; and (8) investigations of the marine chemistry of the rare earths.

GREEN CENTER FOR THE EARTH SCIENCES

The last of the nearly 400 concrete piles for the Green Building were put in place in early July, 1962, as basement construction got underway. Construction proceeded steadily through the winter and spring months, and the tenth story was poured a few days before the 1963 Commencement. It is expected that the building will be ready for occupancy early in 1964, and plans are being made to start moving the Department in March.

ROBERT R. SHROCK

Department of Mathematics

The number of mathematics majors again showed an increase during the past year. Last fall 290 undergraduates (sophomores, juniors, and seniors) were majoring in mathematics, compared with 258 the preceding fall and 90 in the fall of 1957. The corresponding figures for sophomores in mathematics are 116 last fall, 105 the preceding fall, and 35 in the fall of 1957. These figures indicate an increase in five years of 222 per cent in the number of undergraduate majors and of 231 per cent in the number of sophomore majors. Last fall the total number of mathematics majors for all years, undergraduate and graduate, degree candidates and special students, was third among all those at the Institute. Professional opportunities for graduating seniors and for recipients of graduate degrees continue to be excellent and exceed by a considerable margin the number of available persons. Over half of the seniors graduating last year continued with graduate work.

TEACHING PROGRAMS

In the fall of 1962 Professor Arthur P. Mattuck, who has general supervision of the content and examination for the first term of required mathematics, instituted a system of supplementary problems in the subject. These problems were intended primarily to emphasize resourcefulness, imagination, and common sense in dealing with mathematical entities. On each problem the student was encouraged to use any approach he could think of in order to obtain the desired information in either precise or approximate form. The Department feels that the use of these supplementary problems will lead its students to increased flexibility and resourcefulness in the application of mathematics in engineering and the other sciences while giving them a more immediate appreciation of the nature and challenge of mathematical thinking.

The number of freshmen entering with advanced placement credit again increased last year. Of last fall's entering class of approximately 900 freshmen, 220 took the advanced placement test in mathematics. Of these 182 did sufficiently well to receive advanced placement and degree credit, 61 for one semester and 121 for two semesters. This compares with 156 who received advanced placement and degree credit in the fall of 1961, 72 for one semester and 84 for two semesters. During the fall semester of 1962 another 20 freshmen received credit at entrance by other means, 10 for the first semester, 6 for the entire first year, and 4 for work beyond the first year.

The Department continued the special honors versions of calculus given to selected freshmen. A number of students who take these honors versions take advanced standing examinations in later work and consequently are able to proceed at a faster pace in their mathematics programs. In September and October of this year a total of 128 students took advanced standing examinations in third-semester calculus, and 68 students took the examination in differential equations. Of these groups, 124 of the 128 passed the former examination and 60 of the 68 passed the latter examination. Of those passing the calculus examination, 49 were sophomores who had taken one of the special honors versions of calculus as freshmen. Of those passing the differential equations examination, 25 had taken one of the honor sections.

APPLIED MATHEMATICS

During the spring and early summer of 1962 a number of discussions about applied mathematics were held. On the basis of these discussions it was recommended that a Committee on Applied Mathematics be set up in the Department of Mathematics, to be concerned with undergraduate and graduate curriculum matters, research, and general and specific topics related to the development of applied mathematics at M.I.T. This Committee has now been established. The Chairman of the Committee is to be appointed annually by the President, and for the first year Professor Chia-Chiao Lin was appointed. The Chairman of the Committee and the Head of the Department confer on curriculum matters, subjects to be offered, teaching assignments affecting applied mathematics, and related matters. The Committee consists of all faculty members and Moore Instructors in the Department of Mathematics concerned with applied mathematics, and there is a smaller steering committee appointed by the Chairman of the Committee.

It was also recommended that there be an applied mathematics curriculum in the Department of Mathematics and that this curriculum be listed in the catalogue. This was established during the year, not as a mathematics option but rather as a sequence of elective subjects which students primarily interested in applied mathematics are encouraged to take. This program will appear in catalogue for 1963.

RESEARCH

Professor Warren Ambrose has been working on the relation between non-linear partial differential equations and differential geometry. In an attempt to formulate such problems geometrically he has been led to prove a number of theorems about higher-order Grassmann bundles.

Professor Kenkichi Iwasawa is continuing his research on algebraic number theory. He has found a new explicit formula for the classical reciprocity law in the cyclotomic fields.

Professor Bertram Kostant recently completed research on the decomposition of a polynomial algebra under the action of an algebraic group, generalizing the classical "separation of variables theorem."

Professor Norman Levinson has obtained results on the eigenfunction problem and Dirichlet problem for $\Delta u + f(u) = 0$. He also obtained results on the general high indices theorem and absolute convergence, on the prime number theorem, on several inequalities, and on the stability of linear real periodic self-adjoint systems of differential equations.

Professor Richard D. Schafer is continuing his research on nonassociative algebras. He has recently proved that any algebra on which a nondegenerate form of degree n permitting composition may be defined is alternative, and he has determined all such forms on finite-dimensional algebras.

Professor Irving E. Segal has continued his investigations of the mathematical theory of quantization in relation to the theory of nonlinear partial differential equations in the large on the one hand and the theory of analysis in function space on the other. A rigorous mathematical explication of the concept of relativistic non-linear quantum field has been given, and the question of the existence of a physical vacuum is being pursued.

Professor Isadore M. Singer, in collaboration with Michael F. Atiyah, has found a formula for the index of an elliptic operator on vector bundles over a compact manifold and is trying to extend the formula to manifolds with boundary.

Professor George W. Whitehead is continuing his joint work with Professor Daniel M. Kan on orientability and Poincaré duality for manifolds, relative to general homology theories. One of the notions to be investigated is the associated "bordism" theory and its relation to the original theory.

The research activities of other members of the Department are too numerous for individual mention, but the work of our faculty and C. L. E. Moore Instructors in the field of applied mathematics serves as an illustration.

Professor Eric Reissner has continued research on asymptotic solutions in elastic shell theory, including the final steps of a resolution of the nature of shell theory as a consequence of three-dimensional elasticity theory.

Much of the research work in applied mathematics has been done by collaboration among several staff members. Professor David J. Benney, besides his own work on nonlinear wave interactions, has been collaborating with Professor Harvey P. Greenspan on the problem of transition of a laminar shear flow to turbulence and solved a basic problem at the crucial stage of the occurrence of "turbulent burst." This work is a continuation of Professor Benney's earlier investigation on nonlinear waves in a shear layer which has also been improved upon during the current year.

Besides the above-mentioned collaborative effort, Professor Greenspan has been engaged in the study of ocean currents and other phenomena in oceanography. The basic problems are essentially those of the motion of rotating fluids, which has become one of the main themes of the efforts of Professors Greenspan and Louis N. Howard. Recently they solved a general problem on the time-dependent motion of a rotating fluid. It is shown that when a viscous fluid is in a rotating axisymmetric container, the physical mechanism governing the details of the transition induced by a small change in angular speed is mainly rotation and not viscous diffusion of vorticity. Further work on these lines, in particular a general study of viscous boundary layers in rotating fluids, is in progress.

Professor Howard is also studying two aspects of the theory of stability of shear flows: (a) investigations of the general theory of inviscid stability problems, and (b) stability problems in stratified shear flow. A major effort of his, however, has been in the problem of thermal convection. An upper bound on convective heat transport has been obtained by maximizing heat flux subject to power integrals as constraints. The maximizing flow resembles actual flows in its mean properties.

Dr. Norman R. Lebovitz has been continuing his work on pulsating stars. The work has been extended to include the effect of rotation on the frequency of the pulsation; the results have been compared with observations.

Professors Lin and Alar Toomre have been studying the theory of stellar dynamics and galactic structure for the past two years. A central problem in their investigation is: Why does a disc galaxy usually show a spiral structure? They have shown that this could be due purely to gravitational instability, without reference to the effect of magnetic fields. The latter has often been adopted for the explanation of the spiral structure but with only partial success at best. Other astrophysical problems, with both long-range and short-range prospects, are being studied.

PERSONNEL

Professor Iwasawa spent the fall semester on leave at Tokyo University, and Professor Reissner spent the year on leave on a Guggenheim Fellowship. Professor Lodewijk Woltjer of the University of Leyden spent the fall semester with us as Visiting Professor, and Professor Michael O. Rabin of the Hebrew University and Professor W. Forrest Stinespring of the University of Chicago were here for the year with us as Visiting Associate Professor and Visiting Assistant Professor, respectively. During the last few months of the spring the Department was honored to have Professor Bengt Strömgren of the Institute for Advanced Study as a Visiting Institute Professor. We were also pleased to have two Visiting Fellows during the year, Professor Selma Soysal of the Technical University of Istanbul and Dr. David M. Topping, who spent the year here on a N.A.T.O. Post-doctoral Fellowship.

Dr. Toomre of the Institute for Advanced Study accepted an appointment as Assistant Professor of Mathematics, beginning on January 1.

WILLIAM T. MARTIN

Department of Meteorology

The program of graduate education and research in meteorology and physical oceanography enjoyed a successful and productive year. In close collaboration with the Department of Geology and Geophysics, further progress has been made in the development of the Center for the Earth Sciences which will reach fruition when we occupy the new Green Building that is rapidly piercing the sky on the East Campus.

The number of regular graduate students increased by 30 per cent as compared to the previous year. At the same time the number of special students decreased sharply so that the total of all students remained the same. This is considered to be a very desirable change since it means that our limited space is now used almost entirely for regular students who are candidates for advanced degrees. The quality of the entering students has been very satisfactory and their academic performance has been correspondingly good. The students have exhibited broad interests in the earth sciences and in space and planetary sciences. Appropriate arrangements have been made to provide the necessary guidance of the many students whose interests extend beyond the offerings in the earth science departments. This is one of the responsibilities of a new faculty committee on general geophysics. This committee is also charged with proposing new subjects of instruction and cooperates closely with a similar committee of the Department of Geology and Geophysics.

It is apparent that the earth sciences are attracting the interest of an increasing segment of the scientific community. In part this is due to the close relationship, verging on identity, between the earth sciences and certain aspects of the space and planetary sciences and astrophysics. One manifestation of this growing interest at M.I.T. is the Committee on Planetary and Space Science (COMPASS) which entered on its second year of activity. This interdepartmental committee has sponsored a highly-successful seminar series and has done much to promote education and research in the planetary and space sciences. Faculty of the Department have played an active part in the work of this committee. Evidence that this increasing interest has reached the students is to be found in the growing numbers of students from other departments who register for one or more of the subject offerings of the Department of Meteorology.

CURRICULUM

The physical oceanography problems subject that was offered a year ago on an experimental basis was given again this year by Professor Delbar P. Keily. In view of its success we now plan to offer this subject on a regular basis. Further consideration has been given to our other subject offerings in physical oceanography. The addition of new faculty in this area next year will permit us to further extend and strengthen our program in oceanography that is attracting the attention of an increasing number of students.

As reported in previous years, there is strong evidence that the predoctoral fellowships in the atmospheric sciences and oceanography, supported by a grant from the Ford Foundation, have played a major role in attracting outstanding students to the Department. On the basis of our successful use of these fellowship funds the Ford Foundation has made a supplementary grant that will permit the continuation of this program for about two more years.

RESEARCH

The sponsored research program of the Department continued at about the same level as last year. Essentially all of the graduate students participate in the research program which is therefore an integral part of the program of graduate education.

Professor Jule G. Charney and Visiting Professor Arnt Eliassen have developed a new theory regarding the formation of hurricanes. They propose that the hurricane develops by a kind of secondary instability in which cumulus convection is organized in regions of horizontal convergence and quenched in regions of divergence. The cumulus and hurricane scales of motion are to be regarded as cooperating; the cumulus convection releases latent heat to drive the hurricane and the hurricane circulation provides the necessary inflow of water vapor in the boundary layer to feed the cumulus convection. It is found that the atmosphere may be statically unstable for cumulus convection while still being stable for hurricane-scale motion. A preliminary numerical solution suggests that, under appropriate conditions, a hurricane-scale circulation may develop in the order of one day.

Professor Charney has investigated the effect of the observed approximate balance between the horizontal pressure force and the Coriolis force on three-dimensional flows. Under these conditions he finds that non-linear interactions do not transfer energy to smaller and smaller wavelengths as is possible in the more general case of turbulent motion in which the balance between the pressure and Coriolis forces is not maintained. These findings point up an important limitation in the widely-used assumption that the pressure force is exactly balanced by the Coriolis force.

Professor Edward N. Lorenz and his group have been studying the degree to which hydrodynamic flow in general, and atmospheric flow in particular, is predictable. For this purpose they have examined the numerical solutions of systems of hydrodynamic equations which have been subjected to differing degrees of simplification. The simplest systems exhibit only steady or periodic behavior, while the less simplified systems possess much of the irregularity of the atmosphere. For very long time periods the predictability depends upon the presence or absence of periodicity. In systems with strictly nonperiodic solutions, two slightly different initial states almost always eventually develop into unrecognizably different states. Although it cannot be claimed that these systems are strictly representative of the atmosphere, they are derived from the basic hydrodynamical equations, and their behavior is qualitatively similar to the real atmosphere. Since there is as yet no evidence that the atmosphere is periodic, the inference is that there is a definite limit to the time period for which a useful forecast may be made.

Work performed under the direction of Professors Victor P. Starr and Reginald E. Newell has shown that the eddying motions characteristic of the Gulf Stream carry heat from the colder coastal water eastward toward the warmer Sargasso Sea. This countergradient heat transport is similar to the analogous phenomenon in the lower stratosphere and upper troposphere. At these levels atmospheric heat is transported poleward by large eddies in spite of a poleward increase in temperature. It was also found that poleward eddy momentum fluxes exist up to an altitude of 60 km, the action being similar to the well-known effects of this kind in the troposphere. In other studies Professors Starr and Newell have continued their work on galactic dynamics. It appears that a spiral mass distribution in a galaxy implies an outward flux of angular momentum in consequence of gravitational torques. These systems appear in certain other ways to be similar to the atmosphere.

Professor Hurd C. Willett is continuing with the statistical evaluation of the significance of solar-weather relationships as they appear both in long-term climatic trends and in sudden day-to-day changes of the hemispheric pattern of the general circulation. Involvement of atmospheric ozone in some of these relationships continues to be strongly indicated statistically, but the presently available observational data are quite inadequate to determine the physical connection. The processing of data to establish the importance of the storage of heat in the oceans to long-term climatic trends is being started.

Professor Keily has been conducting a laboratory investigation of the dynamical and electrical processes that occur as a small droplet impinges at sonic speed on a metal target maintained at a suitable electric potential. This is the basis of an instrument previously developed by Professor Keily for the measurement of the size of cloud drops from an aircraft. When the mechanism is more fully understood it is believed that the instrument may yield further information on the electric charge on the drops and may be capable of distinguishing liquid droplets from ice particles.

Professor Norman A. Phillips has developed and tested a numerical technique for computer solution of the equations of hydrodynamics which seems to be stable. A stable numerical method is important for the extension of numerical weather prediction to periods longer than several days. Previous methods have proved unstable or have required very large artificial viscosities to damp the instabilities.

Professor Frederick Sanders has studied the transport and condensation of water vapor in the atmosphere in an attempt to account for the development and motion of large areas of cloud and precipitation. A model was tested in which details of the moisture field are smoothed and only the vertical integral of the water vapor is predicted. Success of the predictions of the model suggests that the details of the moisture field, which present great theoretical and observational difficulty, may exert only a secondary effect upon its large-scale evolution. Bias due to neglect of evaporation from the earth's surface in the model was detected, however, in 24-hour predictions over a continental region. Evidently this process is important even for short-range weather prediction.

Dr. Yoshimitsu Ogura has continued his work on numerical computations of small-scale convective motions in the atmosphere. In particular, the evolution of an axially-symmetric convective circulation generated by release of an isolated buoyant mass in a conditionally unstable moist atmosphere has been investigated by integrating the dynamic equations numerically. The resulting clouds are found to resemble in many aspects those observed in nature. A comparison has also been made of the behavior of the calculated clouds with various theoretical models such as bubble models with constant or increasing total buoyancy, steady plume models, and starting plume models. This work shows promise of providing, for the first time, a sound theoretical framework for the study of the ubiquitous and important process of cumulus convection.

Department of Meteorology

Under the general direction of Professor Henry G. Houghton and the immediate supervision of Dr. Harrison E. Cramer, the research group at the Round Hill Field Station have continued their empirical investigation of energy transfer processes in the atmospheric surface layer. Spectral and cospectral analyses of field measurements of the fluctuations in wind velocity, air temperature, and humidity have led to increased understanding of the partitioning of turbulent energy and have resulted in a confirmation of certain predictions made by A. N. Kolmogoroff in 1941 concerning energy transfer mechanisms. The data have also been used to calculate the rate of energy dissipation per unit mass and the Eulerian scales of turbulence under various conditions of surface roughness and thermal stratification. The program of field observations and data analysis is continuing to permit extension of the work to greater heights above ground, different roughness regimes, and other time and space domains.

The Weather Radar Project, under the supervision of Dr. Pauline M. Austin, has taken a large number of quantitative radar data during a variety of weather situations in all seasons. These data have been reduced to digital form and are being processed to provide descriptions of the structure and behavior of the storms in terms of the three-dimensional distribution of precipitation. Particular attention has been paid to a comparison of precipitation from convective or cellular structures with that due to more uniform and large-scale systems. The relationship between the radar data and the three-dimensional fields of wind, temperature, and moisture are being studied both theoretically and empirically. Methods have been developed for determining the influence of various observed precipitation patterns on the close-in fall out of radioactive debris from surface nuclear explosions. New instrumentation is being developed to improve the accuracy and resolution of the measurements and to automate the handling of the data.

PERSONNEL

We were extremely fortunate to have with us as Visiting Professor Dr. Arnt Eliassen, who is Professor of Meteorology at the University of Oslo. Professor Eliassen provided additional stimulation to a number of our graduate students and collaborated with the faculty in several areas of research. It is a great pleasure to report that Professor Henry M. Stommel, one of the most distinguished physical oceanographers of the world, will join us as Professor of Oceanography next year.

HENRY G. HOUGHTON

Department of Nutrition and Food Science

Graduate enrollment in the Department has increased from 35 in 1960-61 and 32 in 1961-62 to 58 in the current year, and we expect a further sharp growth during the 1963-64 academic year. Corresponding numbers of post-doctoral fellows have been 3 in 1960-61, 2 in 1961-62, and 11 during the current year.

DEPARTMENTAL ACTIVITIES

During the past year, the Department has received a training grant for S.M. and Ph.D. candidates in food science and technology, another for physicians who wish to obtain an S.M. or Ph.D. degree in clinical nutrition and metabolism, a third in oral sciences leading to the Ph.D. degree in nutrition for dentists, and a fourth leading to a Ph.D. degree in physiological chemistry for veterinary pathologists. A similar training program in food toxicology is to be introduced during the coming year.

Support for individual research projects has increased substantially both in number of grant awards and in the amount of funds approved in individual project awards.

A facilities grant for the establishment of the M.I.T. Clinical Research Center has been awarded to the Department by the National Institutes of Health. The grant provides funds for the renovation of 18,000 square feet of floor space to house a clinic in the Daggett complex, and this work is currently underway. The grant also provides basic support for staff, equipment, supplies, and hospitalization expenses for eight years.

Through the Second Century Fund, the first endowed chair in the Department has been created, and Professor Alfred E. Harper has been designated as the General Foods Professor of Nutrition.

The entire Department faculty has been concerned with a complete analysis of the doctoral programs in food science and in nutrition. Two committees were formed—one to study the food science curriculum under the chairmanship of Professor Samuel A. Goldblith and the other to study the nutrition curriculum under the chairmanship of Professor Harper. These committees have conducted searching examinations into classroom and laboratory content and into degree requirements in the various subspecialties in the Department. As a result, several new subjects were introduced and others were reorganized and adjusted.

The Department held two highly successful symposia this year. The first was entitled "Recent Advances in the Appraisal of the

Nutrient Intake and the Nutritional Status of Man," sponsored by The National Vitamin Foundation, Inc. The second symposium, for participants in the M.I.T. Industrial Liaison Program, was entitled "Exploration in Future Food Processing Techniques."

NUTRITION

The physiological chemistry group has centered attention on biochemical effects of nutritional deficiencies and dietary alterations.

Professor Harper and Dr. Quinton R. Rogers have demonstrated that depressions in food intake due to excess leucine and amino acid imbalances are associated with changes in the pattern of free amino acids in the blood. They have also found that enzymatic adaptations which occur when an animal is fed a high-protein diet make the animal more susceptible to ammonia toxicity following injections of amino acids or ammonium salts. Professor Robert S. Harris has discovered that increased oxygen tension alleviates the signs of encephalomalacia due to vitamin E deficiency and is continuing his studies to elucidate the mechanism by which phosphates reduce the susceptibility of rats to dental decay.

Professor George Wolf has shown that the activity of a sulfate-activating enzyme is depressed in vitamin A-deficient rats and that inactive enzyme from such animals can be activated by a lipid compound which contains vitamin A or some metabolic product of the vitamin. They have also found that the quaternary base, carnitine, is incorporated into phospholipids in chick and rat embryos. Professor Sanford A. Miller and Dr. Henry A. Dymsza have developed a satisfactory artificial diet for infant rats which make possible studies of the effects of dietary changes during early life on the subsequent development of this experimental animal. They have also continued their studies on the metabolism of compounds having a high-energy content and have evidence that 1,3-butanediol and 2,4-dimethyl-heptanoic acid are utilized like carbohydrates rather than fatty acids.

Professor Louis C. Fillios has found that dietary and endocrine factors affect protein synthesis in the liver and has observed an inverse relationship between serum cholesterol concentration in rats subjected to various treatments and the capacity of liver microsomes from these animals to synthesize protein.

The clinical nutrition work has included studies by Professor Nevin S. Scrimshaw and Visiting Professor Guillermo Arroyave on the effect on metabolism of mild infections, examinations, and reversal of the sleep-work pattern in M.I.T. undergraduates. Professor Donald

M. Watkin has measured the effect of heavy muscular exercise on the protein requirements of young men.

FOOD SCIENCE AND TECHNOLOGY

Professor John T. R. Nickerson has continued his research program on the utilization of ionizing energy for the preservation of sea food products. This research program is opening up an additional method of food preservation for the food industry. Dr. Gerald Silverman has continued his studies on the basic effects of ionizing energy on bacteria and, in conjunction with Dr. Norman S. Davis, has also continued his research program with the National Research Corporation on the effects of ultra-high vacuum on microorganisms.

Professor Goldblith and Dr. Silverman have initiated a new program on microbiological considerations in freeze-dried foods, approaching this problem from a basic and fundamental level. Professor Marcus Karel has continued his research program on the basic chemical changes taking place in simplified models of food systems and has initiated a new program on the chemical and physical-chemical parameters and their role in the freeze dehydration of foods.

Dr. Joseph J. Licciardello has been studying the complementary effects of thermal and ionizing energy on bacteria and has found some interesting synergistic results which reduce the radiation dose requirements when these energies are used simultaneously. Professor Richard I. Mateles has an active research group in biochemical engineering concerned primarily with the dynamics of continuous cultures and the kinetics of the transformation of steroids.

Professor Stanley E. Charm has been continuing his studies on the dynamics of fluid flow; and his new book, *The Fundamentals of Food Engineering*, has just been published. Dr. Emily L. Wick, recently promoted to Associate Professor, is continuing her work on the chemistry of flavor with several postdoctorate fellows and graduate students.

Dr. Phillip Issenberg, presently on leave of absence for military duty, will return to the Department in January, 1964, as Assistant Professor to develop a program on new basic physicochemical techniques which may be useful in the detection and measurement of compounds in foods, such as the flavor molecules which are present in such small quantities. Dr. Issenberg will also develop a new subject in food science, to be presented for the first time this coming year, for graduate students. Professor Cecil G. Dunn has been active in studies on the cultivation of mushrooms and diseases affecting them.

FOOD TOXICOLOGY

A program grant for research support in food toxicology has been awarded to the Department. This grant will provide broad, relatively unrestricted financial support for the entire range of research activities in food toxicology. The award includes a substantial contribution toward the renovation costs of a center for food toxicology and animal pathology, and this work is presently underway in the Daggett properties.

In food toxicology, Professors Leo Friedman and Gerald N. Wogan have initiated a program of research on the physiological effects of food components, other than nutrients, that will emphasize application of the most recent knowledge and techniques of the biological and related disciplines. Activities will focus on the development of reliable, sensitive, and rapid procedures to detect and study toxic and carcinogenic effects, with particular attention to problems of the safety of potentially important human food sources. The application of tissue and cell culture techniques and the use of the developing chick embryo to these problems is being explored by Dr. Janis Z. Gabliks.

Studies led by Professor Wogan have shown that mycotoxin from a variant of the ubiquitous mold *Aspergillus flavus,* found originally in peanut meal, can be produced experimentally in varying degree in all foodstuffs studied, as well as in simple chemical fermentation media. Collaboration of Professor George H. Büchi's group of the Department of Chemistry in elucidation of the chemical structure of aflatoxins B_1 and G_1 is a splendid example of successful interdepartmental and interdisciplinary cooperation.

In animal pathology, Professors Paul M. Newberne and William W. Carlton are engaged in studies in carcinogenesis associated with dietary chlorine deficiency, feeding ethionine, or feeding of various toxin-containing peanut meals originating and produced in the United States. Pathology of the cardiovascular system produced by dietary copper deficiency in chicks and rats and the teratogenic effects on the offspring of vitamin B_{12} deficiency in pregnant rats is related to abnormalities in elastin and mycopolysaccharide components.

NEVIN S. SCRIMSHAW

Department of Physics

During the past year the Department has devoted considerable time to a continuing discussion of the advisability of a major alteration of the content and method of presentation of the two year sequence in elementary physics. This has led to a general conviction that a more unified presentation of this basic material, including the point of view of modern physics, would be highly desirable and also that such a revision will involve a major effort on the part of the Department faculty. The Science Teaching Center, under the direction of Professor Jerrold R. Zacharias, is prepared to assist the Department in the development of such a new presentation, and Professors Nathaniel H. Frank and Anthony P. French will be devoting most of their time to this activity. We hope to be prepared to offer this sequence beginning with the 1964-65 academic year.

While this discussion and planning has been in progress, some experience has been gained with respect to methods for presenting such new material to first-year students. During this past year, Professor Frank conducted a seminar in physics during the first term with approximately sixty-five students of the entering class. He was assisted by Professors Albert G. Hill, John G. King, William Bertozzi, and French. The seminar incorporated some of the ideas and techniques which had been developed in the Science Teaching Center and proved to be of considerable value and interest to the students. Professor King conducted a laboratory sequence as a companion course to Professor Frank's seminar, and this program was continued during the second term although with a reduced number of students.

In order to better coordinate our undergraduate counselling activities we are establishing an Undergraduate Office somewhat along the lines of the Graduate Office which has operated successfully for many years under the supervision of Professor Philip M. Morse. Professor George E. Valley, Jr., will serve as the Undergraduate Registration Officer in general charge of our registration and counselling responsibilities, and it is expected that this new Office will be of considerable value to the large undergraduate student body majoring in physics.

One new subject of interest to a large number of departments was added during the past year. Dr. Robert A. Smith, who had been head of the Physics Department at the University of Sheffield, England, arrived in October to take on his new duties as Professor of Physics and also as Director of the Center for Materials Science and Engineering. During the second term he conducted a new graduate subject in Solid State Physics, which covered an introduction to wave-mechanics of crystalline solids, wave-motion of electrons and the lattice in perfect crystals, crystal momentum, phonons, etc.; scattering of electrons by imperfections, interaction of photons with electrons and phonons; and the electrical, optical, and thermal properties of metals, insulators, and semi-conductors, such as specific heat, lattice vibrations, and optical absorption, as well as the more usual transport properties such as electrical and thermal conduction.

RESEARCH

The research interests of the faculty of the Department cover a wide spectrum and it is not feasible to describe all these in any detail. The general scope of some of these activities is outlined in the following paragraphs.

During the past year Professor John C. Slater has been engaged in writing the second volume of *Quantum Theory of Molecules and Solids.* In the course of the preparation of this volume he has derived for the first time the irreducible representations of a number of space groups of importance in solid-state theory. In addition he has looked anew into the problem of atomic and ionic radii in crystals and come upon a revised set of radii which fit a very large number of interatomic distances occurring in molecules and solids.

Professor John H. Wood has been engaged in directing a large effort of the solid-state group in computing the energy-band structure of a number of elements. His greatest effort has been on the energy-band structure of gallium. In addition he has collaborated with Dr. Leonard F. Mattheiss, who has calculated band structures for argon and some of the transition metals.

Professor George F. Koster has worked on the theory of the rare-earth ions. He and Dr. Clair W. Nielson have computed the coefficients of fractional parentage for all f^n configurations and have prepared tables of other constants involved in the theory of these configurations. In addition the problem of exchange interactions in rare-earth-ion garnet crystals has been investigated. Along a different line, Professor Koster and Dr. Jean Hanus have investigated the problem of the interaction of spin waves in a simple cubic lattice.

Professor George B. Benedek is engaged in a study of the electronic structure of solids using the techniques of nuclear magnetic resonance, paramagnetic resonance, and optical spectroscopy. He and his students have observed the nuclear magnetic resonance in ferromagnetic iron while the sample was subjected to pressures as high as 65,000 atmospheres. This represents the first nuclear magnetic resonance experiment in the "superpressure" region. They have also succeeded in explaining in terms of the spin fluctuations their measurements of the nuclear resonance line width in the immediate vicinity of the paramagnetic-antiferromagnetic critical point in M_nF_2.

Professor Clifford G. Shull's neutron scattering experiments using spin-polarized neutrons have detected the very weak polarization of the nuclear moments in paramagnetic vanadium. In the course of these experiments a fundamental asymmetry in the scattering of polarized neutrons was discovered which is produced by the spin orbit interaction between the neutron magnetic moment and the nuclear charge. Dr. Shull and his students have also discovered that the magnetic moments of the conduction electrons in ferromagnetic cobalt and iron are polarized in a direction opposite to the moments of the magnetic d electrons.

Professor John F. Cochran and Dr. Mohammed Yagub have succeeded in growing small single crystals of gallium which are so perfect that measurements of the electrical resistivity and magnetoresistance show that the mean free path for the conduction electrons is about 1 cm at 1.2°K. Previous to their work, the largest mean free path seen in metals was $\sim$2 mm.

Professor Malcom W. P. Strandberg and his associates were able to demonstrate, both theoretically and experimentally, the effect of the defect character of the ion site in a dilute paramagnetic crystal on spin-lattice relaxation phenomena.

Professors Charles H. Townes and Ali Javan have continued a broad program of investigation of the more fundamental aspects of optical and infrared masers and their utilization for physical experiments. Using He-Ne masers, they have achieved very high frequency stability which has allowed detection of rapidly changing displacements as small as 4×10^{-12} cm. An experiment to detect "ether drift" or anisotropy of space of the Michelson-Morley type was carried out to capitalize on the precision in detection of such minute changes of length. The first version of the experiment confirmed the Lorentz-Fitzgerald contraction due to the earth's orbital velocity to about one part in one thousand. Maser techniques were also used to determine spectroscopic quantities such as isotope shift in optical transitions. With the aid of the high intensity of the output beam, which allows saturation of atomic resonances, a number of experiments were carried out in which detailed pictures of the interaction of atoms with a monochromatic optical field were obtained. These measurements yielded accurate information on the line shape of optical transitions and their relaxation processes.

In plasma physics, Professors Sanborn C. Brown and George

Bekefi have made two significant advances in the past year. Following many years of studying the microwave radiation from laboratory plasmas, a theory was developed which, after being tested on laboratory plasmas, was successfully applied to the microwave radiation from the planet Jupiter. For studying higher and higher density plasmas, experiments have been pushed to shorter and shorter wavelengths to the point that 0.3-millimeter infrared studies of laboratory plasmas have provided a new tool for studying high-density phenomena.

Professors Bruno B. Rossi, Alan J. Lazarus, and Frank Scherb have continued to investigate a broad range of topics, almost all of which concern phenomena outside the earth's atmosphere. The data from the Explorer X plasma probe have now been completely analyzed and the results have been submitted for publication. New probes have been designed to permit measurement of the directional properties of the plasma and to allow measurement of electrons as well as ions. These new probes are scheduled for flights on the EOGO (Eccentric Orbiting Geophysical Observatory), IMP (Interplanetary Monitoring Probe), and Mariner C (Mars Probe) space vehicles.

Professor Stanislaw Olbert has been involved in the analysis of plasma and magnetic field data from Explorers X and XII and from the Venus probe, Mariner II. This analysis has shown the importance of the external magnetic field in the interaction of the "solar wind" with the earth's magnetosphere. Although the energy content of the external field far from the earth is small compared to the energy in the solar wind, the field plays an important role in the interaction region.

Professors William L. Kraushaar and George W. Clark have worked on analyzing the data obtained from the gamma ray satellite, Explorer XI. The results of the analysis provided a meaningful upper bound to this cosmic gamma-ray intensity and have, among other things, proven to be inconsistent with one cosmological model. The new instrument that is being designed for flight in the orbiting Solar Observatory should be capable of measuring a cosmic gamma-ray intensity two orders of magnitude smaller than the upper bound set by the Explorer XI instrument.

Professors Clark and Hale V. D. Bradt have been involved in the cooperative air shower experiment at the Mt. Chacaltaya Laboratory in Bolivia. This experiment was designed to detect gamma-ray-induced showers and to investigate certain details of the nuclear and electronic cascade processes that are responsible for air shower development. Useful data on both of these topics are being obtained, but analyses are still in process.

Professors Bertozzi and Peter T. Demos, in collaboration with Drs. Charles P. Sargent and William E. Turchinetz, have been using the nanosecond-duration electron beams from the linear accelerator to carry out neutron energy-spectra measurements by time-of-flight techniques in a continuing study of nuclear structure properties that manifest themselves in the photoexcitation of nuclei leading to neutron emission. Recently the group has developed a neutron polarimeter to determine photoneutron polarizations, allowing further quantitative information to be obtained complementing the program of photoneutron energy and angular distribution studies. The experimentation includes a study of the two- and three-body systems as well as other selected nuclei. Particular emphasis has recently been placed on understanding the details of the photodisintegration of the deuteron.

Professors William W. Buechner and Harald A. Enge, Dr. Thomas A. Belote, and their collaborators in the Laboratory for Nuclear Science have continued their research program on nuclear energy-level spectroscopy through charged particle reactions such as inelastic proton scattering and deuteron stripping, with particular emphasis on heavy elements in the region of strong nuclear deformation. They have also been working on the development of new instruments and techniques for possible use in research with the proposed new tandem facility.

Professor Bertram E. Warren has obtained a new measurement of the short-range order parameters in Cu_3Au, incorporating all of the corrections which have been discovered since the early work, leading to parameter values which are significantly larger. New information concerning the nature of cold work in a metal has been obtained by using order-disorder alloys for the cold-worked sample.

The molecular beam group of Professors Zacharias, John G. King, and Kenneth Billman has been engaged in high-precision studies of atomic and molecular radiofrequency spectra, an example being the study of the rotational spectrum of HF and the development and intercomparison of atomic frequency standards of which the CS electric resonance studies and the ammonia molecule decelerator are examples.

Research by Professor Aron Bernstein and his associates includes an experimental verification of the possible existence of H^4 and H^5 as particle stable nuclei, an important issue recently raised on experimental and theoretical grounds. Current work also includes an effort to design a system for computer analysis of scattering data and a semi-empirical survey of the effective g factors and β-decay coupling constants in nuclei.

Professor Robley D. Evans and his associates are continuing their studies in α-ray spectroscopy of heavy nuclides, using semi-conductor detectors. Measurements of the angular correlation between α rays and γ rays are providing information on the nuclear angular momentum of weakly populated excited levels, while observations of delayed coincidences between α rays and conversion electrons, in the subnanosecond domain, provide measurements of the mean life of rotational levels. Development and production of semiconductor counters with thick depletion depths continues.

The long-term biological effects on humans of the ingestion or inhalation of radioelements, especially radium or mesothorium, continues as another major interest of this group. The radiation protection standards for internal emitters used throughout the world have been provided by these long-term studies. The development of radiation dosimetry and instrumentation techniques permits routine periodic measurements of the accumulation in human subjects of radionuclides from weapons-test fallout. Geophysical radioactivity studies of radon flux through the earth-to-air interface have provided a potential method of on-site inspection for underground weapons tests.

In the past year there have been several major experimental research developments in elementary particle physics. Under the direction of Professor M. Stanley Livingston, the Cambridge Electron Accelerator (CEA) has been completed and brought into successful operation. Professors Irwin A. Pless and Lawrence Rosenson made a determination of the spin of the N-meson from data taken at Brookhaven National Laboratory. Professor Martin Deutsch, using data taken at Cornell University, developed the measurement of the Compton scattering of photons by protons at high energies. Professor David H. Frisch and Dr. Lester A. Sodickson, with data from Brookhaven National Laboratory, worked on the angular distribution of π-proton and K-proton scattering. Professor Louis S. Osborne and Dr. Raymond A. Alvarez worked on the photoproduction of π-mesons at the CEA. Professors Henry W. Kendall and Jerome I. Friedman worked on the photoproduction of μ-meson pairs from carbon at CEA.

There have been continuing major technical developments, including work by Professor Deutsch on an automatic photointerpretive system for spark chamber tracks, by Professor Pless on a precision encoding and pattern recognition system for bubble chamber tracks, and by Professor Frisch on a high-Z large-solid-angle spark chamber.

The main areas of research in theoretical physics were in relativistic quantum theory (quantum field theory and elementary particle theory) and nuclear structure theory. In quantum field theory Professor Francis E. Low and Visiting Professors Marvin Goldberger and Murray Gell-Mann have investigated the validity of the "Regge-pole" hypothesis; Professor Paul G. Federbush has studied the high-energy behavior of Feynman-amplitudes; and Professor Kenneth A. Johnson is developing a finite quantum-electrodynamics, which includes a prediction of the fundamental fine structure constant e^2/hc.

In elementary particle theory, Visiting Professor Gell-Mann and Professors Kerson Huang and Bernard T. Feld are concerned with the symmetry classification of particles and, more recently, with the so-called "bootstrap" problem. Professor Earle L. Lomon has developed a successful model to describe elementary particle scattering processes.

Visiting Professor Gerald E. Brown and Dr. Gottfried T. Schappert have studied improved approximation methods in the "nuclear matter" problem. Professor Arthur K. Kerman has developed a generalized Hartree-Fock approximation. The theory of nuclear reactions has been under investigation by Professor Felix M. H. Villars (general formalism) and Dr. Carl M. Shakin and Professor Richard H. Lemmer (application to specific processes).

Professor Lee Grodzins has been carrying out investigations of the magnetic and quadrupole moments, the charge radius, and the lifetimes of nuclear excited states, by means of angular correlation and Mőssbauer techniques. In a related series of experiments, the high precision of Mőssbauer scattering is being used to investigate the influence of macroscopic parameters on the nuclear gamma ray energy.

Professor Karl U. Ingard has simulated and studied in some detail the dynamics of the types of instabilities that occur in plasma physics, utilizing conducting liquids such as mercury and liquid sodium. During these studies a new type of instability resulting in a stream bifurcation was encountered at high magnetic fields.

Professor Clive H. Perry has investigated the reflection spectra of some perovskite titanates up to 300 microns wavelength. The optical properties of these materials in the infrared region was obtained from a Kramers-Kronig analysis of the reflection data, and the objective was to relate these properties to the ferro-electric behavior of the titanates.

Professor Hans Mueller has extended the development of a phenomenological theory of optics dealing with the complex polarization phenomena in heterogeneous materials and problems of coherence, incoherence, and partial coherence. Instrumentation for accurate verification of the postulates of this theory has been developed, and new methods for measuring optical constants have been successfully tested.

PERSONNEL

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 a year's leave of absence was Professor Herman Feshbach. Professor William P. Allis was on the first year of a two-year leave of absence to serve as Assistant Secretary General for Scientific Affairs of the North Atlantic Treaty Organization. Professor Livingston was on leave from his position as Director of the Cambridge Electron Accelerator to visit various European accelerator installations. Professor Laszlo Tisza, assisted by a Guggenheim Fellowship, spent the year on the faculty of the University of Paris. Professor Hill was on leave for the second term at the California Institute of Technology. Professor Rudolf W. Bauer spent the year at the Livermore Laboratory of the University of California. Professor George W. Clark, with the aid of a Guggenheim Fellowship, worked on his research during the second term at the University of Milan.

A smaller number of the faculty will be on leave during 1963-64. Professor Weisskopf will continue to serve as Director of CERN for the coming year, and Professor Allis will continue on leave to serve at N.A.T.O. Professor Paul G. Federbush will be on leave to serve in the Department of Mathematics at M.I.T.

During the year Dr. Marvin L. Goldberger, Higgins Professor at Princeton University, and Dr. Gerald E. Brown from the Nordisk Institut for Teoretisk Atomfysik served as Visiting Professors; Professor Gell-Mann came from the California Institute of Technology as Visiting Professor during the second term. Professor Brown assumed new duties as Associate Dean of the Graduate School in February, 1963, remaining on a part-time basis in the Physics Department.

During the coming year Professor Philip Morrison of Cornell University will be at M.I.T. during the second semester to be the first Francis L. Friedman Lecturer and to serve also as a Visiting Professor of Physics. Dr. Luiz C. Gomes of the Universidade de Sao Paulo will serve as a Visiting Assistant Professor in the Department during the coming year.

WILLIAM W. BUECHNER

Computation Center

The growth of computational capacity at M.I.T. over the past decade has been tremendous. The Computation Center alone has more than tripled its computing power since the first I.B.M. 704 was installed in 1957. Yet this growth has not been sufficient, and many groups at M.I.T. are finding, in the limitation of computing facilities, justification for acquiring their own machines. There are now about thirty computers on campus alone, with more to come.

This justification is usually based on the problem of accessibility. The heavy demands experienced by the Center create long queues; and, though efficient use of the computer is assured, the delays imposed are serious impediments to human effort. The acquisition of several small computers may alleviate this problem for a few users; but there are already large classes of problems for which the largest and fastest machines are inadequate and the use of the smaller computers is very limited in comparison.

For several years now the staff of the Center has been working on the development of an approach designed to provide immediate access to many users, each of whom would have all the capabilities of a large computer at their disposal. In this approach, called time-sharing, the computer sequentially runs each user's program for a short burst of computation. Each user has access to the computer through a remote input-output console which can be merely a typewriter but which more ideally would contain graphical input and output devices. He has complete access to the machine, is in close contact with it, and can work at his own pace without concern for the activity of others using the system.

The result of this work has been the development of the M.I.T. Compatible Time-Sharing System which is described in a programmer's guide published by the M.I.T. Press. This initial system uses the I.B.M. 7090 equipped with several special features. Its command language is similar to that of other monitor systems in present use, and the programming languages available are those already in wide acceptance. The system is, therefore, truly compatible with previous systems and even allows monitor runs to proceed in the "background," using the computer whenever there is no demand for the consoles. Considerable experience has been gained with this system on engineering and research problems, and experiments in classroom use will be conducted this fall.

The remote consoles in use at present are standard teletypes;

but with connection of the Electrical Engineering Department's PDP-1 and the Civil Engineering Department's I.B.M. 1620 to the 7090, ideas can be developed for more sophisticated and flexible consoles which can be simulated on these computers.

This work has shown that time-sharing concepts can be implemented on conventional computers and do provide a unique solution to the problem of accessibility. The next big step, the development of a truly integrated time-sharing system with each element designed to fit the system concept, requires the effort of many groups if the plans of the scope envisioned are to be realized at the speed demanded by increasing computer usage. Project MAC, an Institute-wide effort in which members of the faculties and staffs of many departments and centers will participate, was organized this past winter for this purpose. The Computation Center welcomed the opportunity to join in the organization of this project and to act as its agent in the installation and operation of the computing equipment required.

The eventual implementation of the very large central time-shared computer, with the many and varied consoles presently envisioned, should stimulate advances in many areas by making the use of powerful and sophisticated techniques practical for all problems. Such a system could be used on computations not now practical because of their size while still allowing the scientist or engineer casual use of the computer in real-life problems. The possibilities of its use in classrooms as a teaching aid are intriguing. In the laboratory it becomes a device with almost limitless usefulness and may cause a general reorientation of laboratory techniques. It would have all the physical aspects of a large information retrieval system, large secondary memories, and remote inquiry stations and should find considerable use in that field.

In addition to the development of the Compatible Time-Sharing System, the staff of the Center has been active in a number of other aspects of computer science. Such activities include work in numerical analysis, artificial intelligence, and the design and development of devices for graphical input and output.

The Center's part, as a service group, in the research and academic activities of the Institute as a whole is, of course, its most important function. Every department of the Institute has used the computer in the past year in its research projects, and over two dozen M.I.T. subjects include use of the computer as part of their instructional program.

PHILIP M. MORSE

Cooperative Computing Laboratory

The Cooperative Computing Laboratory has now completed twenty months of operation as a computation facility used by many members of the Institute and as a laboratory whose staff is pursuing a vigorous program of research in computer science. The Laboratory houses an I.B.M. 709 computer and associated magnetic tape and punched card equipment. The computer has on-line graphic display facilities which are integrated with on-line keyboard and graphic input devices; it also is equipped to deal with rapidly sampled continuum input signals. A Photon S-560 paper-tape-driven photocomposing unit was installed in the Laboratory in April, 1963.

The equipment in the Laboratory has been used by some 400 members of the Institute in the past year, primarily for research calculations and to a lesser extent for teaching and seminar activities and administrative data handling. Users include faculty, D.S.R. staff, graduate and undergraduate students, and members of the administration. Research calculations of a theoretical nature have used more computer time than calculations which were concerned with the reduction of experimental data. However, during the year there has been a relative increase in calculations of the latter type. A considerable amount of time has been used in studies of on-line computer-aided design and in the processing of non-numeric information in studies of mechanized documentation.

A few groups have used rather substantial amounts of computer time during the past year, the Solid State and Molecular Theory Group and the research staff of the Laboratory being the two largest users. Quantum mechanical calculations, directed by Professors John C. Slater, Michael P. Barnett, George F. Koster, and John H. Wood have been concerned with the study of the band structure of solids, molecular behavior, and crystal field theory. The computer-aided design project, a collaborative effort of the Electronic Systems Laboratory and the Mechanical Engineering Department under the direction of Douglas T. Ross and Professors Steven A. Coons and Robert W. Mann, has made impressive progress during the year. Several members of the Laboratory for Nuclear Science have used considerable computer time, as have the studies of Professors Jule G. Charney and Norman A. Phillips in theoretical meteorology, and the studies of Professors Stephen M. Simpson and Theodore R. Madden in geophysics.

The program of research in non-numeric applications of computers conducted by the staff of the Laboratory has expanded in the last year. Techniques of syntactic scanning and symbol manipulation have been applied to a variety of problems which relate to the processing of mathematical expressions, chemical formulae, and verbal texts. The computer has been used to perform tedious algebraic processes in quantum chemistry and planetary theory. Dr. David A. Luce has continued his investigations in musical acoustics, in association with Dr. M. Clark who initiated this work and who has left the Institute during the year to accept an appointment elsewhere. The computer-controlled photocomposition project has derived considerable benefit from the cooperation of John I. Mattill of the Office of Publications and from collaborative efforts with Richard L. Snyder of the M.I.T. Libraries and members of his staff. This latter collaboration has led to the completion of photolithographic originals of a 180-page Union Listing of Chinese Communist Periodicals that probably will be the first book to be produced by computer-controlled printing methods.

MICHAEL P. BARNETT

Laboratory for Nuclear Science

There was reviewed in last year's report our continuing effort to appraise properly the Laboratory's future research effort and to plan and carry through its implementation. The timely provision of a number of research facilities will be essential to a proper fulfillment of M.I.T.'s capability for leadership in the fields of nuclear and elementary particle physics, and our main and very real preoccupation concerns this crucial task. This report outlines the present position of our proposals for the acquisition of two new particle accelerators (a linear accelerator and a tandem Van de Graaff machine), the construction and organization of experimental staging and assembly areas for high energy researches, and the development and acquisition of instrumentation for analysis of the enormous yields of complex information which accompany almost every experiment in these fields. The time is right also to intensify our quantitative theoretical investigation of problems of nuclear structure and elementary particle theory, and we regard as especially important our plans for the further implementation of our theoretical effort as outlined elsewhere in this report.

In parallel with planning for new facilities has been the orderly retirement of old ones. We noted last year the retirement of the Laboratory's 4-Mev electrostatic (Rockefeller) generator. We have this year dismantled our 330-Mev synchrotron. Our work in high-energy photon-induced reactions, the foundation for which was laid with the synchrotron program, has now shifted solidly to the Cambridge Electron Accelerator (CEA), the 6-Bev machine built and operated jointly with Harvard University. The research area and facilities at the synchrotron site are now in use as development laboratories for our experiments with the CEA and Brookhaven accelerators. This constitutes a significant step in our plans for establishing a properly equipped research staging area with shop and apparatus-assembly and data-analysis facilities suited to the large-scale experiments which must be performed during the coming two decades. It is relevant to note that our plan for on-site logistic support of this kind follows not only as a necessary next step in our immediate effort; it also presents the only way in which there can be fruitful long-range participation by the academic community in research with the very large accelerators now being contemplated for construction on a national scale.

Another important phase of our facilities improvement program has been completed this year with the extension of the research laboratory and experimental areas surrounding the Laboratory's cyclotron. The details of these modifications are given later. The observation to be made here is that while the improvements are of specific importance to current programs of research involving the cyclotron (including nuclear chemistry and biomedical applications), they also create facilities potentially useful as staging and research areas for nuclear structure physics in general for the more distant future.

Two particularly notable developments in the instrumentation and techniques of data analysis have come to a highly satisfactory state during the past year. These were both originated in the Laboratory to cope with the large amounts of data yielded by present-day nuclear experiments. One of these, SPASS (Spark Chamber Automatic Scanning System), has its application to data from spark chamber experiments. The success and promise of the technique is evidenced by its use in the analysis of a specific experiment in which about 500,000 events were analyzed at a rate from one to several events per second. PEPR (Precision Encoding Pattern Recognition System), the second of these devices, was developed for the measurement of high-energy events by recognizing particle reaction patterns of specified kinds with sufficient precision to allow the analysis of very fine bubble chamber tracks. Both SPASS and PEPR represent original and important steps in data analysis which have already exercised a shaping influence on the field. SPASS shows promise of quite general applicability to measurements of spark chamber data and is at present being developed with such breadth of application in mind. PEPR, though its use in complex problems will entail ingenious computer programs, has already demonstrated the feasibility of its application to a great range of important bubble chamber experiments.

STATUS OF PROPOSED FACILITIES

Four major construction efforts were proposed by the Laboratory in 1961. These included the modernization of our cyclotron; construction of a new linear accelerator facility; construction of a new tandem Van de Graaff facility; and construction of a high-energy research center. The first has been finished; the rest are in one or another stage of proposal and consideration. Details relating to each of these facilities are outlined below.

Cyclotron. The construction associated with the modernization of our cyclotron was completed in March of this year. It accomplished a four-fold extension of area to a total of 13,000 square feet. The cyclotron itself remains unchanged (7 Mev protons, 14 Mev deuterons, 28 Mev alpha particles) for the foreseeable future, but this extension has provided a larger target room (30 by 30 feet) suitable for time-of-flight and magnetic deflection analyses, an improved and isolated radiochemistry area of about 800 square feet, and badly needed research laboratory shop and office areas of about 4,500 square feet.

Linear Accelerator. The machine proposed to succeed the Laboratory's present small linear accelerator for photo-nuclear studies will be a high-intensity linac capable of delivering beams of up to 140 Mev in energy. The machine and r-f vaults, target rooms (14,800 sq. ft. total), and flight paths (up to 300 meters) will be located underground, with approximately 8,200 square feet of office and research area above ground. The entire facility is currently under proposal to the Atomic Energy Commission.

Tandem Van de Graaff. The machine being proposed is a tandem accelerator with a guaranteed 10 Mev terminal voltage but with expected capability to 20 Mev. This machine would be added to the Laboratory's existing 6- to 10-Mev O.N.R. electrostatic accelerator facility. A preliminary design of a laboratory to house this facility has been made. It will provide about 16,000 square feet (net) of total floor space, 10,000 square feet of which is space for the accelerator, analyzing magnet, and target area. A proposal for this facility has been submitted to the Physics Branch of the National Science Foundation.

High-Energy Center. The purpose of this proposed center is to provide research laboratories for staging high-energy, cosmic-ray, and satellite-borne research; a computing and data analysis center; and extended shop and assembly areas. The building has been planned for a two-stage development beginning with a first stage of approximately 56,000 square feet. The urgent matter of establishing support for this important building, or its equivalent, is currently under consideration.

CURRENT RESEARCH

The research of the Laboratory encompasses low-energy nuclear physics (including radioactivity and nuclear chemistry*), high-energy nuclear physics, cosmic rays, and space-related high-energy and cosmic-ray physics, including major efforts in theoretical physics on all fronts. The low-energy experimental program is developed about three accelerators—the Van de Graaff electrostatic accelerator, the cyclotron, and the electron linear accelerator. Our high-energy program centers heavily about the Cambridge Electron Accelerator but includes also a substantial amount of research with accelerators elsewhere (mainly at the Brookhaven Cosmotron and Alternating Gradient Synchrotron).

There was a total of 633 participants in the work of the Laboratory during the past year, including full- and part-time personnel from both Physics and Chemistry Departments. This total includes 53 academic staff members, 176 graduate students, 160 undergraduate students, 70 research associates and D.S.R. staff members at the postdoctoral level, 12 visiting physicists and chemists from other universities, and 162 employees in supporting categories. A total of twenty-three Ph.D. degrees were awarded during the period to students whose thesis research in chemistry or physics was completed within the Laboratory.

COSMIC RAY AND SPACE PHYSICS RESEARCH

The program of cosmic ray and space physics research is divided roughly into four categories: time variations of the cosmic-ray intensity, properties of extensive air showers, investigations concerning primary gamma rays, and studies of the interplanetary plasma.

Time variations in the intensity of the μ-meson component have been studied for the past few years by means of a large meson tele-

* 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 the researches of the chemistry groups is included, as usual, in the report of the Department of Chemistry.

scope located at M.I.T. In general this instrument measures changes in the intensity of the primary component at a mean energy of about 30 Bev. The problems which are being studied include: increases in solar cosmic ray flux associated with large solar flares; short-time modulation effects in the range one to six minutes; the diurnal variations; and Forbush decreases. The data obtained are being correlated with results from neutron monitors and satellites in the interplanetary regions in which are produced the variations in cosmic ray intensity observed on the earth.

Research on extensive air showers is being carried out at Albuquerque, New Mexico, and the Laboratorio di Fisica Cosmica, La Paz, Bolivia, with an appreciable fraction of the analysis being carried out at M.I.T. In the past, the emphasis of the Albuquerque program has been directed toward determination of the energy spectrum of the cosmic radiation at extreme energies. As a result of this work, it is apparent that the spectrum extends to 10^{20} ev without any drastic change in slope. This result means that at least some cosmic rays must be of extra-galactic origin. At present, the Albuquerque experiment is being relocated and some changes are being made to permit a study of nuclear interactions at energies above 10^{14} ev. The new experiment is expected to give significant information about nuclear interactions at these energies. In addition, it should be possible to determine the fraction of the high-energy primary cosmic rays with $Z=1$.

The high-altitude experiment at La Paz is designed primarily to search for high-energy primary gamma rays by selecting only those air showers which contain the electromagnetic component (electrons, positrons, and gamma rays). This program is now in a very active stage, and data have been obtained for a large number of showers which were presumably initiated by high-energy gamma rays. The arrival directions for these events are being examined to see if there is a directional asymmetry with respect to the galaxy. In addition to the search for primary cosmic gamma rays, the Bolivian shower array will be used as a large-area meson detector to monitor the primary cosmic ray intensity in a manner similar to the meson monitor at M.I.T. As part of this program, improved apparatus for the photography of Cerenkov light from extensive air showers using image-intensifying techniques is being designed and constructed. This apparatus will ultimately be used with the Bolivian experiment in an attempt to search for cosmic gamma-ray point sources.

Current space researches of the group include the flying of plasma probe instrumentation on IMP (Interplanetary Monitoring Probe), EGO (Eccentric Geophysical Observatory), Mariner C (Mars), and Pioneer vehicles; and the flying of cosmic gamma-ray detection apparatus on OSO (Orbiting Solar Observatory) vehicles. This work is being done in collaboration with Lincoln Laboratory.

Instrumentation developments of interest include a new gamma-ray detector under development for satellite use; a detecting device capable of measuring the mass and charge of the ions in the solar wind which would permit a determination of the percentage of heavy elements contained therein; a charged-particle detector capable of measuring the charge spectrum of low-energy cosmic rays; and a plasma probe which can determine the direction of the incident plasma beam by an electronic scan mechanism.

Theoretical work is being carried out on nuclear interactions at very high energies, on the nucleonic cascade in the atmosphere, and on the interaction of the interplanetary plasma with the geomagnetic field.

HIGH-ENERGY AND ELEMENTARY PARTICLE PHYSICS

During the past year a number of experiments have been completed, and the results are either published or in process of publication. These include a redetermination of the branching ratios of θ^0's and of Λ^0's (data obtained at Brookhaven National Laboratory), proof of the 2-γ decay mode of the η^0 (BNL), Compton scattering of photons by protons in the 600 Mev region (Cornell), angular distributions of K-p and π-p elastic scattering in the 1 Bev region (BNL), and polarization of protons in the photodisintegration of deuterium at 300 Mev (M.I.T.).

Three experiments have had substantial runs at CEA, and the data gathered in them is being analyzed. They are: (1) the photoproduction of π^0 mesons, using large scintillation counter hodoscopes mounted on a 40-foot swinging arm carrying magnets for momentum analysis (this huge experiment uses the experience of studying the lowest excited state of the nucleon with our M.I.T. synchrotron to study the higher excited states with remarkable precision and speed); (2) the photoproduction of μ-meson pairs to see whether conventional quantum electrodynamics holds for the electromagnetic interactions of μ-mesons at short distances, i.e. at large momentum transfers (in collaboration with a Northeastern University group); and (3) Compton scattering by protons, a continuation to higher energies of the experiment done previously at Cornell. Like the photoproduction of

π-mesons, the last is a basic method of studying the properties of the excited states of elementary particles.

These experiments will soon be expanded and transformed in various ways. In addition, we have three other major experiments under development for CEA. They are photoproduction processes in a very large hydrogen bubble chamber (in collaboration with groups from Brandeis, Brown, and Harvard Universities); (2) peripheral production of vector mesons using "tagged" photons; and (3) in the most distant future, photoproduction processes in a large spark chamber in a magnetic field, also using "tagged" photons. The hydrogen bubble chamber group mounts the largest single experiment at CEA, and it is particularly gratifying that a preliminary run at CEA with a small hydrogen bubble chamber has now shown an event of possible interest in one out of every fifty pictures and a strange-particle event in one out of every fifty of those.

Similarly, several experiments are planned or under way for BNL. A search for the ζ-meson has been made with a 4π solid-angle high-Z spark chamber; the angular distribution of π-meson charge exchange scattering and of η^0 production with large solid-angle spark chambers is about to be run, and the gyromagnetic ratio of the Λ^0 is about to be measured again with improved precision. This latter is particularly interesting as one of the most model-dependent predictions of theories of elementary particles. The 150 kilogauss pulsed magnet to be used with the last experiment was developed in cooperation with the National Magnet Laboratory. Two other experiments are being planned for Brookhaven in the near future, to search for additional excited states of the nucleon and heavy short-lived mesons.

The final experiment on the M.I.T. synchrotron, a spark-chamber study of the photoproduction of π-mesons from deuterium, has been run and is being analyzed.

The rapid utilization of CEA for experiments only months after it came into operation prompted the holding of an international conference by the Laboratory last January on photon interaction in the Bev region, attended by elementary particle physicists. The proceedings of the conference have been published and made broadly available and serve as an excellent up-to-date review of current research in the field of high-energy electromagnetic interactions with elementary particles.

A few remarks are in order here, more detailed than those of the introduction, regarding the spark chamber and bubble chamber data analysis systems SPASS and PEPR.

The latter, a precision encoding and pattern recognition system designed for the measurement of photographed bubble chamber tracks, has as its logic element a digital computer driving a precision cathode ray tube. In the past year all of the system's major components and design features have been successfully tested. A cathode ray tube with 25-micron spot has been operated, under PDP-1 computer control, with dynamic focus and distortion corrections. The linearity of the system is within 0.1 per cent, and stability is better than 0.03 per cent. The components have been assembled into a prototype system which already has been used successfully to read information into a computer memory from actual photographs of bubble chamber events. Extensive computer programs have been written, and the prototype is being prepared for preliminary pattern recognition efforts.

The SPASS automatic spark chamber film scanning and measuring system, designed about the Laboratory's PDP-1 computer with its standard display oscilloscope, has been in operation since November, 1962. About 500,000 frames of film have been processed at a rate of better than one per second. All of these have been part of a single series of experiments (Proton Compton effect). A considerable programming effort is now being exerted to make the system applicable to a very wide range of experiments. The scanning of a second experiment (π-photoproduction) is imminent, and film from three other experiments (obtained by other groups) is waiting to be scanned.

LOW-ENERGY NUCLEAR PHYSICS

The association of "low-energy" with what is perhaps more appropriately described as "nuclear-structure" physics is an incidental consequence of the fact that the nucleus remains essentially intact only at relatively low excitation energies (by present-day standards). The misnomer thus follows from the fact that most experiments directed to this purpose are performed in the "low-energy" region with a resulting misemphasis not only as to the nature of the field but also with respect to the state of its completion. Although many of the important features of the nucleus are understood in the very real sense that predictions can be made as to its behavior, the present status of nuclear theory continues to rest on a somewhat disconnected phenomenological basis. The picture is far from complete, and the mass of nuclear data to be reconciled is very great. The field is one which remains filled with intensive forefront activity, both in experiment and theory, and is one toward which a large part of the effort of the Laboratory must and will continue to be directed for some time to come.

Work currently in progress in the Laboratory in this field includes systematic studies of the static properties (the energies, angular momenta, and other characterizing features) of the states to which nuclei can be excited, as well as the dynamics of nuclear reactions in which the relevance of various models of nuclei and nuclear reactions can be examined. Radioactivity studies, in particular, are being concentrated on the measurement of magnetic moments of short-lived excited states by means of a variety of powerful techniques (Mössbauer scattering and Larmor precession of the correlated γ-γ and γ-α decay of nuclei). During the past year measurements have been completed on the 4+ state in La^{140}, on the quadrupole interaction and the nuclear radius associated with the first excited state of Te^{125}, and on the spins of parities of the low-lying states of Gd^{152}. Work in progress includes measurement of the optical activity of materials to X-rays, the cross-section for 'spin-flip' Rayleigh scattering, and the magnetic moments of the nuclei W^{182}, W^{186}, and Os^{186}.

The Laboratory's particle accelerator groups have continued with studies of energy-level positions, parities, and spins of nuclei. Work with the O.N.R. Van de Graaff generator during the past year has involved angular and energy-distribution measurements of proton and deuterium induced reactions on the nuclei B^{11}, N^{15}, N^{16}, Sc^{46}, Cr^{53}, Cr^{54}, Ce^{140}, Fr^{142}, Lu^{176}, and others. Studies with the cyclotron have been directed toward the dynamics of proton and alpha-particle-induced reactions. A notable result involved the observation of anomalous resonances in large-angle inelastic scattering (α, α') on the important doubly-magic nucleus Ca^{40}. Some of the efforts of the cyclotron group have involved experiments using the higher energy Harvard cyclotron with which some (p, 2p) studies have now been begun.

A major interest continues to be the experimental program in photonuclear physics, considerable attention being focussed on the photodisintegration of light nuclei using gamma-rays up to about 20-Mev. The present program, which forms the basis for our requested new high-intensity linear accelerator, continues to be carried on and extended about time-of-flight energy-spectrum measurements and polarization measurements using the recently developed He-Xe gas scintillator as a polarmeter-spectrometer. There have been measured: the energy and angular distributions of neutrons from U^{238} and Th^{237}; the photoneutron cross sections of C^{13} and Be^9 up to 17 Mev with angular distributions and branching ratios; the photoneutron cross-section near threshold for enriched Pb^{206}, Pb^{207}, Pb^{208}, and Bi^{209}

samples with special attention to gamma-ray absorption to sharply defined (energy) states; the angular distribution of neutrons from the photodisintegration of deuterium; and the polarization of neutrons from the photodisintegration of deuterium in the photon energy range of 8 to 30 Mev.

NUCLEAR THEORY

Research by the Laboratory's theoretical group covers all areas of nuclear physics. In the recent past, an unmistakable trend has been developing towards higher standards of quantitative accuracy, which serves as an expression of the increased confidence of nuclear theorists in the validity and applicability of their concepts. Among other things, it ushers in the era of computers as a central tool in nuclear structure theory. In line with this development, an increasing number of projects are under way which deal with quantitative aspects of the position and widths of nuclear single-particle and collective levels, the magnetic moments of levels and electromagnetic transition rates, and the details of nuclear resonance reactions, to mention only a few.

The new opportunities for quantitative computer-supported work have prompted an effort to step up the range of activities through creation of an increased number of junior and intermediate temporary research positions. For the coming year, four such additional positions are planned.

Most of the work in nuclear structure theory is based on the independent particle model, together with new and more powerful techniques to handle the effects of residual interactions. Successful applications have been made to problems of the structure of nuclear quadrupole vibrations, rotational levels and magnetic g-factors, the statistical theory of nuclear resonance reactions, and the detailed behavior of reaction cross-sections in light nuclei. Expected results in the near future are mainly the understanding of more complicated situations, like the higher collective energy levels, the coupling of collective- and single-particle levels, and collective excitations in nuclear reactions.

Theoretical research in the field of high-energy physics deals basically with the analysis of elementary particle processes in terms of current theories and hypotheses. In that sense, the work is closely correlated or inspired by current experiments in high-energy physics. The wealth of new data which has recently come into being has triggered a re-examination of the predictions of conventional field theory, and some novel and startling conclusions have emerged from our work in this area. The new experimental results indicate the inadequacy and obsolescence of the conventional concepts of quantum field theory, and the possibility of integrating new hypotheses into existing theories has been explored.

An important result concerns the high-energy limit of cross sections, where it is found that at least one "field theory" gives the same answer as the popular "Regge-pole hypothesis." In addition, new mathematical techniques are being developed to solve the field equation which have helped to clarify the concept of an "elementary" particle. A closely related area of research deals with the description in terms of simple models of all of the "strong" elementary particle interactions, using a minimal theoretical framework. The new experiments have led to the emergence of a number of incompletely integrated hypotheses, which serve to demonstrate the transitional, fluid state of this field of research.

The Laboratory was fortunate to have Professor Murray Gell-Mann and Dr. M. E. Goldberger as visitors during 1962-63. Both contributed much toward the generation and discussion of new ideas so essential to a new field of research in full flux. We anticipate that the stepped-up experimental programs in high-energy physics will make it possible for us to have in residence one or two outstanding senior scientists each year, supplemented in their efforts by a group of junior research workers.

PETER T. DEMOS

Operations Research Center

Staff members and students in many M.I.T. departments have research and educational interests in operations research. The Operations Research Center is a focal point for this activity, providing a meeting place for students and faculty, conducting a weekly seminar series by guests from the government, industry, and other universities, and carrying out sponsored research in problem areas of central interest to all the applications of operations research. The Operations Research Center completes its tenth year with a record of continued growth in students, staff, and research.

An extensive program of subjects in operations research is now offered by the Institute. A part of one subject, an introduction to methods of analysis, has been devoted to examining operating problems of the Institute, such as parking, examination scheduling, and library use. Special programs for master's and doctor's degrees are coordinated by the Interdepartmental Committee on Operations Research.

Sponsored research is active in the following areas: traffic flow and queueing phenomena, allocation of search effort, probabilistic aspects of communication system design and operation, probabilistic systems analysis, statistical decision theory, and logical design of computer-directed teaching machines. The Center continues to benefit from a grant in support of research in fundamental techniques of operations research. The current program of sponsored research affords an excellent medium for the long-term research interests of the staff and adds importantly to the education of the students.

Research in the Center covers the major areas of operations research. Probability theory and statistical inference are an important theme, finding application to problems of control system design, traffic, search, reliability engineering, and scheduling. Mathematical programming and other methods of optimization provide solutions to problems of resource allocation and to various aspects of system design.

Members of the Operations Research Center staff participate in the activities of several government agencies and industrial firms and have conducted regular summer sessions for introducing recent advances in operations research to the practitioner in government, the military, and industry.

Visiting scientists working in the Operations Research Center during the past year included N.A.T.O. fellows Dr. Klaus Kirschgassner (Freiburg University), Tore Danielson (Norway), Pieter J. Weeda (Netherlands), and Erik Sparre (Norway).

PHILIP M. MORSE

Spectroscopy Laboratory

Activities in the Spectroscopy Laboratory covered an unusually wide range both of the electromagnetic spectrum and of scientific fields. In addition to more conventional applications of spectroscopy, extensive studies were carried out in the spectroscopy of ferroelectric solids, of radioactive nuclei in excited states, of desoxyribonucleic acids and related genetic materials, and of systems in the powerful fields of laser beams.

The groups in the Laboratory concerned with molecular structure and solid-state physics concentrated their efforts on spectroscopic studies in the far-infrared region and on the improvement of the instrumentation for these studies. Professor Clive H. Perry completed a series of investigations of ferroelectric solids comprising the titanates of barium, strontium, calcium, and lead. He has also studied the spectra of some solid inorganic fluorides (e.g., $KMgF_3$) having the perovskite structure, as well as other fluorides (MgF_2, etc.) and halogenated complexes (K_2PtCl_4, etc.). His cryostat for operation of a far-infrared detector in the range 1 to 2°K has been rebuilt to make more efficient use of the liquid helium refrigerant. In addition, the cryostat is now connected, by means of an extended optical system which permits different kinds of samples to be investigated, to the vacuum case of the far-infrared spectrometer. Thus the spectrometer can be operated with either the conventional room-temperature Golay detector or various low-temperature detectors.

The spectra of a number of molecules having unusually low frequencies have been studied by Professor Richard C. Lord and his students. These include further examples of the recently discovered quartic mode of oscillation in small ring molecules, crystals with low frequencies, and gaseous inorganic fluorides not previously investigated.

Spectroscopic work by Professor Alexander Rich, Professor Lord and their associates on compounds of biophysical interest has been continued by extending the studies on hydration of DNA to hydration of synthetic polynucleotides such as polyadenylic acid. In view of the importance of hydrogen bonding in the structure of the DNA helix, an attempt was made to determine by spectroscopic means the equilibrium constants for H-bonded association of certain purine and pyrimidine bases (for example, derivatives of adenine and uracil). Solubility difficulties in non-aqueous media have hampered the work, but progress is encouraging and the work is being continued.

Professors Charles H. Townes and Ali Javan and their associates have been using optical maser techniques to study the unusual kinds of phenomena produced when the Raman effect is excited inside or outside the optically resonating system. Investigation is also under way on near-infrared absorption spectra of gaseous molecules with a maser source, on pressure-broadening of spectral lines in gases, and on isotope shifts in the spectra of the rare gases. Other maser studies are concerned with non-linear optical effects in various media, including diffraction of light by standing light waves in such media and frequency mixing to generate both high and low frequencies. The presence of the maser research teams in the Laboratory has been mutually fruitful for the researches of both the maser groups and of the more traditional spectroscopists.

Work on the development of improved diffraction gratings has continued under the direction of Professor George R. Harrison. Although earth vibrations associated with the very active building program of the Institute have interfered considerably with ruling activities, a number of outstanding gratings and echelles have been ruled on the 10-inch engine. Construction of the 18-inch ruling engine continues, and it is expected that the first test gratings from this will be available during the coming year. The demand for large gratings and echelles of new types, especially from astronomers and from scientists connected with the space programs, continues to increase.

Results of the work of the Spectroscopy Laboratory are published in scientific papers listed under the publications of the Departments of Biology, Chemistry, and Physics.

Visiting scientists working in the Laboratory during the past year included Dr. Graham R. Hunt of the University of Sydney (Australia), Dr. Thadho Jaseja and Dr. B. N. Khanna of Aligarh University (India), Dr. Richard Lumley Jones of the Chester Beatty Research Institute (London, England), Professor Samuel Schrage of the University of Illinois (Chicago campus), Professor Koichi Shimoda of the University of Tokyo (Japan), and Dr. Abraham Szoke of Hebrew University (Israel).

RICHARD C. LORD

GRADUATE SCHOOL

THE GRADUATE SCHOOL activities of the past year are reported under five main topics: the academic program, the size and growth of the Graduate School, the organization of the Dean's Office, the problem of subsidy for graduate students, and graduate student life.

TRENDS IN THE ACADEMIC PROGRAM

Graduate students and graduate study are so integral a part of all new developments in the main stream of M.I.T.'s activity that we tend scarcely to notice the growth and development, both in breadth and in depth, of the graduate program. Yet if we detach ourselves and view our graduate work in the national perspective, we can see clearly why, for example, so many holders of national fellowships come to us. For our graduate students are at the very center of the research and innovation that express the basic vitality of M.I.T., integrated fully into these activities as junior colleagues. The creative unit, the vanguard in the exploration of new intellectual territory, comprises one or a few professors who have some new ideas that are recognized and supported by the administration and who attract a group of graduate students as junior partners. By thus participating as a partner in the actual achievement of new knowledge, each graduate student becomes skilled in the art himself. As necessary foundation and support, there are, of course, classes, seminars, and less formal discussions in which the education of the four-year baccalaureate degree-holder is deepened and brought up to date to include the growing front of knowledge in his field where his research will make its contribution, both to knowledge and to his education.

Thus, whenever we read of new discoveries, new programs for producing such discoveries, or new facilities for aiding and catalyzing them, we should include in our mental picture graduate students as an integral part of the growing and knowledge-generating organism.

In this operation, the term "graduate school" is used to identify those activities having primarily to do with the graduate student and his growth and development. It is a role of the graduate administration, including the Committee on Graduate School Policy, the Dean, and his colleagues, to assure that our graduate degrees represent standards of accomplishment acceptable to the faculty and to facilitate in all possible ways the attainment of these standards of accomplishment by our graduate students.

An even more important role is to encourage and assist developments in the graduate program responsive to new fields and new faculty ideas.

In addition to the continuing and ever-regenerating growth of graduate work as a part of the main stream of M.I.T. activity in science and technology, elements of growth in coordinate and supporting fields that have equal significance in their own right have been emerging. This growth is indicated by the fields in which the Corporation has authorized the award of the doctorate in recent years. In the past ten years, for example, the award of doctorates in nine new fields has been authorized by the Corporation upon recommendation of the faculty and administration: Biochemical Engineering (1953), Nuclear Engineering (1955), Political Science (1958), City Planning (1958), Materials (1960), Industrial Management (1960), Oceanography (1960), Linguistics (1961), and Psychology (1962).

The authorization in such fields as Linguistics, Psychology, and Political Science does not represent a radical redefinition of the nature of M.I.T. but rather a growing interaction between science and other fields and the growing contribution of the scientific method and techniques to these fields. The list of publications and other contributions of the research activities in these fields bears eloquent testimony to the vitality and prolific character of developments stemming from this interaction. We believe that both the scientific fields and the social and humanistic fields benefit by these interactions.

There is now under discussion a doctoral program in yet another field which seems, superficially, to be less directly related to our main stream. There is in process of evaluation a request for authorization of the Ph.D. in the field of philosophy, with particular but not exclusive emphasis on the philosophy of science. The process by which we examine the appropriateness and adequacy of our resources to offer a new doctorate of high quality is well illustrated in this case, and the facts testify rather emphatically that the examination process is more than a mere formality. Our Philosophy Section and the School of Humanities and Social Science have felt for some time that in philosophy, equally with other areas of major endeavor at M.I.T., an essential component of work of quality, including that offered to undergraduates, is graduate work and creative professional work in the field. By the beginning of 1963, the Philosophy Section and the School felt that their resources had reached a level justifying formal request for authorization to award the Ph.D. Degree. In accord with the procedures followed in recent years, the Dean of the Graduate School appointed an *ad hoc* committee to recommend action by the Committee on Graduate School Policy. This *ad hoc* committee included three philosophers of recognized national standing from sister institutions and three senior professors from M.I.T., as follows: Dr. Robert M. Solow (Chairman) of the M.I.T. Department of Economics and Social Science; Dr. William K. Frankena, Visiting Professor of Education and Philosophy at Harvard University; Dr. Murray Gell-Mann, Visiting Professor of Physics at M.I.T.; Dr. Norwood Hanson, Chairman of the Department of History and Logic of Science at Indiana University; Dr. Harold S. Mickley, Chairman of the Faculty at M.I.T.; and Dr. Willard Van Orman Quine, Edgar Pierce Professor of Philosophy at Harvard University. The committee was generally impressed with the quality and strength of the resources but had some reservations, fearing that the total scope proposed was overly ambitious and that the program did not provide for as much interaction between scientists and philosophers in the area of the Philosophy of Science as our resources justified and as the best development of graduate work in the field required. Out of further study and consultation emerged some changes of emphasis in the formal proposal that both the philosophers on the faculty and the *ad hoc* committee consider to add substantially to the strength and stature of the program. Much challenging, serious, and constructive thought intervened between the initial diversities in concept of a doctoral program and the eventual agreement on a program that all regarded as not merely acceptable but superior. The program has been formally approved in principle by the Committee on Graduate School Policy as satisfactory and sufficiently matured for presentation to the faculty early this fall. It is hoped that the faculty will approve the program and recommend to the Corporation that it authorize the Department of Humanities to offer this degree.

The foreign language requirement for the doctorate has undergone a new examination this year by a subcommittee under the chairmanship of Professor Solow. The subcommittee affirmed the present requirement, that a candidate be able to read technical literature in his field in two foreign languages; and it recommended the optional alternative requirement of "substantial competence," including speaking ability, in a single foreign language important in the professional field. A further requirement has been added: a student whose first language is not English must demonstrate his competence in English. The Department of Modern Languages is responsible for administering the examinations and rating the competence of each candidate in languages. There was a strong concensus in the Committee on Graduate School Policy that the new requirement is superior to the old and has practical meaning for a sufficiently large fraction of our graduate students so that M.I.T. can feel that its foreign language requirement for the doctorate has significance. This position is somewhat in contrast to the national picture generally, in which a substantial fraction of graduate deans and graduate students regard the foreign language requirement as more symbol than substance.

Another area of increasing concern in our academic program is the determination of appropriate conditions under which data-gathering and research for a doctoral thesis may be done away from M.I.T. Our general principle, consistently applied, is that the M.I.T. degree is basically a degree earned in residence including research and writing the thesis. This concept of the requirement of M.I.T. for its degree has been frequently re-examined and regularly re-affirmed as our basic policy. However, the Committee on Graduate School Policy recognizes that there are good problems on which the research or data-gathering can only, or best, be done away from the campus. For example, superior facilities for some kinds of experimental work which may be scientifically and educationally significant exist only at certain of the great national, specialized centers; experimental work requiring such facilities can be done only at those centers. In other fields, such as economics, political science, or urban planning, data for important and educationally first-class problems are obtainable only in the field, sometimes in places that are half way around the world. The Graduate Committee, therefore, is being called on increasingly to approve such data-gathering *in absentia* under the Committee's standing condition that it will grant such approval only if it is persuaded of the superiority of the educational opportunity thereby made available. The hazard, of course, is the loss of associations with M.I.T., including contribution to the scholarly community and less effective supervision by the M.I.T. faculty, both of which we regard as important elements of our degree. Research *in absentia* can raise difficult questions of registration and tuition with which we are currently struggling. Our insistence upon residential research and thesis for the general case has spared us almost completely the "A.B.D." ("All-But-Dissertation") problem that is of serious concern to many of our sister institutions, especially in the nonscience areas. Our faculty, even those brought up academically under less demanding residence rules, tend after experience here to support our more stringent residence requirement as promoting good education.

SIZE AND GROWTH OF THE GRADUATE SCHOOL

The history of graduate enrollment and quotas over the past several years is of interest in the context of questions asked by alumni and outsiders, as well as by members of our own family, about M.I.T.'s apparent trend toward becoming a predominantly graduate institution. Policy on growth is reviewed periodically in the light of our total resources of faculty, facilities, and funding as well as in terms of educational objectives. In the late 1950's the broad policy was affirmed of maintaining the undergraduate enrollment essentially unchanged while permitting the Graduate School to grow at a deliberate and controlled rate. At that time, a general guide was formulated to permit 5 per cent per year normal growth in enrollment, plus additional growth where needed to accommodate graduate students in newly emerging fields, the total not to exceed 7 or 8 per cent. These constraints are expressed in terms of yearly-determined quotas on graduate enrollment in the separate schools. Within this past year, the Academic Council decided that somewhat more emphasis on consolidation and less on growth was indicated.

In Table I are shown figures on the first-term registration of graduate students for the years 1958 to 1962, the ratio of registration to quota, and the increments in quota, and registration for the various intervals. It is notable that, except for the fall of 1958, total registration has been consistently below quota, despite the fact that the increments of quota have been distinctly modest in comparison with

Table I.

Graduate Student Quotas and First-Term Registrations, 1958 to 1962, by Schools*

	1958	*1959*	*1960*	*1961*	*1962*
All Schools					
Quota	1872	1979	2065	2181	2288
Registration	1915	1937	1966	2058	2268
Registration/quota	102.3%	97.9%	95.2%	94.4%	99.1%
Increase in quota	—	5.7%	4.3%	5.6%	4.9%
Increase in registration	—	1.1%	1.5%	4.7%	10.2%
Engineering					
Quota	900	945	992	1042	1050
Registration	965	957	967	965	1033
Registration/quota	107.2%	101.2%	97.5%	92.6%	98.4%
Increase in quota	—	5.0%	5.0%	5.0%	0.8%
Increase in registration	—	−0.9%	1.0%	−0.2%	7.0%
Science					
Quota	642	674	708	745	789
Registration	677	673	666	690	803
Registration/quota	103.9%	99.9%	94.1%	92.7%	101.8%
Increase in quota	—	5.0%	5.0%	5.2%	5.9%
Increase in registration	—	0.9%	−1.0%	3.6%	16.4%
Architecture and Planning					
Quota	70	70	75	79	82
Registration	66	63	63	66	65
Registration/quota	94.3%	90.0%	84.0%	83.5%	79.3%
Increase in quota	—	0.0%	7.1%	5.3%	3.8%
Increase in registration	—	−4.5%	0.0%	4.8%	−1.5%
Humanities and Social Science					
Quota	60	90	90	105	132
Registration	62	92	90	110	137
Registration/quota	103.3%	102.2%	100.0%	104.8%	103.8%
Increase in quota	—	50.0%	0.0%	16.7%	25.7%
Increase in registration	—	48.4%	−2.2%	22.2%	24.5%
Industrial Management					
Quota	200	200	200	210	235
Registration	155	152	180	227	230
Registration/quota	77.5%	76.0%	90.0%	108.1%	97.9%
Increase in quota	—	0.0%	0.0%	5.0%	11.9%
Increase in registration	—	−1.9%	18.4%	26.1%	1.3%

* Registration is given in equivalent full-time Regular Graduate Students at the middle of the third week of the first term. In the Schools of Science and of Architecture and Planning every Regular Graduate Student is counted as a full-time student.

the permitted 7 to 8 per cent total growth and the new Ph.D. authorizations noted above. There are real and strong pressures for growth, but there has been obvious restraint exercised at the source—namely, in departmental actions on admissions. This appears attributable to the departments' emphasis on high standards and their awareness that high standards are not compatible with over-crowding.

Details of the Graduate School enrollment and degrees awarded for 1962-63 are given in Table II.

Table II. Graduate School Statistics, 1962-63

Advanced Degrees Conferred	*S.M.*	*Engineer*	*Sc.D.*	*Ph.D.*	*Total*
September, 1962	224	10	25	56	315
February, 1963	119	15	29	56	219
June, 1963	349	58	33	75	515
Total	692	83	87	187	1049

Graduate School Registration	*Summer, 1962*	*Fall, 1962*	*Spring, 1963*
School of Engineering	844	1668	1554
School of Science	321	938	847
School of Architecture and Planning	28	72	62
School of Humanities and Social Science	13	180	167
School of Industrial Management	90	284	259
Total	1296	3142	2889
U.S. and Canadian citizens		2679	
Other nationalities		463	
Total		3142	
Regular Students		2637	
Special Students		505	
Total		3142	
Civilian students (male)		2914	
Civilian students (female)		110	
Military students		118[1]	
		3142	

CHANGES IN ORGANIZATION IN THE DEAN'S OFFICE

On February 28, 1963, Professor Ernest H. Huntress retired in accord with his earlier expressed wish from the faculty of M.I.T. and as Secretary of the Graduate School. He had served as Deputy Dean from 1950 to 1953 and in the responsible position of Secretary of the Graduate School from 1953 until his retirement. One of his major

[1] Includes Air Force, 33; Army, 10; Coast Guard, 1; Marine Corps, 1; and Navy, 66.

contributions was notably successful handling of Selective Service deferments and Reserve Commission postponements to permit our graduate students to undertake and continue their graduate work. He carried responsibility for many of our activities requiring intimate knowledge of the organization and operation of the Institute.

The rapid growth in the number and complexity of problems facing the Graduate School administration has been increasingly apparent during recent years. The need occasioned by this increasing complexity combined with Professor Huntress' retirement was met by the appointment of an Associate Dean and a full-time Executive Officer. On February 1, Professor Sanborn C. Brown became Associate Dean of the Graduate School. He continues his activity as Professor of Physics half time, permitting him to keep up his professional work with his own laboratory and graduate students. Robert K. Weatherall, formerly Associate Director of Admissions, became full-time Executive Officer of the Graduate School on May 1. The Dean's staff, thus augmented, is enabled to be more responsive to the increasing responsibilities being placed upon this office. For example, there are many newly emerging national fellowship programs, and the administrative responsibilities under these programs are shifting to the institutions themselves. Also, the appropriate handling of industrial fellowship grants requires increasingly substantial and perceptive effort.

The guiding principle of the Dean regarding the role of his office is that M.I.T.'s basic and all-important resource for the education of graduate students lies in the departments. There is clear need for means whereby the faculty can develop and express its policy on graduate standards and operations and for the departments to provide mutual support to each other in achieving high standards. Certain administrative matters, such as the keeping of official student records and the clerical processing of applications for admission and financial aid, both requiring considerable clerical effort, are best handled in the Registrar's and Admissions Offices. The Graduate Dean's office aims to concern itself primarily with matters involving educational policy and to minimize administrative matters best handled elsewhere. However, this minimum administrative load is growing, and growing rather rapidly as illustrated by the fellowship area mentioned above. The present organization appears to be adequate for the immediately foreseeable future.

GRADUATE STUDENT SUBSIDY

The subject of graduate student subsidy is a hardy perennial. Last year's discussion of the increasing role of federal fellowship programs and the fact that they cannot be a substitute for funds under institutional control remains cogent. The most prestigious national fellowship programs in our field, those of the National Science Foundation, have stipend levels below those of many institutional and industrial fellowships, making it necessary for them to draw upon their prestige for their attractiveness. Throughout the country competition for an important portion of the very ablest graduate students takes the form of premium institutional fellowships that, coupled with good graduate programs at many institutions, provide us with nontrivial competition. We do not have to offer the highest fellowships, of course, to attract the ablest people, but we cannot be far below the market level. Our unrestricted-endowment-supported graduate fellowship monies, amounting to about $90,000 a year, provide twenty to twenty-five fellowships completely under our control. Three times this total would provide a few fellowships in each of our major areas of study. This total would permit us to feature—as we cannot do now—the availability of these few fellowships in the informational literature issued by each department, an important asset. This would be minimally sufficient to attract a more desirable number of outstanding applicants and to get a reasonable fraction of acceptances. Five times our present unrestricted M.I.T. fellowship funds would enable us to do a really good job of attracting more superior students. It would also provide financial assistance to substantial numbers of our present graduate students who now take time and energy from their graduate work to earn their living with non-educational work.

Those who recall their days of money struggle as students tend, understandably, to raise eyebrows at the graduate student today who feels entitled to support for wife and family and a standard of living which includes ownership of an automobile. But we live in a real world, characterized far more by an unprecedented national affluence than by soft moral fiber in graduate students. We have to run a graduate school in the milieu of today, keeping pressures for frugality on where possible but keeping these pressures within limits that permit us to compete freely and successfully for those ablest graduate students who set the whole tone of our operation.

The wise and fair administration of the fellowship funds under our control, and the best pattern of awarding them to complement the other sources of graduate subsidy, have become very complex. During this past year, in making awards for the 1963-64 academic year, we have tried experimentally a new pattern of decentralizing discretionary judgment. Previously we had used an Institute-wide competition at the Graduate Committee level for awarding our M.I.T.-endowed fellowships. This past spring we tried a shift of discretionary judgment to the departmental level, on the basis that the gain from each department's intimate knowledge of its applicants, of all its subsidy resources, and of its need for graduate assistants more than offset any loss in standard of quality incurred by dropping the M.I.T.-wide competition. The results of this experiment are still under study, but it appears likely that we have not yet reached the optimal pattern. Despite repeated serious study, no clear pattern has emerged yet as a wise solution to a very complicated question.

The federal programs in support of graduate study are playing a very significant role. M.I.T.'s participation in these in 1962-63 is shown in Table III.

Table III. Numbers of Graduate Students Holding U. S. Government Agency Fellowships and Traineeships†

National Science Foundation Graduate Fellowships (National competition—student elects institution)	165
National Science Foundation Graduate Cooperative Fellowships (Student applies through institution)	44
National Defense Education Act Fellowships*	25
National Institutes of Health Traineeships	25
Atomic Energy Commission Fellowships	32
Total	**291**

In addition to the federal programs, the Woodrow Wilson Foundation operates an important national program placing fellowships to encourage graduate work among prospective teachers. Under this program, sixteen Fellows elected M.I.T. for study in 1962-63. With each Woodrow Wilson Fellowship comes a $2,000 subvention, which M.I.T. has used to subsidize what we call, in agreement with the Woodrow Wilson Foundation, "M.I.T.-Wilson Fellowships," for aid to graduate students interested in teaching, of which we were able to award ten this year.

In engineering, the Sloan Foundation first-year fellowships for

† In June, a National Aeronautics and Space Administration Training Grant was formalized with M.I.T. that provides 15 excellent traineeships, each renewable with good performance for 2 additional years, effective for September, 1963.

* The total number of Fellows in a complex pattern. In each field we apply each year for approval of a "new or expanded" program and a specific number of three-year fellowships for that program. The total shown is the actual number of individuals in all years on N.D.E.A. Fellowships at M.I.T. during the year 1962-63.

the support of engineering graduate students expressing serious interest in teaching careers have been most helpful. Similarly, the Ford Foundation loans having a "forgiveness" provision effective if the recipient goes into teaching have served as a valuable incentive and aid.

A summary of known aid to our graduate students from funds administered by M.I.T. is given in Table IV.

Table IV. Graduate Financial Aids Awarded by M.I.T., 1962-63

Fellowships from industrial and special funds	$ 883,178
Fellowships and scholarships from M.I.T. general funds	93,996
Staff tuition scholarships	422,801
Staff Salaries	4,089,267
Loans	305,789
Total	**$5,795,031**

GRADUATE STUDENT LIFE

The ideal graduate school would provide education, in the broadest sense, best fitted to the needs and maturity of the graduate student. A comparison of ideal and actuality is aided by distinguishing two aspects of the educational experience: first, professional education in the specific sense; and second, personal growth.

In specific education for a profession we do well. The standards we hold in faculty, laboratory, library, student ability, demands made on the student, and professional spirit and tone are high—very high. Serious effort, the best each can give, and high accomplishment, in substance and in creative imagination, are taken for granted as the norm. Here we have unquestioned strength, including enough dissatisfaction to keep us moving ahead. The basic motivations are strong and built-in for both high accomplishment and constant improvement. With our faculty and administrative leadership, this part of our operation—specific education for a profession—is self-sustaining.

In the area of personal growth we face a far more difficult problem and do correspondingly less well. We are here concerned with such qualities as capacity to lead, capacity and motivation to participate and contribute not only to the advance of the profession but to important affairs in the community, to our culture, and to the nation. This ability requires a certain breadth of sympathy, interest, and background of understanding, together with knowledge of men and skill in the art of working with them. It also requires some understanding as a layman of other fields, of other cultures, of the important problems we as humans face, of the serious issues of the day and of our times. To this understanding must be added awareness and sensitivity to men and ideas and, most important, the urge to make some personal contribution to wise resolution of these issues. Dean John E. Burchard presented this concept and challenge well in his Baccalaureate address this June.

Are these elements of personal growth a responsibility of a Graduate School? If so, why?

I believe that making active contributions to personal growth must be accepted as a responsibility of a graduate school even though they may be much more difficult to achieve and though we contribute far less fully to them than to specific education for a profession, for the following three reasons:

First, a graduate school has a responsibility in a large sense to complement and compensate for the intense forces that tend toward a tunnel-vision concept by a student of his profession. Such tunnel-vision can lower the ceiling on ultimate professional contribution and on contribution to community and nation, and it can limit richness of experience in living. For the student who is possessed by an overriding singleness of purpose and who also has great creative productivity, we should perhaps not try to alter urges; and there is little likelihood we could, anyway. For others we should provide a uniquely rich opportunity for personal growth and the stimulus to embrace it.

Second, the graduate student is at a period of his development when he is highly susceptible to growth. He is youthful enough to embrace bold new concepts, mentally sophisticated enough to understand and respond to them, and energetic enough to act on new ideas; from these follows the responsibility of the educational agency concerned with him.

Third, because the environment for growth is at a peak for the graduate student, the Graduate School has a corresponding responsibility to enhance the educational impact of this environment. The graduate student is a member of a community with exceptional wealth of resources for growth and enlargement of horizons. The level of intellectual capacity in this community is as good as or better than that of any community in which he will ever live. The community presents a diversity of fields and interests that only a university can provide. The graduate student is surrounded by greater multi-national and multi-cultural resources for enhancing personal knowledge and understanding than he is likely ever again to have. The exceptional opportunity in our metropolitan area and local region for meeting and associating with peers of the opposite sex is important to many. The atmosphere of learning and free inquiry is found primarily and most fully expressed in a university.

These three major elements—a counter to a too-narrowly conceived professionalism, the youthful yet sophisticated capacity to develop, and a uniquely rich environment for growth—constitute a formidable challenge to a graduate school, the more so because effective response is so difficult.

We are making some, though far short of ideal, efforts. We see opportunities which are clearer in broad concepts and general outlines than in specific and detailed means for responding to these responsibilities.

Present activities to this end include those associated with the Graduate Student Council, our present Graduate House (and the work this year of its resident faculty couple), the married student housing just being completed, and the prospective Graduate Center.

The Graduate Student Council (GSC) continues the revision, publication, and distribution of the *Guide to Graduate Life* which appears to fill a felt need. Its unofficial character permits an informality and freedom in approach and subject matter not appropriate in an official document. It is an experienced graduate student talking to another, less experienced, in a way that has proved helpful.

The GSC organizes and runs the welcoming dinner for new foreign graduate students. This past fall 200 out of 250 attended, together with about thirty-five U.S. graduate students and forty faculty. This is regarded as an excellent operation.

Two newsletters were prepared and circulated to graduate students concerning the confused income-tax status of assistantship salaries. A good relationship has developed between the GSC officers and the M.I.T. officials concerned, resulting in a better understanding by th GSC of the complexities and limitations placed on M.I.T. by issues unresolved in the Bureau of Internal Revenue. Through the GSC newsletter this understanding can be shared with the graduate student body.

The social program of the GSC included four informal dances at the Faculty Club with capacity attendance and skating and square dance parties in collaboration with the Graduate House, all successful occasions.

An important decision on the Graduate Center was taken this year. It will be located immediately west of Kresge Auditorium, and for the foreseeable future the present Graduate House will be continued and renovated better to serve as a graduate student residence and as a component of the Graduate Center. The Graduate House, though housing only a small fraction of single graduate students, is a focal point for personal education and is an excellent indicator of the pattern of activity to be served by the new Graduate Center. Thus has the subject of study of several successive committees over a number of years been resolved with a strong consensus that at last a good solution has been evolved. Interestingly, the issues, resolved differently by each of the successive committees, refused in each case to stay resolved in the absence of clear consensus in the M.I.T. community on the overall soundness of the various recommendations. With the present strong consensus, the present position appears firm.

This year Professor and Mrs. Francis Bitter have made major contributions to life in the Graduate House and to clearer concepts for the design of the new Graduate Center. With great dedication and energy they have provided many and varied occasions to bring residents of the House into more active social interchanges. More informally, they have been increasingly involved in personal discussion and counsel. The presence of a woman's understanding has been widely appreciated and sought out, clearly supporting the expectation that the Bitters' coming would open new opportunities for the House Master.

In addition, the Bitters' experience and insights from their year yield invaluable guides for the new Graduate Center as well as for improvement of the present House.

Their characterization merits quotation with the precaution that it emphasizes the vastness of unrealized potentials rather than the very real accomplishments, even though they be modest by comparison. "Apart from the relatively simple aspects of the job, such as helping to organize social functions, advising on minor complaints and desires as handled by the House Executive Committee, and occasionally acting as house father or mother, there is one over-riding, stimulating, yet formidable challenge in extra-curricular matters, namely *to help change the attitudes of graduate students and faculty towards the campus and toward each other.*

"In the House the students have very few friends and acquaintances, a majority knowing perhaps as few as from half a dozen to a dozen other residents. Some like this kind of isolation, but many simply have to accept it because at present there is not much alternative. On entering the House there is no inviting place which beckons one to scan one's mail or the newspapers and exchange a word or two with others before moving on to one's room. The dining room is full of small tables seating from three to five, and the tendency is to look for an empty table rather than to take an empty seat at an already-occupied table where conversation might be possible. The only large public lounge is perpetually darkened for the benefit of the relatively few TV fans. The Buttery, the Games Room, the laundry, and the shower room provide a much more relaxed social atmosphere and provide at present the most encouraging aspects of the whole picture, but they are not at all adequate for bringing residents together.

"There is almost no provision for mixing graduate students living outside the House with those in the House, and the campus has very little going on to attract faculty members and their wives after five o'clock, except in Kresge Auditorium. All the elements for an active and full campus life are, in fact, present except the momentum of actual events.

"Of course, many of us would like to change all this, and we do not manage to do so because it is an exceedingly difficult job requiring a large cooperative effort and considerable time—let us say a dozen or more faculty families working cooperatively for at least a generation (a human, rather than a college, generation).

"Finally, it seems to us that the potentialities of leadership in this situation are almost unlimited and should ideally be shared among a much larger number of the faculty members who are predominantly concerned with graduate students."

Here certainly is pregnant guidance for conceptual design of the Graduate Center.

The married student housing nearing completion at the west end of the campus is expected to fill an urgent need, served for many years valuably, if not elegantly, by the no-longer-existent "temporary," wartime construction of Westgate and Westgate West. Some integration of this new community into the total graduate student life is expected.

In this graduate campus development the new apartment facility associated with the School of Industrial Management will play its part, all the more as it will encourage inclusion of its graduate residents as an integral part of the total M.I.T. graduate community.

All of these developments point more and more clearly to a developing urgency for the new Graduate Center, and to providing in it a design and facilities "to help change the attitude of graduate students and faculty toward the campus and toward each other."

HAROLD L. HAZEN

VICE PRESIDENT, ACADEMIC ADMINISTRATION

THE VICE PRESIDENT, ACADEMIC ADMINISTRATION represents the President in a variety of administrative activities, most of which have as their main purpose service to the students and faculty. The growth in the student and faculty population and in the complexity of the Institute has made this an increasingly interesting assignment.

Detailed reports of the heads of these several administrative activities follow. However, particular attention is due certain accomplishments of the past year which have special significance and which resulted from long periods of planning and hard work on the part of many of my associates.

1. The completion of the Institute's first permanent housing to accommodate 210 married students and their families;

2. The completion of McCormick Hall, a magnificent undergraduate women's residence for 116 students;

3. The start of construction of the Student Center;

4. The signing of a sale and purchase agreement for the Sancta Maria Hospital, to be used when acquired (in the summer of 1966) for the purposes of the Medical Department; and

5. The raising of $6,000,000, part of the Second Century Fund, as an addition to our over-all undergraduate student financial aid resources.

Vice President, Academic Administration

Even though substantial progress has been made with regard to the following problems, much time and effort will be devoted in the year ahead to:

1. The need to increase still further the quantity and quality of undergraduate and graduate student housing;

2. The need to review our policies and procedures with respect to undergraduate student financial aid, in the light of our new resources. At a time when costs to the student continue to rise, the Institute's student aid program becomes an activity of ever more critical importance.

MALCOLM G. KISPERT

Dean of Student Affairs

During the fall of 1962, I was asked to discuss "the typical M.I.T. student" at the Alumni Officers Conference and again as a part of a program to welcome new faculty members and their families to the M.I.T. community. As I prepared a few notes on this topic, I found myself impressed more than ever by the extraordinary diversity within our undergraduate and graduate student bodies—in their ethnic and social backgrounds, their academic and extra-curricular interests, their professional ambitions, their personalities, and their scales of values. The Admissions Office certainly does succeed in making impossible the literal discussion of the topic "the typical M.I.T. student."

Undoubtedly, it is this diversity among our students and a similar diversity throughout the faculty which provide the bases for the interesting and challenging life experienced by the Dean's office staff as we work with the students and the faculty in a wide variety of situations. Our students sense the excitement and the challenge which pervade M.I.T. in the formal teaching and research programs. They bring to those areas of primary concern to the Dean's office a similar sense of "constructive dissatisfaction" with the *status quo* and a sense of responsibility and excitement as they work individually, in all-student groups, or in student-faculty groups to meet our goals of excellence in all aspects of our educational program.

STUDENT GOVERNMENT AND ACTIVITIES

There were during the academic year 1962-63 several noteworthy examples of the success of our "indirect" educational program:

The Undergraduate Association sponsored during April a three-day national intercollegiate conference which was attended by student representatives and a few faculty members from thirty-two American colleges and universities. Together with such leaders as Abba P. Lerner, Paul A. Samuelson, Paul McCracken, Jerome B. Wiesner, William O. Baker, George P. Shultz, Saul Wallen, and Don K. Price, they grappled with several topics under the general theme "The Federal Government—How Much?" A Karl Taylor Compton Prize was awarded to the Undergraduate Intercollegiate Conference Committee under the leadership of Stephen P. Kaufman '63 for their "foresight, initiative, and hard work (. . . which) broadened the horizons of students and teachers of M.I.T. and sister institutions across the nation."

The long and arduous work of numerous student and student-faculty committees which began as early as 1953 culminated this year in our decision to proceed with the construction of the long-awaited Student Center. To recognize the great assistance which the Class of 1963 provided in arriving at the final design concept, a symbolic groundbreaking was held at the annual Awards Convocation in May. We expect the actual groundbreaking will take place early this fall. Professor Eduardo Catalano's brilliant design of the Student Center will compliment our developing residential system and will provide cultural opportunities and commercial facilities not now readily available in our urban but somewhat isolated environment. Appropriate areas are provided for our strong extra-curricular activities program and for student government. Consistent with our underlying philosophy of encouraging student freedom and responsibility, we do not plan a highly-directed program for the Student Center. Instead we will provide support and guidance as needed; the contributions to campus life made possible by this building will depend in large part on student imagination and initiative. The programs to be undertaken and the methods of operation are currently under study by the student-staff Student Center Committee.

Following a review by the Undergraduate Association and the Dean's office of numerous problems associated with student entrepreneural activity, we have decided to form a new corporation called "Technology Student Enterprises, Inc." Large-scale operations such as charter flights and other travel services will be handled by students operating under franchise agreements with this corporation. The corporation will also handle manufacturers' sales franchises and similar ventures. We hope to develop within the corporation means to assist students in developing their own profit-making enterprises, consistent with good business practices and general community welfare. The board of directors will be composed of undergraduates, graduates, staff, and alumni. Stock will be held by three trustees, and, since we definitely intend that the profit motive be present, those profits which do accrue will go to M.I.T. scholarship funds.

Increased student interest, particularly at the undergraduate level, in foreign study and work opportunities was evident during the academic year. Largely sparked by the leadership of Henry W. Bowman '63, Undergraduate Association President, and Paul Shapiro '63, Chairman of the Secretariat, a number of discussions were held to assist students and staff in identifying appropriate opportunities in foreign countries. Thomas W. Harrington, Jr., Placement Officer, has agreed to act as a coordinator for the large number of employment plans presently available. We hope shortly to appoint a Foreign Study Adviser who will be able to assist students in selecting the most suitable foreign educational opportunities and who may be able to formulate study programs uniquely suited to the needs of M.I.T. students.

Indicative of our students' continued interest in assuming responsibility in the surrounding community are this year's Open House—for the entire metropolitan Boston area—and the Junior Science Symposium—for high school students and science teachers of the Greater Boston area. Open House has become a biannual tradition at M.I.T.; the diverse program under able co-chairmen Robert Blumberg '64 and Chester Knight, Jr. '64 provided some understanding of M.I.T.'s many areas of interest for over 10,000 persons who attended. The Junior Science Symposium was sponsored jointly by the U.S. Army Research Office, the International Business Machines Corporation, and M.I.T. and was planned and carried out by a committee of M.I.T. students led by Richard Carpenter '64. Seventeen high school students and three M.I.T. students presented papers on their own original research during the two-day meeting, and they and their teachers participated in experiments in M.I.T. laboratories and heard presentations by Professors Edwin H. Land, Charles H. Townes, C. Stark Draper, and Hans-Lukas Teuber.

Student interest in fostering good teaching continues at a high level, and this year the Everett Moore Baker Foundation inaugurated a new award for outstanding undergraduate teaching. The award was presented at the annual Awards Convocation to Professor Alan J. Lazarus of the Department of Physics "in recognition of exceptional and demonstrated interest in undergraduate teaching." The Student Committee on Educational Policy experimented with a "feedback" program at the freshman level. At feedback sessions, freshman section representatives met with instructors in the freshman subjects to discuss the objectives, methods, and content of freshman subjects. S.C.E.P. also plans to experiment next year with a peer-group tutoring system in which upperclassmen will provide tutorial assistance to freshmen.

The Activities Development Board provides a means of working effectively with the undergraduate Finance Board and Activities Council in the development of extra-curricular activities. Chaired by Professor Herbert H. Woodson, the Board this year continued to encourage establishment of alumni and/or faculty advisory groups to the various activities to promote continuity and to provide "nondirective" assistance in numerous areas of interest to our seventy-odd student activities. The Board sponsored a joint meeting on the common problems of all publications at which means to assist the publications groups were discussed. A system of awards to recognize outstanding performance in activities similar to the athletic awards for outstanding performance in athletics will be inaugurated during the coming year.

The Chairman of the Undergraduate Finance Board for 1962-63, Peter T. Van Aken '63, was awarded a Karl Taylor Compton Prize "for acumen, understanding, and effectiveness in the administration of student affairs at M.I.T." In the field of publications, William T. Brydges '62, general manager of *The Tech* for 1962-63, received a Karl Taylor Compton Prize "for consistent and devoted service in the growth and betterment of student journalism at the Institute."

MUSIC AND DRAMA

Both the music and drama programs at the Institute continued to grow in quality and quantity during 1962-63. For many students, the extra-curricular programs support the curricular programs in these areas just as the laboratories support the lecture and recitation work in technical subjects. This year, for the first time, the catalogue of subjects offered by the Humanities Department included work in theater arts, in which enrolled students worked directly with considerable success in actual productions and received credit for this participation. For many other students, these extra-curricular programs provide unique opportunities to develop performing skills or managerial skills and to find enjoyment in the performing arts at many levels. Although music and drama provide "fun" for many, it is important to note that Professor Klaus Liepmann, Director of Music, and Professor Joseph D. Everingham, Director of Drama, have been uniquely successful in developing a quality of intellectual stimulation in their respective fields which discourages dilettantism.

The details of the year's dramatic and musical events are given in the report of the School of Humanities and Social Science.

It has become increasingly evident that our music and drama programs have almost outgrown the facilities provided in Kresge Auditorium. We find ourselves in need of more suitable music and drama practice and rehearsal rooms, scene construction area, and office space. We have been forced to curtail the times at which we can make available Kresge facilities to the M.I.T. Community Players, and we have found it necessary to discontinue provision of scene construction and storage space to this community group. We have found interim storage space for drama in the basement of the Armory, but the anticipated moves of the Hobby Shop and the Rifle and Pistol Range into this space will force us to find a more satisfactory solution in the near future. The Institute Planning Officer is currently engaged in searching for appropriate solutions to the severe space limitations faced by the music and drama activities as a part of his study of the overall development of West Campus.

FACULTY COMMITTEE ON STUDENT ENVIRONMENT

The Committee on Educational Policy last year established two parallel study groups to carry out broad and intensive studies of all phases of our undergraduate education—curricular and non-curricular. As the major effort for 1962-63 in the study of the non-curricular aspects, the faculty Committee on Student Environment undertook a careful review of our undergraduate residential system. Under the chairmanship of Professor Robert J. Hansen and with considerable staff assistance from a number of administrative officers, the Committee surveyed the residential programs at a number of other educational institutions and considered at length the goals and means to achieve these goals which should characterize the M.I.T. system.

Although the findings of the Committee are in tentative form at this writing, it appears certain that the major recommendations will include the following: (1) that the Institute continue to support independent living groups—the fraternities and the M.I.T. Student House; (2) that the Institute provide residence space for about 2,100 male undergraduates in Institute-owned Houses located on both East and West Campuses; (3) that the Institute undertake a major remodeling program of the present Houses and construction of two new Houses for 300 men each—to provide in our residences levels of quality and character consistent with the excellence of our academic facilities and programs; (4) that the Housemaster-Tutor Plan be extended to all Institute-owned undergraduate Houses as rapidly as physical changes permit and that further faculty involvement in the residence programs be encouraged by the development of a plan of Faculty Fellows for the various Houses; (5) that support of our system of strong and responsible student governments within all residential units be continued; and (6) that no formal academic "mechanics" or academic subject offerings be converted to a residential basis, but that these and our formal disciplinary procedures continue to be handled within the framework of the formal academic and administrative departments.

The capital costs required to achieve the goals the Committee has set are great, estimated by the Committee to be about $12,000,000. Nevertheless, the Committee feels that the realization of the great educational potentials inherent in residential systems justifies the major contributions of faculty and administrative effort required.

STUDENT RECORDS

In cooperation with several other administrative offices and the Faculty Council, we undertook this year an extensive review of our policies with respect to the dissemination of information concerning our students to prospective employers, graduate schools, government investigators, and other legitimate inquirers. We have been able to formulate more orderly procedures than we have had within our many administrative offices and academic departments for the fair dissemination of information in categories of academic performance, general technical competence, personal character, and extra-curricular interests.

To assist us in providing valid information to legitimate inquirers, each graduating senior, commencing with the Class of 1963, will be asked to file in the Dean's office a general reference information card. Among the classes of information requested will be names of faculty advisers, thesis supervisors, other personal references, job experience at the Institute, and athletic and extra-curricular activities. Inclusion of the latter categories provides very useful "non-academic" information for our future use and for evaluation by various inquirers; it also provides a kind of partial recognition of student effort outside the classroom, a subject which has been of considerable interest to undergraduates for some time.

STATISTICS ON OFFICE ACTIVITY

Like most members of the Institute staff (and like most students, for that matter), members of the Dean's office staff find themselves hard at work for long hours each day. To assist us as we assess the validity of certain phases of our work and as we plan for the future, we initiated last November a daily tally of various categories of visitors. Although we have not yet conducted this survey for a full academic year, I believe we have gained considerable insight from this admittedly rather rudimentary study. Our figures indicate numbers of visits to the professional staff and do not account for the large numbers of persons who are assisted by the secretarial staff. Further, the numbers do not take account of those persons seen outside the Dean's office—in other Institute offices, evening meetings, and similar contacts—which are necessarily important parts of our overall effort.

Of the total of 6,551 visits to the professional staff from November through June, 72 per cent were student visits made by a total of 1,631 individual students. The remaining 28 per cent of the visits were by 424 individual persons. Only 16 per cent of the student visits were at our request; the vast majority came on their own initiative or upon referral. A breakdown of visits in categories indicates no single outstanding reason for student visits. One-fifth were for academic reasons (984), a like number for residential problems (985), and almost that many for extra-curricular (836), administrative (821), and personal reasons (762). Only the discipline category is well below the others, 280 visits having been primarily for disciplinary reasons. I hasten to add that only a fraction of the 280 "discipline visits" were by students subject to disciplinary action; many of these visits were by members of the undergraduate judicial committees who are concerned with the disciplinary problems of that small number of students who require some disciplinary action.

PERSONNEL

The opening of McCormick Hall in September, 1963, will provide for the first time a proper residence hall for the Institute's women students. This magnificent building is symbolic evidence of the Institute's renewed commitment to provide challenging educational opportunities for women at undergraduate, graduate and post-graduate levels.

The anticipated expansion in numbers of women students makes necessary to an even greater degree than heretofore the augmenting of the Dean's office staff with a professional woman who can provide the "feminine touch." We feel fortunate in having interested Mrs.

Jacquelyn A. Mattfeld in this challenging area. Dr. Mattfeld, presently Associate Dean of Instruction and Dean of East House at Radcliffe College, will join us in September as Associate Dean of Student Affairs. She will assume primary responsibility for the needs of women students over the complete range of Institute affairs. She will also participate with the Dean's office in the planning and direction of our residential and extra-curricular programs and in our cooperative efforts with numerous student-faculty and faculty committees in these and in academic areas.

As in the past, I have asked several of my associates to report on those areas of primary concern to them. Their reports follow.

KENNETH R. WADLEIGH

STUDENT RESIDENCE

In the Institute's residential system, this report year was one of consolidation and planning. As the year drew to a close, construction of McCormick Hall, the new dormitory for women, and of the new West Campus apartment complex for married students was virtually complete. Hence we may confidently expect that these important additions to the residence system will be occupied at the start of the academic year 1963-64. This fact carries several implications. For one thing, the number of girls admitted to the freshman class may now be appreciably increased. For another, the residence on campus of several score of married graduate students will provide opportunity for the development of closer relationships between the married and unmarried groups at the graduate level—in which the Graduate Student Council, the Executive Committee of the Graduate House, the Technology Dames, and the offices of Student Residence and the Graduate School may collaborate. Finally, the addition of some six or seven hundred to the resident population of the campus is bound to exert influences in the M.I.T. community and in the larger society of which it is a part.

The effect on the local real-estate market of the availability of the Institute's 210 apartments and the 400 or so which Harvard University is presently building for married students is in some measure offset by urban renewal projects which have replaced some moderate-cost housing with superior structures that are likely to be beyond student means. It is clear, therefore, that the Off-Campus Housing Bureau in this office will continue to deal with a rising demand, in assisting students and staff to find accommodations in the Boston-Cambridge area. During the report year, approximately 1,500 people made use of this service. The peak load, of course, occurs in August and September; in 1962 August brought 269 persons to consult the Bureau's listings; September, 250. The Bureau keeps in touch with the Massachusetts Commission against Discrimination and requires from landlords a signed statement of compliance with legislation for fair practices in housing. One case of purported discrimination occurred during the year and when properly checked was shown to be unfounded.

As a partial and immediate answer to the problem posed by our lack of accommodations for undergraduate men, we decided this spring to utilize Bexley Hall as a fifth undergraduate House commencing in the fall of 1963. Ultimately some 140 men can be housed there, in apartments for two, three, or four occupants. We anticipate that about 100 will be in residence there in the fall, with Professor Emmet J. Larkin as Faculty Resident. Professor Larkin will be successor to Douglas A. East, who, with Mrs. East, contributed most effectively as Faculty Resident during the period when one unit of Bexley Hall was used as a residence for upperclass and graduate women. It is planned that Bexley Hall as a residence for men will have student government in the M.I.T. tradition and will share in extra-curricular activities, intramural athletics, and social affairs as a House, in parallel with Burton, Baker, East Campus, and the Senior House. A few interior changes are to be made during the summer, and suitable furniture is to be installed to make Bexley ready for its new role.

Incorporation of Bexley Hall into the residential system, however, is a palliative rather than a true solution. The general physical arrangement, size, and age of Bexley Hall are such that we cannot regard it as a satisfactory undergraduate residence over a long time period. Remodeling of the present Houses and construction of new Houses on West Campus as recommended by the Faculty Committee on Student Environment may, it is hoped, be accomplished in the not too distant future. When, by these means, we do achieve sufficient capacity in other units of the residential system, we plan to discontinue the use of Bexley Hall as an undergraduate residence.

HOUSE MASTERS AND TUTORS

The Housemaster-Tutor plan for undergraduate residences is now in the sixth year of operation with Senior House, Baker House, and Burton House operating under this plan. For two of the Masters of the undergraduate residences, the report year was their first in office.

Professor E. Lee Gamble, Master of Baker House, and Professor David C. White, Master of Burton House, each used the year as one of initiation and indoctrination both for themselves and families and for the House governments and residents with whose well being they are concerned.

At the graduate level, Professor Francis Bitter also completed his first year in office as Master of the Graduate House, following the retirement of the "dean" of all M.I.T. Masters, Professor Avery A. Ashdown. Professor and Mrs. Bitter have entered into their new responsibilities with energy and enthusiasm, and they have been received warmly by the graduate students in residence. The Bitters have generally encouraged the development of house spirit and, in particular, have encouraged informal discussions among faculty and graduate students. Some modest physical renovations to the public rooms are planned to provide more satisfactory facilities.

As we move toward the development of a new Graduate Center, the experience and observation of Professor and Mrs. Bitter will prove most helpful. Harry Weese, architect for the Center, will work with the Bitters as well as with administrative officers in planning modifications of the present Graduate House as a part of the development of the new Center just west of Kresge Auditorium.

Several meetings of the Masters and their wives and of the tutorial residential group as a whole were held in the course of the year for discussion of common problems and analysis of ways of meeting them.

It is becoming increasingly clear that the faculty and graduate students in residence provide mature non-directive influence on the quality of undergraduate living experience. To date, the cooperation between the faculty residents and the strong and responsible student governing groups has been most encouraging. We look forward to a continuation of these good working relationships. We also plan to establish closer ties between residents and those faculty and administrative groups charged with the more formal aspects of our student counseling programs.

Professor William H. Curry, Jr., after a most effective year as Faculty Resident of the East Campus, had to leave the post because of new duties in the Navy. Professor Curry and his family left a very warm spot in the hearts of East Campus men. Professor Ernst Frankel of the Department of Naval Architecture and Marine Engineering succeeds Professor Curry.

The tutorial roster was enlarged by the inclusion of Tutors in residence in six fraternities, and as the year ended it appeared that some ten fraternities would avail themselves of the Institute's support of resident Tutors in the fraternities next year.

FRATERNITIES

The twenty-eight fraternity chapters and their 1,100 members began the academic year 1962-63 with the most successful Rush Week on record. During the autumn the pledge classes of five chapters joined in a work party on a Saturday, and under the direction of the Boston Park Department did a manful job of clearing and cleaning the park along the Muddy River in the Fenway. They were emulated later in the year by two chapters which joined with the Neighborhood Association of the Back Bay in a tree-planting program along Commonwealth Avenue. The Interfraternity Conference has for several years been a member of the Association.

The high point of the year from the fraternity point of view took place in March when, at the instance of the Executive Committee of the Interfraternity Conference, representatives of the alumni house-owning corporations, of the active chapters, of the chapter advisers, and of the Institute administration met to consider ways of implementing the progress report on fraternities issued a year earlier. Completed, continuing, and beginning programs for the renovation and improvement of chapter houses were discussed by speakers, and general methods of approach were explained. The Institute's readiness to aid chapter corporations to upgrade accommodations was stated, and various possible channels were explored. As a result of the meeting, a permanent steering committee of house corporation representatives is being formed under the leadership of D. Reid Weedon, Jr., former President of the Alumni Association; through this medium, arrangements for continuing co-operation between the Institute and its fraternities will be facilitated.

In part for his splendid leadership as President of the Interfraternity Conference for 1962-63, James A. Champy '63 was awarded a Karl Taylor Compton Prize as "unselfish leader, exemplar of good will in undergraduate life."

FREDERICK G. FASSETT, JR.

ATHLETICS

As I prepare my Annual Report at the close of my second year at M.I.T., I am singularly impressed by the ever-increasing need for a well-rounded program of athletics for all students at M.I.T. I recall the 1930 report of the Secretary to the Advisory Board on Athletics, Dr. Allen Winter Rowe, in which he stated: "With the exact circumscription that the required academic work enforces, our students are peculiarly in need of what the various athletic teams have to offer." In 1963, I simply refer to the tremendous increase in discipline and academic rigor which have accompanied the development of the educational curriculum in science and technology since the 1930's. The need for athletics in the day-to-day living of our students is greater than at any time in the history of the Institute.

The expansion of the Institute as a residential community and the continued upgrading of the broad extra-curricular educational programs, including athletics, have strengthened our ability to attract students who will develop personally as well as professionally. Keen competition exists among superior educational institutions for those outstanding students who are both academically qualified and capable of strengthening community activities. As Professor Roland B. Greeley has told high schools, "We seek students of this sort to enrich our campus life and because we believe that these are the individuals who are most likely to contribute greatly to their professions, their communities, and society in later life."

The year 1962-63 witnessed a considerable increase in overall participation in athletics by undergraduates, graduate students, faculty and staff, and other personnel affiliated with the expanding M.I.T. Community. Approximately 6,160 individuals registered for use of the athletic facilities, including the Sailing Pavilion, compared with 5,830 in 1961-62. This represents an increase of 190 students and of 110 faculty and staff members.

Based upon surveys conducted this past year, we estimate that the du Pont Athletic Center accommodates in excess of 900 persons daily in physical education, intercollegiate and intramural athletics, and informal recreation. The Alumni Swimming Pool and squash courts attract a daily average of 300 participants. Total attendance at the du Pont Tennis Courts during the outdoor season is about 20,500, and, by actual count, the skating rink catered to 19,354 skaters between the dates of November 19 and March 18.

An innovation this year was a noon-time program for faculty and staff under the guidance of Richard D. Erickson, Freshman Rowing Coach. Other members of the athletic staff assisted in the instruction of general conditioning, volleyball, squash, and tennis. A flexible schedule, arranged to meet individual requests, was most enthusiastically received. We feel that the very real benefits to the thirty-one faculty who participated warrant continuation of the program as long as the interest exists.

The hours at the swimming pool were adjusted to give additional time for mixed swimming and to make this popular facility available over the weekends when students are better able to seek relaxation from their academic commitments. The additional opportunities for recreation have justified the increased costs of operation.

The Summer Day Camp continues to provide desirable service within the Institute community. Approximately 750 children participated for periods ranging from two to eight weeks. The average attendance of the campers was about four weeks. During the past year the athletic staff and facilities have been utilized on special occasions associated with the Newcomers Program and Alumni Day. Instruction has been offered to children of faculty and staff in swimming and ice skating. Family night at the swimming pool has attracted record attendance.

ATHLETIC STAFF

Instruction in physical education, the coaching of intercollegiate teams, and the supervision of intramurals, club athletics, and informal recreation are coordinated within one staff. Personnel accept responsibility as teachers to develop skills, attitudes, and habits associated with all elements of the athletic program. The staff adhere to a philosophy of promoting those worthwhile experiences which sports offers to individuals in an educational atmosphere where academic standards are necessarily foremost. Each student is urged to relate an appraisal of his athletic interests with his abilities. He is encouraged to acquire an appreciation for regular activity as a means toward a productive and happy life.

There were several changes in the staff this past year: John S. Merriman, Jr., succeeded Glenn P. Strehle as Assistant to the Director, the latter having accepted an opportunity in business; Wilfred R. Chassey was appointed Instructor in Physical Education and Coach of Wrestling to replace Alexander Sotir, who resigned to accept a position at Wesleyan University; Peter M. Close was named to the position of Director of Sports Information; Gordon V. Kelly was appointed Instructor in Physical Education with coaching duties in freshman track and cross country; and Thomas J. Murray, Jr., was appointed Instructor in Physical Education and Freshman Swimming Coach.

PHYSICAL EDUCATION PROGRAM

All male undergraduates are introduced to recreational interests and to the Institute's excellent athletic facilities through the Physical Education Program. Each man elects four activities to be completed during his first two years. The emphasis is on those sports which may be continued throughout life. Our goal is to develop an appreciation for the importance of recreative physical activity in achieving good health and general physical and mental well-being.

Entering men are screened for swimming ability and physical fitness. Swimming instruction is provided to enable all students to attain accepted standards of water safety. Those who score poorly in the fitness test are encouraged to register for a course in physical development.

The more popular choices in the Physical Education Program this past year were swimming, tennis, sailing, physical development, ice skating, and golf. These sports accounted for 68 per cent of the total of 3,527 registrations in 1962-63. Other sports offered were volleyball, judo, archery, fencing, squash, badminton, lacrosse, basketball, softball, and soccer in order of popularity.

In addition to the Program for men, ten undergraduate women received instruction in physical education classes in swimming and tennis. Also, there were 366 students and staff registrations for non-credit instruction.

INTERCOLLEGIATE ATHLETICS

Intercollegiate athletics appeal to a large group of undergraduate students at M.I.T. Varsity and freshman teams compete in eighteen sports, with junior varsity competitions arranged where practical. The program is among the most complete of any university's in the country, excluding only intercollegiate football. In addition to the formal program, there are informal clubs in rugby, water polo, judo, weight-lifting and cricket. Some 985 students participated in 443 intercollegiate contests, including tournaments and championships, in 1962-63. The varsity teams compiled a record of 104 victories, 97 defeats, and two ties. A total of 586 varsity letters and freshman numerals were awarded.

During the fall season the soccer team lost only to Middlebury in the final of eight games.

Among the winter sports, the basketball team won twelve of its last thirteen games in completing a season of fourteen wins and eight losses, including winning the Montreal Invitational Basketball Tournament held during the Christmas recess. The wrestling team enjoyed a season's record of ten wins against three defeats and one tie;

M.I.T. finished second in the New England Wrestling Tournament. Indoor track and swimming had winning seasons. The rifle team captured the New England Championship.

Outstanding among the spring sports were the heavyweight and lightweight crews, outdoor track, and tennis. Highlights for the heavyweight oarsmen were the victory over Yale and the American Henley Championship at Lake Saratoga in which M.I.T. defeated the Vesper Boat Club of Philadelphia, the United States representative in the recent Pan American Games. The climax of the season, however, was a great race at the annual Intercollegiate Rowing Association Regatta on June 15 at Lake Onondaga, Syracuse, where M.I.T. placed third among fifteen of the best crews in the country. Only Cornell and Navy were able to outrow the M.I.T. crew, who placed ahead of California, Washington, and Wisconsin among others. The lightweight crew was undefeated until the final Spring Championships on May 18 when they were finally edged by Cornell, whom they had defeated one week earlier to win the Geiger Cup.

Outdoor track climaxed its most successful season in recent years in winning the Eastern Intercollegiate Championships, representative of the small colleges in New England. James Flink '64 set M.I.T. records in the 100- and the 220-yard dashes. The tennis team completed its eighth consecutive winning season in defeating three of five opponents in the spring recess training trip and moving through New England competition with eight victories against three defeats, two of the latter being 4-5 losses to Dartmouth and Williams.

INTRAMURAL ATHLETICS

This has been a banner year for intramural athletics. Two new sports, cross country and rifle, were added to the program. As shown in the table on the next page, the program included a total of seventeen sports in which 456 teams involving 4,212 participants competed in over 1,500 contests during the year.

The practice of classifying touch football, basketball, hockey, and softball into divisions separating the stronger from the weaker teams again proved successful by fostering more even competition among the contestants.

The rule prohibiting varsity, freshman, and junior varsity squad members from competing on intramural squads during the same season is now accepted by living groups. A greater number of participants in intramural contests is apparent, in contrast with past experience when the more athletic members of the living groups tended to

Participation in Intramural Athletics, 1962-63

Sport	*Number of teams*	*Number of participants*
FALL		
Cross country*	11	38
Football (touch)	38	570
Sailing	14	56
Wrestling	23	138
Tennis	15	150
WINTER		
Badminton	24	96
Basketball	57	855
Bowling	22	66
Hockey	24	288
Rifle*	27	81
Swimming	11	88
Volleyball	59	472
SPRING		
Golf	20	80
Softball	45	900
Squash	32	128
Table tennis	16	80
Track	18	126
	456	4,212

* Introduced in 1962-63.

monopolize much of the intramural competition at the expense of the less gifted in athletic skills.

In summary, a very healthy condition exists throughout the intramural program. The continued use of students as referees and umpires is proving successful. A very favorable indication of student interest is the keen competition for managerial positions in all intramural sports.

THE UNDERGRADUATE ATHLETIC ASSOCIATION

Of long-standing tradition, undergraduate participation in planning athletics at the Institute contributes immeasurably to the success of the program. The Athletic Association has been of real assistance in relating the athletic program to the interests and needs of the student community. His splendid leadership in athletics and other areas won for James E. Evans '63, President of the Association for 1962-63, a

Karl Taylor Compton Prize inscribed to "sportsman, scholar, administrator of excellence in work and play."

The vast intramural program has been completely organized under the direction of Thomas P. Gerrity, Jr. '63, head of the Intramural Council. This includes organization of each sport, scheduling all contests, training and assigning student officials, and handling all matters of procedures, rules, eligibility, protests, etc.

Richard M. Harris '63, Varsity Vice President, has supervised the many details of the eighteen intercollegiate team managers, including arrangements for team travel. John J. Lamberti, Jr. '63, Publicity Chairman; Anthony M. Weikel '63, President of the T Club; Steven W. Brostoff '64, Club Vice President; and R. Neal Harvey '64, Recorder, have rendered outstanding service. In October, 1962, the responsibility for the operation of the informal athletic clubs was transferred from the jurisdiction of the Institute Committee to that of the Athletic Association. The office of a Club Vice President was established and a classification scheme adopted to encourage a continuity of club leadership and activity.

MAJOR ATHLETIC AWARDS

In addition to the Karl Taylor Compton Award to Mr. Evans, three outstanding students were recognized for achievement in athletics at the Awards Convocation. The Clifford Award of the Class of 1948, for the outstanding senior athlete of the year, was presented to H. Bent Aasnaes of Oslo, Norway, one of the top tennis players in collegiate competition and past winner of the Eastern Intercollegiate Ski Jumping Championship. Robert E. Vernon, captain of the lightweight crew, received the Admiral Edward L. Cochrane Award for the senior who best demonstrates qualities of leadership, humility and scholarship. The Eastern College Athletic Conference Merit Medal, annually awarded to the senior who best combines scholarship and athletic achievement, went to Mr. Gerrity, co-captain of wrestling, a varsity lacrosse player, and head of the Intramural Council, who completed his program in electrical engineering with highest honors.

ATHLETIC BOARD

The Athletic Board continues to contribute effectively to the success of the Institute's athletic program, particularly through the evaluation of goals and the philosophy which determine policies governing specific areas of activity.

During the fall and winter months a portion of each Board meeting was devoted to a review of the physical education program, intercollegiate athletics, intramural athletics, and opportunities for informal or casual recreation. Particular emphasis was placed on scheduling practices which influence optimal utilization of athletic facilities. A committee of the undergraduate members of the Board and Professor Kent F. Hansen made a survey of student participation in athletics and the forces which favorably influence or limit student participation. At the same time Professor George A. Brown, through a series of interviews with coaches and faculty, reported on adequacy of the place of athletics in the overall M.I.T. program. Further reference to Professor Brown's report is made at the conclusion of this report.

Special appreciation is extended to Professor Robert E. MacMaster upon completion of two years of outstanding service as Chairman of the Athletic Board and to Arthur L. Bryant, Alumni Representative, who is leaving the Board in regular rotation. Mr. Bryant's interest in the Institute and his long and close association with the athletic program have made him a valued member of the Board.

LOOKING AHEAD

We face three major problems which vitally affect the immediate future of the athletic program.

It is imperative that no further encroachment be made on Briggs Field as plans move forward for the development of the Graduate center on the West Campus. The existing athletic fields represent many years of careful planning, and the present athletic program requires all the area within the limits of Briggs Field. As the interest of undergraduates, graduate students, and staff continues to increase, further demands on Briggs Feld must be met. A second consideration is the importance of maintaining access between the du Pont Athletic Center and the athletic fields. If the Graduate Center is located approximately on the site of the new parking area west of Kresge Auditorium, access to the center must be planned in such a way as to avoid loss of the ice rink and running track and to avoid isolation of the du Pont facilities from Briggs Field. The Institute Planning Officer and the Athletic Department are currently exploring solutions to these and other problems in the further development of the West Campus.

A second major concern centers about providing desirable athletic facilities for the increasing number of women students anticipated with the completion of McCormick Hall. Some program integration is possible within existing facilities at the swimming pool, ice rink, and tennis courts. However, the indoor facilities at the du Pont Athletic Center are already bulging with men's activities, and existing athletic fields are fully committed to current activities.

Finally, a problem of broad implications is the mounting encroachment of the class schedule upon the too few hours our students are able to devote to activities outside the classroom. Professor Brown's review of this problem has been submitted to the Dean of Student Affairs.

ROSS H. SMITH

COUNSELING

Counseling throughout the Institute is an activity which by its nature is difficult to measure. If one tries to measure it, one quickly recognizes the truth of a statement by the late William Temple, Archbishop of Canterbury, in his Gifford Lectures of 1932-34 that "if you begin by attending to objects only in so far as they are measurable, you are likely to end by having only their measurements before your attention." In spite of this inherent difficulty, I believe there are two observations about counseling at the Institute which can be made with confidence.

The first is this. Ten years ago, a large number of students came to the Dean's office for counsel near the end of each term. Looking back, I am now struck by the fact that most of these students had not previously sought help from or even discussed their difficulties with any one else. Now, ten years later, while the number of students visiting the Dean's office seeking counsel has remained relatively constant, a great many have already sought help or counsel from their instructors or faculty counselors, from a member of the psychiatric staff, from their House Masters or Tutors, or from others. The change makes it clear that the faculty are more available for counseling and that students recognize they are more available and are making more effective use of this availability.

The second observation is this. Ten years ago students whose difficulties were seriously affecting their academic performance tended to feel that their fate at the end of the term would be decided in an arbitrary, impersonal fashion, on the basis of rigid and complicated rules. Some students become expert "sea lawyers;" others diverted their attention from their real difficulties into complicated efforts to demonstrate that "extenuating circumstances" warranted setting aside the rules. Now, ten years later, the Committee on Academic Performance has so revised and simplified its policies and procedures that faculty counselors and students can concentrate their attention on the significant issues in the student's situation, confident that special consideration will be given a student when circumstances provide a valid reason for doing so.

The new policies of the Committee on Academic Performance in respect to disqualification and probation were described a year ago. During the past year the Committee has introduced greater freedom in respect to the number of hours a student may carry and in respect to dropping subjects during the term. It is significant that, taking the student body as a whole, relatively few students found it necessary to take advantage of these changes; an M.I.T. student is more apt to carry an overload than an underload.

We sometimes assume that the Institute does not approve of holding students' hands, and that it does approve of the principle of sink or swim. A more accurate statement is that the students themselves quite rightly object to hand-holding, that the Institute does believe in self-reliance, but that the Institute does not believe in waiting for the bubbles to stop before seeing if a student is drowning. If one must use the sink-or-swim analogy, one can say that the Institute believes that a student in difficulty fifteen feet from shore ought to be tossed a sixteen-foot rope, not a fourteen-foot one. If, however, he is having difficulty but is managing successfully on his own, it is not the Institute's policy to stun him by aiming a life ring at his head, or drown him in the waves of a rescue launch.

The Institute cannot claim that its counseling resources cure all ills. M.I.T. is not immune to the forces that operate in our society. Successful counseling depends in part on efficient administrative machinery, but perhaps it is best understood as one expression of social and ethical attitudes. One of the general hindrances to counseling is the tremendous demand on each faculty member's time and energy arising from a combination of his professional obligations, committee assignments, family and community commitments, and the need to guide research projects which benefit both his graduate and undergraduate students.

Another hindrance, and a relatively rare one, is the fact that there will probably always be a few members of the faculty who feel M.I.T. would be a far better institution to work in if it had no students at all or at best only graduate students. This attitude can be dressed up in academic and educational theory, but I suspect it represents nothing more than the fact that there are some people who think all children are nuisances and who dislike even adults who annoy them.

Among constructive attitudes, two in particular are strongly represented at M.I.T. One is the conviction that one of the chief human virtues is hard work. The other is the realization that an individual's accomplishment is based not only on his native ability and industry but also on the support that M.I.T. as a whole is constantly supplying to him. It is as a result of these attitudes that many students discover, sometimes to their surprise, that a faculty member responds to a request for help with energy and generosity that effectively dispel the image of an impersonal factory. There is always the tendency—certainly not confined to M.I.T.—for the individual to put his own advancement in first priority. If not balanced by some measure of humility, this tendency can occasionally result in a frame of mind that jumps to two conclusions: one, that any student in difficulty is guilty of sloth, and the other, that activities like student counseling, which do not contribute to professional advancement, are a waste of time.

Counseling at the Institute, therefore, is influenced by the same negative and positive tendencies that affect all human relationships. The machinery of counseling could undoubtedly be improved. But its strength lies in the wealth of intelligent concern that most of the faculty have for students faced by the double job of learning and maturing in a world that makes great demands on their courage.

With the increased flexibility in both freshman and upperclass curricula, and with the ever-increasing scope of research and educational interests at M.I.T., the need for more individual attention to student academic programs is evident. As reported in the following section, certain steps have already been taken to achieve better liaison between the Freshman Advisory Council and the faculty responsible for instruction in freshmen subjects. In cooperation with the Committee on Academic Performance, the Dean's office staff plans to initiate on an experimental basis next year a few "adviser's advisory seminars." Through this means we hope to provide assistance to both freshman advisers and upperclass faculty counselors as they tackle their increased counseling responsibilities.

In response to considerable student demand, the Dean's office made arrangements for a voluntary, non-credit reading course. Enrollment was open to all undergraduates, but since it was necessary to limit the total enrollment to 150 a considerable number had to be turned away. The cost to each student was $30. There were two sections, each meeting for a total of twenty hours, from 8 to 8:55 a.m., conducted by George W. Gibson, Director of the Division of Audio-Visual Education at the Harvard Graduate School of Business Administration. With the help of the Student Committee on Educational Policy, an assessment is presently being made of the responses to the course of those enrolled. It is planned to offer the course again in 1963-64, with several changes in content and method. Mr. Gibson will again be available for individual interviews.

WILLIAM SPEER

FRESHMAN WEEK END AND FRESHMAN ADVISORY COUNCIL

The Freshman Week End program is the formal method currently employed to assist the entering class of 900 students to gain an introductory acquaintance with the several dimensions and areas of undergraduate life. Utilizing the four days preceding Registration Day, it is a joint venture of the Dean's office, the Freshman Advisory Council, and the Freshman Coordinating Committee of the Institute Committee.

Although the Week End schedule has undergone continuous revision and shifts of emphasis, the prime time in the program continues to be allotted to the Freshman Advisory Council for academic matters and for the establishment of individual acquaintance with students. Other major portions of time are utilized for introductions to the physical environment, residential groupings, and student activities, athletics, and government. Several meetings of the class as a whole provide the occasion for greetings of welcome, the introduction of students and staff who may be of especial assistance to freshmen, and the presentation of a short series of talks by faculty concerning some aspects of their teaching or research. The Week End concludes with a reception for students and their parents given by President and Mrs. Stratton at their home; fourteen hundred invited guests attended this reception last year. In order to reduce the pace and to introduce more time for personal conferences, the period of orientation will be extended to four and one-half days in 1963.

This not-insignificant program of greeting, friendship, and hospitality, which involves directly over 300 members of the faculty, staff, and undergraduate body, proceeds on a decentralized basis; it stands as a visible testament of our enduring concern for our newest colleagues.

Throughout the freshman year the responsibility for the general academic and personal counseling of the entering class is centered in the Freshman Advisory Council. Professor Nathan H. Cook is Chairman of the Council, composed of eighty faculty members; Professor William M. Siebert assumed responsibility for the "undesignated sophomore" program and the "Introduction to Technology" lecture series; and Richard W. Willard and Professor Henry A. Millon were in charge of the Course selection program in the early spring.

Of especial help to the Council this year has been the acceptance of membership on the Council Executive Committee by the members of the faculty in charge of the required freshman subjects. The contributions of Professors Clark C. Stephenson, E. Lee Gamble, Alan J. Lazarus, Arthur P. Mattuck, and Harald A. T. O. Reiche have been of major importance and of direct benefit to first-year students.

The invitation to the Class of 1966 to indicate the school, department, or area of the Institute with which they would like to have their adviser associated was accepted by over two-thirds of the class. This matching of faculty interest and student interest appears to be the most reliable single ingredient in the successful grouping of adviser and advisee. The heart of the advisory system, however, continues to center in the nature of the personal relationship developed between faculty and student. The initiative taken by the advisers to broaden and deepen this relationship by means of hospitality and conference has never been more fully employed than during this past year. To extend this initiative more specifically in the coming year, several advisers will take on advisory groups composed of students all of whom are residents of a single living group. It is hoped that the already-substantial liaison between the Council and the residential system will be strengthened by this new development.

ROBERT J. HOLDEN

RELIGIOUS ACTIVITIES

The several religious traditions continue their ministries to the individuals of the community through a variety of means. At one end of the methodological spectrum are student religious groups which independently carry on active programs and services, while at the other end are professional representatives who carry on their functions. Between these poles are several types of cooperative endeavors which imaginatively link student groups and religious counselors. This year the M.I.T. Hillel Society, a student religious organization, was the recipient of a Karl Taylor Compton Prize in recognition of "major contributions, over many years, to the intellectual and cultural life of the M.I.T. community."

The essentially personal and private nature of religious belief and practice which seems to be characteristic of the present religious climate continues to engage the religious counselors in heavy counseling schedules. In addition to regular worship services in the Chapel, many discussions in small study groups within the various traditions have taken place during the year. Student and student-faculty meetings with the religious counselors both on-campus and off-campus also made for fruitful exchanges on meaning and faith.

Our entire religious program is founded on the Institute's "responsibility to provide opportunity, in a manner wholly elective, for the development of spiritual maturity and the exercise of spiritual interests," as expressed by Dr. James R. Killian, Jr., in his 1954 annual report as President. On this premise, we have been able to develop over the past decade unique and rewarding religious programs, but we recognize that there are many problems still to be solved. To gain insight into these problems and to explore means for their solution, we have this year held a number of candid and mutually helpful discussions among the counselors, their sponsoring groups, and several members of the administrative staff. We look forward, in particular, to the establishment of more clear-cut definitions of role and responsibilities of the counselors as members of the Institute family and to the establishment of still better and more sensitive means of communication among the various groups concerned.

It is with deep regret that we note the deaths during the year of Swami Akilananda and the Reverend J. Edward Nugent. Both had been closely associated with the religious program here for over a decade and were held in affectionate regard and respect by students, staff, and colleagues. Swami Sarvagatananda and the Reverend Harry J. Dooley have taken on their duties.

To expand its ministry among foreign students, the Protestant Ministry has invited the Reverend Reginald Smart to serve with them during the coming year.

ROBERT J. HOLDEN

Student Aid Center

The academic year 1962-63 marked the completion of the first ten-year period of the operation of the Student Aid Center. The undergraduate student body this year numbered 3,557, only a few more than 1961-62; about 50 per cent, 1,766 individuals, received financial assistance during the year. To this number, $1,536,546 was granted in scholarships and $639,374 was awarded in loans, a total of $2,175,920; this sum represents a 10 per cent increase over 1961-62. Student earnings were $938,126, almost identical with 1961-62, which makes the total aid for the year $3,114,046.

A comparison of the amount of student aid granted in 1952-53 with that of 1962-63 brings into sharp focus the fact that the Institute has provided financial help from its scholarship and loan resources in amounts that have far exceeded the increment in the tuition fee:

	1952-53	*1962-63*	*Per cent increase*
Tuition fee	$800	$1700	112
Number receiving scholarships	636	1414	122
Total scholarship awards	$265,990	$1,536,546	477
Number receiving loans	283	855	200
Total loans	$167,540	$639,374	282
Total number of students assisted	819	1766	105
Total assistance (scholarships and loans)	$433,530	$2,175,920	409
Average grant (scholarships and loans)	$529	$1232	133

SCHOLARSHIPS

The undergraduate scholarship endowment was augmented during the past year by the establishment of new funds by gifts from A. Rufus Applegarth '35, Mrs. Marie C. Dennett, Thomas Mayor, and John J. Watson. Through a bequest by his sister, Mrs. Margaret Piza Crane, a memorial scholarship fund in the name of St. Elmo Tower Piza '15 was established. A new fund under the name of the Second Century Fund, with more than $200,000 capital, will become operative next year. To previously established scholarship endowment funds substantial gifts were made by Nils Anderson, Thomas D. Cabot, Rudolph E. Gruber '16, Gustav R. Lindberg, Theodore A. Mangelsdorf '26, Otto Morningstar '39, and the estate of Sarah M. Rand. The cumulative effect of all these gifts was to increase the total scholarship endowment by almost 5 per cent.

Formal and grateful acknowledgment is made to the 247 donors whose contributions of more than $950,000 made it possible to assist 861 undergraduates in all four classes. As reported in previous years, these funds have come from widely different sources ranging from individuals and fraternal groups to foundations, trusts, and corporations. In many instances, in addition to the financial grant to students, an unrestricted gift is made to the Institute; this year $227,675 was received in this way, an increase of 25 per cent compared to 1961-62.

LOAN FUNDS

The cumulative record of the Technology Loan Fund at the close of the fiscal year shows that $8,011,667 has been borrowed by 7,620 individuals since the start of the Fund. Of these debtors, 4,203 have completely repaid their obligations; notes outstanding of 3,417 debtors amount to $3,975,379. The $98,771.19 added to the Fund during the 1962-63 year *exceeds* the *total* in this category of the past thirty-two years. In large part this increase resulted from the efforts of the Second Century Fund.

The Technology Loan Fund experienced its greatest demand in a single academic year, loaning more than $761,000 to 992 individuals, 15 per cent of the student body, graduate and undergraduate. During the year 1,243 applications for loan assistance were received and 1,150 were considered for help from the Technology Loan Fund; 158 (14 per cent) were denied and 992 (86 per cent) were acted upon favorably. Among the 992 receiving grants were 196 graduate students; the amount loaned to graduate students was $174,019. These data represent increases in both numbers and dollar amounts for graduate students over the previous year.

Although the Technology Loan Fund continues as the major loan fund resource, the Institute holds more than twenty other loan funds that are administered in the same manner as the Technology Loan Fund. From these funds $81,069 was loaned to 59 undergraduates and 34 graduate students, or a total of 93 individuals. The year's operation of Institute loan funds may thus be summarized:

Total loaned	$842,663
Number assisted	1085
Number denied	158

The Installment Credit Plan, another form of credit extension made available by the Institute, was used by 65 students for $34,315.

In last year's report it was noted that the Ford Foundation had established a special fund of "forgivable loans" for doctoral candidates in engineering fields who plan to remain in college or university work. For the academic year, forty-five graduate students received $93,550 in grants.

The following tabulation illustrates the total of all forms of credit extension of almost $1 million to 1,195 individuals:

	Number	*Amount*
Technology Loan Fund	992	$761,054
Other M.I.T. loan funds	93	81,609
Installment Credit Plan	65	34,415
Ford Forgivable Loans	45	93,550
	1,195	**$970,628**

Undergraduate Scholarships and Loans, 1962-63

	1962-63			1961-62		
	Number	*Awards*	*Total*	*Number*	*Awards*	*Total*
UNDERGRADUATE SCHOLARSHIPS						
From M.I.T. endowment funds						
Freshman scholarships	229	$275,200.00		247	$244,978.80	
Other undergraduate scholarships	324	$301,498.50		285	$286,533.00	
			$576,698.50			$531,511.80
From outside sources						
Freshman scholarships	220	$252,158.72		229	$258,802.10	
Other undergraduate scholarships	641	$707,689.30		612	$659,886.85	
			$959,848.02			$918,688.95
	1,414		**$1,536,546.52**	**1,373**		**$1,450,220.75**
UNDERGRADUATE LOANS						
Technology Loan Fund	796	$587,035.00		781	$515,958.00	
Mead Fund	16	15,899.00		15	15,110.00	
Other loan funds	43	36,440.00		3	2,000.00	
			$639,374.00			$533,068.00
	1,766*		**$2,175,920.52**	**1,722***		**$1,983,288.75**

* This total is modified to allow for individuals receiving both scholarship and loan.

Since the establishment of the Massachusetts Higher Education Loan Plan (HELP) in 1956 by the General Court of Massachusetts, through which local banks are legally empowered to make student loans, many other states have passed similar legislation. This office has acted as the Institute's liaison in certifying M.I.T. students who have made application to banks in their home states where loans are available. This year ninety-two students received $71,831 in bank loans for their expenses at the Institute.

FACULTY CHILDREN SCHOLARSHIP PLAN

Scholarship grants in the amount of $120,400 were furnished to 139 faculty children during the year. Nine undergraduates were enrolled at M.I.T. and 130 were in attendance at seventy-three different colleges and universities throughout the United States. In the four-year period that this Plan has been in effect, sixty faculty children have successfully completed their work and received the Baccalaureate degree.

For the purpose of record, the only student receiving benefits under the Tuition Exchange Plan graduated June, 1963. During 1962-63 ten children of M.I.T. employees received the half-tuition fee reduction.

OTHER BENEFITS

The number of students receiving benefits under Public Law 550 sharply decreased during the year.

First Term, 1962-63	31
Second Term, 1962-63	20
Summer, 1963	4

As retiring Director of Student Aid, it is most appropriate for me to record in conclusion my sincere and personal appreciation for the cordial and cooperative assistance given me on untold occasions by members of the administration, faculty, and staff in fulfilling the stewardship of this office. To the men and women in this office who have assisted me with their loyal support and skill, I express my deepest gratitude.

THOMAS P. PITRE

Admissions Office

Statistics on Admissions Office activity for the past year have been adjusted to reflect the situation for the twelve-month period ending

October 1, 1963. In general they show no significant changes from the immediately preceding year: the numbers of applications, admissions, and staff contacts have all remained relatively constant.

Entrants from secondary schools	*1962*	*1963*
Preliminary applications	5,559	5,311
Final applications	3,276	3,276
Admissions offered	1,590	1,590
Actual registrations	885	900
Registrations as per cent of admissions	55.7%	56.6%
Number of secondary schools represented	675	711
Per cent of students from nine northeastern states	44%	47%
College transfers		
Total applications	448	413
Applications completed	231	209
Admissions offered	126	136
Actual registrations	86	110
Registrations as per cent of admissions	68%	31%
Graduate students		
Total applications	4,382	4,620
Admissions offered	2,307	2,427
Actual registrations	1,410	1,498
Registrations as per cent of admissions	61%	62%

Advanced Placement

	Number of students seeking credit		*Number of subjects credited*	
PROCEDURE	*1962*	*1963*	*1962*	*1963*
College Board test program	271	325	476	569
Advanced standing examinations	13	19	32	21
College transcript	32	29	47	53
	292[1]	**351**[1]	**555**	**643**

SUBJECTS CREDITED	*Number of students given credit of one semester or more*	
	1962	*1963*
Chemistry	51	74
Mathematics	202	242
Physics	13	10
Freshman elective	59	66

[1] In some cases credit was sought and earned through two procedures; duplication is eliminated in the totals.

Contacts

	1962	1963
NUMBER OF SECONDARY SCHOOLS VISITED		
By Educational Counselors (college nights)	147	141
By faculty and administrative staff members	542	328
By the Admissions Office staff	194	415
Total	**883**	**907**
NUMBER OF PERSONAL INTERVIEWS		
At M.I.T.	1,181	1,422
In New York	131	131
By Educational Counselors	2,537	2,514
Total	**3,849**	**4,067**
Number of persons taking tours of M.I.T.	**4,024**	**5,825**

TREND IN NUMBERS

The past year witnessed a levelling off of the downward trend in numbers of freshman applicants which had characterized the period 1960-62. Although it is too early to assert that the trend has been reversed, it seems likely that numbers of applications will increase in each of the next two years, due to the substantial increase in the numbers who will graduate from secondary schools in each of those years. Beginning in 1965 we may again expect a plateau in the curve of total college admissions—and hence, possibly, in the numbers of applicants to M.I.T. But until then the numbers of applications should be relatively high and competition very stiff.

The number of qualified applicants for admission with advanced standing (transfer students) remains relatively constant and has for many years. Unless specific steps are taken to alter the situation, it seems likely that we will continue to register fewer than one hundred new transfers per year. On the other hand, rapid development of new two-year community colleges could alter the supply of would-be transfers in the near future—especially if our policy on student aid is such as to make financial aid available in such cases.

Applications for admission to the Graduate School rose again this year; we acted on 30 per cent more applications than we did four years ago. Similarly, the number of those admitted and registered continues to increase about 5 per cent per year.

Already the number of *new* graduate students registered each year is 50 per cent higher than the number of new undergraduates. If the present trend continues, the total number of graduate students will exceed the total number of undergraduates in only two years. This can have serious implications for our public image. There is now a general impression that the graduate school is more important than the undergraduate program; this impression would tend to be confirmed and emphasized if the graduate enrollment were in fact larger than the undergraduate enrollment.

WOMEN STUDENTS

The opening of McCormick Hall for women students was marked by relatively little fanfare or publicity. Nevertheless, the opportunity to admit more undergraduate coeds has met with gratifying response. The number of completed applications was up 12 per cent over a year ago, and of those who applied we were able to admit and register 50 per cent more than a year ago without being in any sense less selective than we have been with the male applicants. As the excellence of our accommodations for female students becomes better known, it is probable that the number of coed freshmen registered each year can be increased well above this year's figure, should that appear desirable.

CAREER CHOICE

Although no significance is attached to the answers, except for statistical purposes, each applicant is asked to indicate his career interests. For several years, the number of those admitted who mentioned areas represented by the three small schools—architecture, humanities, and management—has remained relatively constant, at only 2 or 3 per cent of the total (this year, architecture was listed by fifteen students, humanities by two, and management by twelve). Until this year there has been a consistent decline in the proportion indicating interest in engineering and a corresponding increase in science. Among the group admitted this year, there was a slight increase in the proportion choosing engineering—although the number remains less than 40 per cent of the total. It is too soon to speculate as to the significance of this slight deviation from the previous pattern.

YIELD

One of the major consequences of multiple applications, accentuated by highly competitive patterns of financial aid, is the significant difference in numbers between those admitted and those who register—the "yield." A few small, high-prestige colleges have specialized admissions practices which seem to link admission with "first choice" on the part of the student. But among the large proportion of competitive-admissions colleges whose admissions procedures are designed to give the student maximum choice, yields above two-thirds are rare, and yields below 50 per cent are common. Again this past year, our yield was somewhat below 60 per cent. As far as we can discover, this yield is as high as that of any technological institution, but it is lower than that of several liberal arts colleges with whom we have many applicants in common. This suggests that we must find some ways of interpreting more effectively to the public the strong points of our type of undergraduate program in our unique academic community.

On the other hand, it may also mean that we cannot expect to compete any more successfully than we have in the past with the private liberal arts colleges and state universities which offer truly strong programs in the physical sciences. For a great many students the apparent choice is between: a technological institution, where they can get the excellent "pure" science they desire, with applied science or engineering as alternative majors; and a university which offers strong science courses, with the whole gamut of "liberal arts" offerings available for those who change their minds. For many of these students it must be expected that the university, with its greater variety of curricula, is the logical choice.

ADVANCED PLACEMENT

The number of advanced placement scores submitted by entering freshmen continues to rise: approximately one-third of those registering in September earned credit, averaging two semester subjects apiece. Our policy of granting entrance credit on the basis of strict evaluation of equivalents seems to be accepted and respected. It seems fairer than giving credit on a time-spent basis; and insofar as we can judge, it is far preferable to the possible alternative of raising admissions requirements and then expecting "extra" work after matriculation on the part of those who fail to meet the raised requirements—at least until it seems clear that the higher requirements can be met by programs regularly offered in a clear majority of the good secondary schools.

NON-ACADEMIC FACTORS

There is still much to be learned about the extent to which non-academic factors can be effectively used as selection criteria. There is general agreement that the use of such factors is desirable. But there is little true consensus on what specific criteria should be applied; there is great difficulty in obtaining meaningful evaluation of the students, and there is much uncertainty as to whether the most sought-after characteristics are in fact identifiable and predictable.

We note with great interest the studies being carried on by Dr. Benson R. Snyder and Professor John T. Rule into factors relating to under-achievement and changes in career interest. We are endeavoring to detect relationships between the pre-admission evaluation of our students and a variety of unusual characteristics which have shown up during their stay on campus. Studies with similar objectives are being conducted under a great variety of auspices at many institutions. Until much more becomes known in the future, use of non-academic criteria will continue to be highly subjective and will have little significance beyond the first year or two of college life. Even so, we are confident that we can get a more interesting and versatile freshman class by applying these subjective criteria than by selecting on the basis of academic factors only.

SPECIAL ACTIVITIES

In October, 1962, the Admissions Office held its seventh annual Guidance Conference for a group of ninety-two guidance counselors and administrative officers from schools in thirty-two states. These guests were here for two very full days to exchange ideas on counseling, become familiar with our admissions procedures, and get a full picture of what goes on in the M.I.T. community. We have ample assurance that the guests found the Conference enjoyable and informative. We believe it is an unusually effective device for communicating with key persons in the secondary school field.

In April, M.I.T. cooperated with the U.S. Army Research Office (Durham) and with the International Business Machines Corporation in sponsoring a Junior Science Symposium. A group of 150 selected students and forty-seven science or mathematics teachers from fifty-nine schools in Greater Boston came together for two days of talks, laboratory experiences, and exchange of ideas. Although primary responsibility rested in a Steering Committee representing faculty, administration, the co-sponsoring organizations, and the Massachusetts Department of Education, a student committee made virtually all the arrangements and succeeded in conducting what all agreed was an unusually well-run Symposium.

Through the auspices of Beaver Key (junior honorary society), we are now in a position to offer overnight hospitality to the occasional secondary school student who comes from some distance to visit us while the Institute is in session. As long as arrangements can be made in advance, the Key undertakes to provide an M.I.T. student host for each such visitor, entertaining him for the evening and putting him up for the night in a dormitory or fraternity house. As yet, relatively few visitors have availed themselves of this opportunity. It has, nevertheless, proven very helpful on several occasions and will, we hope, be used more frequently in the future.

OPERATIONS

During the past year there have been three staff changes of note: Robert K. Weatherall transferred from the Admissions Office to become Executive Officer of the Graduate School; M. Bryce Leggett assumed additional duties as Executive Officer of the Committee on Academic Performance, and he will continue as an Associate Director of Admissions; and Paul E. Johnson transferred from the Registrar's Office to become Assistant to the Director of Admissions. We also wish to acknowledge part-time assistance in the Admissions Office by J. Samuel Jones of the Student Aid Center and Peter T. Van Aken of the Office of the Vice-President, Academic Administration.

The following members of the faculty and administration contributed greatly to the effectiveness of admissions operations by devoting one or two weeks of their busy schedules to visiting secondary schools (a total of twenty-five man-weeks, involving visits to 364 schools): Professors John Blair, Jere H. Brophy, Thomas R. Clevenger, James W. Daily, William H. Dennen, James C. Emery, Robert Evans, Jr., Robley D. Evans, S. William Gouse, Edward F. Kurtz, Walter McKay, Sanford A. Miller, John R. Myer, Ernest Rabinowicz, George S. Reichenbach, Edward B. Roberts, Bradbury Seasholes, Thomas B. Sheridan, Arthur C. Smith, and Egons Tons; and George Davies, J. Samuel Jones, and Constantine B. Simonides.

We are also indebted to many of those named above and to most of the members of the Admissions Committee for assistance in reviewing freshman application folders. Dean and Mrs. Frederick G. Fassett, Jr., merit honorable mention for the extraordinary contribution which they made in this respect. In addition, some 31 members of the faculty and administration reviewed a total of more than 1,300 applications.

The participation of the faculty in school visits and in reviewing folders, and the assistance of the 800 alumni members of the Educational Council in interviewing potential students, have value far beyond the lightening of the Admissions Office load. These activities provide extremely helpful insights into faculty and alumni attitudes about the kinds of students they want admitted to M.I.T.

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 30, 1945. For statistics not listed in the following pages, see 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	1962–63	6,695
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
			1962	1,748	1,763

* 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

	1958	1959	1960	1961	1962
Faculty members of the staff:					
Professors	209	230	246	265	281
Associate Professors	171	179	188	209	229
Assistant Professors	211	211	199	213	218
Ex-Officio	16	16	17	17	18
Professors Emeriti (Lecturers)	17	16	19	26	26
Research Associates	1	1	1	1	1
Total faculty	**625**	**653**	**670**	**731**	**773**
Other members of the staff:					
Instructors	136	145	179	166	159
Technical Instructors	12	12	14	13	15
Graduate Assistants	..	..	..	..	169
Teaching Assistants	286	282	326	306	308
Lecturers	51	55	52	61	77
Research Associates	140	163	184	183	190
Research Assistants	647	653	665	696	690
Technical Assistants	52	47	58	62	60
Total of other staff	**1,324**	**1,357**	**1,478**	**1,487**	**1,668**
Total staff	**1,949**	**2,010**	**2,148**	**2,218**	**2,441**
Other members of the faculty:					
Faculty and administrative officers, Emeriti (not Lecturers)	58	58	49	50	53
Total of other faculty	**58**	**58**	**49**	**50**	**53**

Table 3. Classification of Students since 1960

Course	1960–61 2	3	4	G	Total	1961–62 2	3	4	G	Total	1962–63 2	3	4	G	Total	Course Number
School of Architecture and Planning:																
Architecture (IV-A)	25	30	29	37	121	28	25	26	39	118	22	32	27	25	106	IV-A
Fifth year	..	..	30	..	30	..	..	29	..	29	..	..	40	..	40	
City and Regional Planning (IV-B)	..	..	..	40	40	..	..	..	43	43	..	..	..	47	47	IV-B
Total	**25**	**30**	**59**	**77**	**191**	**28**	**25**	**55**	**82**	**190**	**22**	**32**	**67**	**72**	**193**	
School of Engineering:																
Aeronautics and Astronautics (XVI)	44	47	28	190	309	55	33	47	187	322	60	43	34	224	361	XVI
Aeronautics and Astronautics (XVI-B) (Cooperative)	..	7	10	..	17	..	13	8	..	21	..	11	10	..	21	XVI-B
Building Engineering and Construction (XVII)	..	..	..	21	21	..	..	..	21	21	Discontinued					XVII
Chemical Engineering (X, X-A, X-B)	54	62	79	168	363	46	47	67	144	304	36	51	45	159	291	X
Civil Engineering (I)	22	33	35	111	201	12	21	35	123	191	13	11	28	156	208	I
Army Engineer	..	..	..	7	7	..	..	..	7	7	..	..	..	7	7	
Electrical Engineering (VI)	185	125	99	431	840	..	..	..	..	..	..	..	..	..	..	VI
Electrical Engineering (VI-1)	..	..	..	..	..	171	156	155	479	961	164	158	159	480	961	VI-1
Electrical Science and Engineering (VI-2)	..	..	..	..	..	51	30	27	2	110	53	30	22	..	105	VI-2
Electrical Engineering (VI-A) (Cooperative)	..	55	45	20	120	..	48	39	27	114	..	48	58	27	133	VI-A
Electrical Science and Engineering (VI-B)	33	26	19	10	88	..	..	..	..	..	..	..	..	..	..	VI-B
Mechanical Engineering (II)	54	61	79	214	408	49	55	75	213	392	51	54	57	213	375	II
Textile Technology	..	..	..	12	12	..	..	..	9	9	..	..	..	8	8	II-T
Mechanical Engineering (II-B) (Cooperative)	..	8	11	..	19	..	5	8	..	13	..	3	9	..	12	II-B
Metallurgy (III-A)	8	7	30	158	240	10	10	5	156	217	4	10	5	155	211	III
Materials Science (III-B)	11	10	..			10	16	10			4	15	18			
Ceramics	..	..	..	16	16	..	..	..	17	17	..	..	..	23	23	
Naval Architecture and Marine Engineering (XIII)	6	7	10	19	42	5	7	3	22	37	5	8	7	24	44	XIII
Naval Construction and Engineering (XIII-A)	..	..	..	69	69#	..	..	..	60	60#	..	..	..	73	73#	XIII-A
Nuclear Engineering (XXII)	..	..	..	122	122	..	..	..	125	125	..	..	..	117	117	XXII
Sanitary Engineering (XI)	..	..	..	19	19	..	..	..	15	15	Discontinued					XI
Shipping and Shipbuilding Management (XIII-B)	..	..	..	2	2	..	..	..	..	..	..	..	1	2	3	XIII-B
Total	**417**	**448**	**445**	**1,589**	**2,899**	**409**	**441**	**479**	**1,607**	**2,936**	**390**	**442**	**453**	**1,668**	**2,953**	

School of Humanities and Social Science:																			
Economics, Politics, and Engineering (XIV-A)		9	1	10	120	156		5	10	3	127	177		6	13	14	157	221	XIV
Economics, Politics, and Science (XIV-B)		3	9	4				3	20	9				4	8	19			
Humanities and Engineering (XXI-A)		2	3	12	..	17		3	5	4	..	12		1	5	4	..	10	XXI-A
Humanities and Science (XXI-B)		16	36	20	..	72		13	21	34	..	68		10	21	34	..	65	XXI-B
Modern Languages (XXIII)		..	..	..	..	..		..	..	..	10	10		..	..	..	23	23	XXIII
Total		**30**	**49**	**46**	**120**	**245**		**24**	**56**	**50**	**137**	**267**		**21**	**47**	**71**	**180**	**319**	
School of Industrial Management:																			
Industrial Management (XV)		**39**	**55**	**70**	**218**	**382**		**23**	**50**	**72**	**254**	**399**		**32**	**50**	**55**	**284**	**421**	XV
School of Science:																			
Biochemical Engineering (XX-B)		..	1	2	..	3		..	..	..	..	..		Discontinued					XX-B
Chemistry (V)		42	16	29	203	290		39	41	14	206	300		31	31	38	222	322	V
Geology and Geophysics (XII)		8	10	12	58	88		6	14	12	60	92		7	5	16	73	101	XII
Geology and Geophysics (XII-A)		..	..	..	2	2		..	..	..	..	..		..	..	..	..	..	XII-A
¶Life Sciences (VII)		22	28	18	60	128		27	31	31	75	164		26	28	21	91	166	VII
Mathematics (XVIII)		83	68	59	135	345		105	87	66	136	394		116	97	77	150	440	XVIII
Meteorology (XIX)		..	..	..	54	54		..	..	..	46	46		..	..	..	45	45	XIX
*Nutrition and Food Science (XX)		3	3	4	35	45		..	..	..	32	32		..	..	..	58	58	XX
Physics (VIII)		178	112	124	246	660		130	147	107	257	641		149	115	141 .	299	704	VIII
Total		**336**	**238**	**248**	**793**	**1,615**		**307**	**320**	**230**	**812**	**1,669**		**329**	**276**	**293**	**938**	**1,836**	
Undesignated		58	..	..	..	58		85	..	..	..	85		81	..	..	..	81	Undesignated
First year	899	..	..	..	..	899	908	..	..	..	..	908	892	..	..	..	..	892	First year
Grand total	**899**	**905**	**820**	**868†**	**2,797**	**6,289**	**908**	**876**	**892**	**886†**	**2,892**	**6,454**	**892**	**875**	**847**	**939†**	**3,142**	**6,695**	Grand total
					#First graduate year — 18 Second graduate year — 26 Third graduate year — 25						#First graduate year — 16 Second graduate year — 21 Third graduate year — 23						#First graduate year — 37 Second graduate year — 16 Third graduate year — 20		

¶ Prior to 1961–62, Quantitative Biology.
* Prior to 1961–62, Food Technology.
† These totals include the fifth year in Architecture (IV-A).

Table 3-A. Women Students Classified by Schools, Courses, and Years, 1962–63

Course		Year				
		2	3	4	G	Total
School of Architecture and Planning:						
Architecture (IV-A)		..	2	2	..	4
Fifth year		..	..	2	..	2
City and Regional Planning (IV-B)		..	..	..	5	5
Total		..	**2**	**4**	**5**	**11**
School of Engineering:						
Aeronautics and Astronautics (XVI)		1	1	..	1	3
Chemical Engineering (X)		1	3	..	..	4
Civil Engineering (I)		..	..	..	1	1
Electrical Engineering (VI-1)		..	3	..	2	5
Electrical Science and Engineering (VI-2)		..	1	..	..	1
Mechanical Engineering (II)		..	1	1	..	2
Mechanical Engineering (Cooperative) (II-B)		..	..	1	..	1
Materials Science (III-B)		..	..	1	..	1
Total		**2**	**9**	**3**	**4**	**18**
School of Humanities and Social Science:						
Economics, Politics, and Engineering or Science (XIV, XIV-A, XIV-B)		..	..	1	21	22
Humanities and Engineering or Science (XXI-A, XXI-B)		..	1	1	..	2
Modern Languages (XXIII)		..	..	..	2	2
Total		..	**1**	**2**	**23**	**26**
School of Industrial Management:						
Industrial Management (XV)		..	..	..	**2**	**2**
School of Science:						
Chemistry (V)		2	..	3	19	24
Geology and Geophysics (XII)		..	..	..	4	4
Life Sciences (VII)		3	3	3	17	26
Mathematics (XVIII)		8	8	5	11	32
Meteorology (XIX)		..	..	..	2	2
Nutrition and Food Science (XX)		..	..	..	7	7
Physics (VIII)		5	5	3	16	29
Total		**18**	**16**	**14**	**76**	**124**
Undesignated		4	..	..	..	4
First-year students	23	..	..	..	..	23
Grand total	**23**	**24**	**28**	**23**	**110**	**208**

Table 3-B. Special Students Classified by Schools, Courses, and Years, 1962–63[1]

Course		Year				
		2	3	4	G	Total
School of Architecture and Planning:						
Architecture (IV-A)		..	4	5	5	14
Fifth year		..	..	1	..	1
City and Regional Planning (IV-B)		..	..	..	3	3
Total		..	**4**	**6**	**8**	**18**
School of Engineering:						
Aeronautics and Astronautics (XVI)		..	..	..	72	72
Chemical Engineering (X)		..	..	..	8	8
Civil Engineering (I)		1	..	..	13	14
Electrical Engineering (VI-1)		1	2	2	138	143
Electrical Science and Engineering (VI-2)		1	..	..	..	1
Mechanical Engineering (II)		..	1	..	42	43
Metallurgy (III, III-A, III-B)		..	1	..	19	20
Ceramics		..	..	..	4	4
Naval Architecture and Marine Engineering (XIII)		..	..	..	5	7
Nuclear Engineering (XXII)		..	..	..	8	8
Total		**3**	**5**	**3**	**309**	**320**
School of Humanities and Social Science:						
Economics, Politics, and Engineering or Science (XIV, XIV-A, XIV-B)		..	1	2	17	20
Humanities and Engineering (XXI-A)		..	..	1	..	1
Modern Languages (XXIII)		..	..	..	7	7
Total		..	**1**	**3**	**24**	**28**
School of Industrial Management:						
Industrial Management (XV)		**1**	**2**	..	**27**	**30**
School of Science:						
Chemistry (V)		..	..	1	8	9
Geology and Geophysics (XII)		..	1	..	6	7
Life Sciences (VII)		..	..	..	32	32
Mathematics (XVIII)		6	1	4	39	50
Meteorology (XIX)		..	..	..	3	3
Nutrition and Food Science (XX)		..	..	..	4	4
Physics (VIII)		..	2	..	45	47
Total		**6**	**4**	**5**	**137**	**152**
Undesignated		2	..	..	..	2
First-year students	2	..	..	..	..	2
Grand total	**2**	**12**	**16**	**17**	**505**	**552**

[1]Included also in Table 3.

Table 4. Continued, Former, and New Students

	1958–59	1959–60	1960–61	1961–62	1962-63
Continued Students:					
Undergraduate and Graduate Students registered at the end of the last academic year (including Special Students)	4,020	4,047	4,178	4,263	4,499
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)	286	312	285	313	321
Undergraduate Students who enrolled for the first time since secondary school (excluding Special Students)	917	917	883	892	883
Undergraduate Students who enrolled for the first time at the Institute and who transferred from another collegiate institution (excluding Special Students)	142	131	76	80	72
Graduate Students who enrolled for the first time at the Institute (excluding Special Students)	681	657	659	685	721
Special Undergraduate and Graduate Students with no previous Institute registration	213	206	208	221	199
Total	**6,259**	**6,270**	**6,289**	**6,454**	**6,695**

Table 5. Regular Students from Other Colleges and Graduates of M.I.T. Classified by Schools and Courses, 1962–63

	Entered with no previous degree	*Entered with Bachelor's degree from other colleges U*	*Entered with Bachelor's degree from other colleges G*	*Entered Graduate School with Bachelor's degree from M.I.T.*
School of Architecture and Planning:				
Architecture (IV-A)	22	23	18	2
City and Regional Planning (IV-B)	..	..	41	3
Total	**22**	**23**	**59**	**5**
School of Engineering:				
Aeronautics and Astronautics (XVI)	12	..	104	48
Chemical Engineering (X)	16	..	92	59
Civil Engineering (I)	17	..	107	43
Electrical Engineering (VI-1, VI-2, VI-A)	47	1	215	154
Mechanical Engineering (II)	27	..	109	62
Textile Technology	..	..	7	1
Metallurgy (III, III-A, III-B)	3	..	89	47
Ceramics	..	..	18	1
Naval Architecture and Marine Engineering (XIII)	6	1	12	7
Naval Construction and Engineering (XIII-A)	..	..	72	1
Nuclear Engineering (XXII)	..	..	90	19
Shipping and Shipbuilding Management (XIII-B)	..	..	2	..
Total	**128**	**2**	**917**	**442**
School of Humanities and Social Science:				
Economics, Politics and Engineering or Science (XIV, XIV-A, XIV-B)	2	1	128	12
Humanities and Engineering or Science (XXI-A, XXI-B)	2	..	..	..
Modern Languages (XXIII)	..	..	13	3
Total	**4**	**1**	**141**	**15**
School of Industrial Management:				
Industrial Management (XV)	**6**	**3**	**199**	**58**
School of Science:				
Biology (VII)	2	..	49	10
Chemistry (V)	4	..	209	5
Geology and Geophysics (XII, XII-A)	2	..	50	17
Mathematics (XVIII)	14	..	91	20
Meteorology (XIX)	..	..	39	3
Nutrition and Food Science (XX)	..	..	45	9
Physics (VIII)	17	4	168	86
Total	**39**	**4**	**651**	**150**
Undesignated	5	..	..	..
Grand total	**204**	**33**	**1,967**	**670**

Table 6. List of American Colleges and Universities with Number of Graduates Entering the Institute as Regular Students, 1962–63

Agricultural & Mechanical College of Texas	1
Akron, University of	1
Albion College	1
Alfred University	1
Amherst College	4
Antioch College	1
Arizona State University	1
Auburn University	1
Boston College	4
Boston University	3
Bradford Durfee College of Technology	1
Brandeis University	1
Brooklyn College	1
Brown University	7
Bucknell University	1
Buffalo, University of	2
Butler University	1
California Institute of Technology	11
California, University of, at Berkeley	10
California, University of, at Davis	1
California, University of, at Los Angeles	4
Carleton College	1
Carnegie Institute of Technology	2
Case Inst. of Tech.	1
Chicago, University of	2
Cincinnati, Univ. of	2
Citadel, The	1
City College, The	11
Clark University	2
Clarkson Coll. of Tech.	2
Clemson Agricultural Coll.	2
Colgate University	4
College of Wooster	2
Colorado School of Mines	1
Colorado State University	2
Colorado, University of	2
Columbia University	7
Connecticut, University of	1
Cooper Union, The	4
Cornell University	12
Dartmouth College	6
Delaware, University of	4
De Paul University	1
DePauw University	1
Detroit, University of	1
Dillard University	1
Drexel Institute of Tech.	2
Duke University	1
Duquesne University	1
Emory University	1
Evansville College	1
Fairleigh Dickinson Univ.	1
Florida State University	2
General Motors Institute	6
Geneva College	1
Georgetown University	2
Georgia Inst. of Tech.	6
Georgia, University of	3
Grinnell College	1
Harvard University	16
Haverford College	1
Hofstra College	3
Holy Cross, College of	1
Howard University	1
Illinois Institute of Tech.	2
Illinois, University of	10
Indiana University	1
Iowa, State University of	3
Iowa State Univ. of Science & Technology	2
John Carroll University	4
Johns Hopkins University	1
Juniata College	1
Kansas State University	1
Kansas, University of	3
Kent State University	1
Lamar State Coll. of Tech.	1
Lawrence College	1
Lehigh University	3
Louisville, University of	1
Lowell Tech. Institute	1
Macalester College	1
Maine, University of	2
Manhattan College	4
Maryland, University of	1
Massachusetts, Univ. of	3
Miami, Univ. of (Florida)	2
Michigan Coll. of Mining & Technology	2
Michigan State University	3
Michigan, University of	10
Middlebury College	2
Middlesex University	1
Minnesota, University of	7
Mississippi State Univ.	2
Missouri School of Mines & Metallurgy	1
Mount Holyoke College	1
Muhlenberg College	2
Muskingum College	1
Nebraska, University of	2
Newark College of Eng.	2
New Bedford Inst. of Tech.	1
New Hampshire, Univ. of	2
New Mexico State Univ. of Agri., Eng., & Science	1
New York University	5
North Dakota, Univ. of	2
Northeastern University	8
Northwestern University	3
Notre Dame, University of	2
Oberlin College	1
Ohio State University	1
Ohio University	1
Ohio Wesleyan University	1
Oklahoma State Univ.	3
Oklahoma, University of	1
Oregon, University of	2
Pennsylvania State College	1
Pennsylvania State Univ.	5
Pennsylvania, Univ. of	4
Pittsburgh, University of	1
Polytechnic Inst. of Brooklyn	6
Pratt Institute	2
Princeton University	15
Purdue University	10
Queens Coll. (New York)	1
Rensselaer Poly. Inst.	16
Rhode Island School of Design	2
Rhode Island, Univ. of	2
Rice Institute	2
Ripon College	1
Rivier College	1
Rochester, University of	5
Rutgers University	2
Saint John's Univ. (Minn.)	1
Saint Louis University	1
Saint Olaf College	1
San Diego State College	1
San Francisco, Univ. of	1
Simmons College	1
Smith College	1
South, University of The	1
South Dakota Coll. of Agriculture	1
South Dakota School of Mines & Technology	1
Southern California, University of	2
Southern Methodist Univ.	2
Stanford University	10
Stevens Institute of Tech.	3
Swarthmore College	8
Syracuse University	1
Tennessee, University of	3
Texas Tech. College	3
Texas, University of	3
Tufts University	7
Tulane University	1
Tulsa, University of	1
Union College (New York)	1
United States Air Force Academy	6
United States Coast Guard Academy	4
United States Merchant Marine Acad.	1
United States Military Academy	8
United States Naval Academy	27
Utah State University	1
Utah, University of	2
Vanderbilt University	2
Vassar College	1
Virginia Polytechnic Inst.	3
Virginia, University of	2
Washington, University of	3
Wayne University	3
Webb Inst. of Naval Arch.	1
Wesleyan University	2
Wheaton College	1
William & Mary, Coll. of	1
Williams College	6
Wisconsin, University of	3
Worcester Polytechnic Institute	4
Yale University	16

In all, graduates of 175 American colleges and universities and 136 foreign colleges (not listed above) entered the Institute.

Table 7. Geographical Distribution of Students, 1962–63

United States:	
Alabama	18
Alaska	7
Arizona	24
Arkansas	14
California	247
Colorado	47
Connecticut	181
Delaware	17
District of Columbia	39
Florida	159
Georgia	42
Hawaii	11
Idaho	8
Illinois	264
Indiana	86
Iowa	29
Kansas	43
Kentucky	23
Louisiana	28
Maine	35
Maryland	114
Massachusetts	1,703
Michigan	143
Minnesota	58
Mississippi	10
Missouri	51
Montana	18
Nebraska	26
Nevada	1
New Hampshire	33
New Jersey	323
New Mexico	18
New York	942
North Carolina	30
North Dakota	10
Ohio	220
Oklahoma	48
Oregon	28
Pennsylvania	316
Rhode Island	39
South Carolina	25
South Dakota	9
Tennessee	42
Texas	110
Utah	24
Vermont	18
Virginia	99
Washington	65
West Virginia	15
Wisconsin	69
Wyoming	10
U.S. Territories and Dependencies:	
Canal Zone	2
Puerto Rico	8
Virgin Islands	1
Total, United States	**5,950**
Foreign countries:	
Argentina	12
Australia	3
Austria	1
Belgium	11
Brazil	18
Canada	111
Ceylon	1
Chile	4
Colombia	19
Cyprus	3
Denmark	2
Dominican Republic	1
Ecuador	2
Eire	4
England	23
Ethiopia	2
Finland	1
Formosa	24
France	26
Ghana	6
Greece	33
Guatemala	4
Haiti	2
Hong Kong	29
Hungary	1
Iceland	1
India	87
Indonesia	1
Iran	8
Iraq	11
Israel	19
Italy	14
Jamaica	3
Japan	30
Kenya	1
Korea	19
Lebanon	9
Liberia	1
Mexico	21
Morocco	2
Netherlands	5
New Zealand	4
Nigeria	10
Norway	13
Okinawa	1
Pakistan	13
Panama	1
Peru	8
Philippines	13
Poland	1
Portugal	2
Salvador	2
Scotland	2
Sierra Leone	1
Singapore	5
South Africa, Republic of	8
Spain	5
Sweden	7
Switzerland	5
Syria	1
Tanganyika	1
Thailand	8
Trinidad and Tobago	4
Tunisia	1
Turkey	7
Union of Soviet Socialist Republic	1
United Arab Republic	22
Uruguay	4
Venezuela	8
Vietnam	4
Wales	1
West Germany	7
Total, foreign	**745**
Grand total	**6,695**

Table 8. Number of Degrees Awarded in September, 1962, January, 1963,

	S.B.			B.Arch.			S.M.			M.Arch. and M.C.P.		
	Sept.	Jan.	June	Sept.	Jan.	June	Sept.	Jan.	June	Sept.	Jan.	June
School of Architecture and Planning:												
Architecture	..	..	..	1	9	22	..	..	..	22	2	..
City and Regional Planning	..	..	..	..	..	..	..	..	..	1	1	6
Total	..	..	..	**1**	**9**	**22**	..	..	..	**23**	**3**	**6**
School of Engineering:												
Aeronautics and Astronautics	2	5	33	..	..	..	12	4	42	..	..	..
Building Engineering and Con.	..	..	..	..	..	..	..	2	1	..	..	..
Ceramics	..	..	..	..	..	..	1	..	..	..	..	..
Chemical Engineering	3	6	40	..	..	..	9	10	24	..	..	..
Chemical Engineering Practice	..	..	..	..	..	..	..	1	5	..	..	..
Civil Engineering	3	1	20	..	..	..	17	12	20	..	..	..
Electrical Engineering	20	16	183	..	..	..	67	25	63	..	..	..
Materials Engineering	..	..	..	..	..	..	..	..	..	..	..	..
Mechanical Engineering	6	10	50	..	..	..	19	10	26	..	..	..
Metallurgy	1	2	19	..	..	..	11	8	10	..	..	..
Naval Arch. and Marine Eng.	..	..	4	..	..	..	6	3	20	..	..	..
Nuclear Engineering	..	..	..	..	..	..	11	6	10	..	..	..
Sanitary Engineering	..	..	..	..	..	..	1	..	1	..	..	..
Textile Technology	..	..	..	..	..	..	1	..	1	..	..	..
Total	**35**	**40**	**349**	..	..	..	**155**	**81**	**223**	..	..	..
School of Humanities and Social Science:												
Economics and Engineering	..	..	..	..	..	..	..	1	..	..	..	..
Economics, Politics, and Eng.	..	1	9	..	..	..	..	..	..	..	..	..
Economics, Politics, and Science	2	..	13	..	..	..	..	..	..	..	..	..
Humanities and Engineering	1	..	4	..	..	..	..	..	..	..	..	..
Humanities and Science	4	4	29	..	..	..	..	..	..	..	..	..
Industrial Economics	..	..	..	..	..	..	..	..	..	..	..	..
Political Science	..	..	..	..	..	..	..	..	..	..	..	..
Total	**7**	**5**	**55**	..	..	..	..	**1**	..	..	..	..
School of Industrial Management:												
Industrial Management	**2**	**2**	**44**	..	..	..	**24**	**12**	**88**	..	..	..
School of Science:												
Biochemical Engineering	1	..	..	..	..	..	..	1	1	..	..	..
Biology	..	..	..	..	..	..	..	..	1	..	..	..
Biophysics	..	..	..	..	..	..	1	..	..	..	..	..
Chemistry	1	..	35	..	..	..	2	2	1	..	..	..
Earth Sciences	..	2	11	..	..	..	..	..	..	..	..	..
Food Science and Technology	..	..	..	..	..	..	1	3	1	..	..	..
Food Technology	..	..	2	..	..	..	..	..	..	..	..	..
Geology and Geophysics	..	..	..	..	..	..	..	2	3	..	..	..
Life Sciences	3	..	13	..	..	..	..	..	..	..	..	..
Mathematics	2	8	62	..	..	..	1	..	8	..	..	..
Meteorology	..	..	..	..	..	..	6	1	2	..	..	..
Oceanography	..	..	..	..	..	..	1	1	1	..	..	..
Physics	1	4	118	..	..	..	2	4	3	..	..	..
Total	**8**	**14**	**241**	..	..	..	**14**	**14**	**21**	..	..	..
Without Course specification	..	..	..	..	..	..	8	8	11	..	..	..
Grand total	**52**	**61**	**689**	**1**	**9**	**22**	**201**	**116**	**343**	**23**	**3**	**6**

and June, 1963

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:
..	..	..	..	..	..	..	..	..	23	11	22	Architecture
..	..	..	..	..	..	..	..	..	1	1	6	City and Regional Planning
..	..	..	..	..	..	..	..	..	**24**	**12**	**28**	Total
												School of Engineering:
..	..	4	..	1	..	1	2	4	15	12	83	Aeronautics and Astronautics
..	..	..	..	..	..	..	..	..	..	2	1	Building Engineering and Con.
..	..	..	..	..	..	1	..	..	2	..	..	Ceramics
1	1	1	..	..	..	1	6	9	14	23	74	Chemical Engineering
..	..	..	..	..	..	..	..	..	..	1	5	Chemical Engineering Practice
1	3	1	..	1	1	3	3	4	24	20	46	Civil Engineering
1	6	21	6	5	7	10	2	2	104	54	276	Electrical Engineering
..	..	..	..	..	..	1	..	1	1	..	1	Materials Engineering
5	5	8	3	..	1	3	3	6	36	28	91	Mechanical Engineering
..	..	3	1	1	4	4	11	6	17	22	42	Metallurgy
..	..	19	1	..	..	..	..	..	7	3	43	Naval Arch. and Marine Eng.
1	..	..	5	3	3	..	1	..	17	10	13	Nuclear Engineering
1	..	1	..	..	..	1	..	..	3	..	2	Sanitary Engineering
..	..	..	..	..	..	..	..	..	1	..	2	Textile Technology
10	**15**	**58**	**16**	**11**	**16**	**25**	**28**	**32**	**241**	**175**	**678**	Total
												School of Humanities and Social Science:
..	..	..	..	..	..	..	..	..	..	1	..	Economics and Engineering
..	..	..	..	..	..	..	..	..	..	1	9	Economics, Politics, and Eng.
..	..	..	..	..	..	..	..	..	2	..	13	Economics, Politics, and Science
..	..	..	..	..	..	..	..	..	1	..	4	Humanities and Engineering
..	..	..	..	..	..	..	..	..	4	4	29	Humanities and Science
..	..	..	5	2	4	..	..	..	5	2	4	Industrial Economics
..	..	..	..	..	1	..	..	..	..	..	1	Political Science
..	..	..	**5**	**2**	**5**	..	..	..	**12**	**8**	**60**	Total
												School of Industrial Management:
..	..	..	..	..	**2**	..	..	..	**26**	**14**	**134**	Industrial Management
												School of Science:
..	..	..	..	..	..	..	..	..	1	1	1	Biochemical Engineering
..	..	..	1	4	3	..	..	..	1	4	4	Biology
..	..	..	..	..	..	..	..	..	1	..	..	Biophysics
..	..	..	12	16	13	..	..	..	15	18	49	Chemistry
..	..	..	..	..	..	..	..	..	..	2	11	Earth Sciences
..	..	..	1	2	..	..	..	..	2	5	1	Food Science and Technology
..	..	..	..	..	..	..	..	..	..	..	2	Food Technology
..	..	..	5	3	8	..	..	..	5	5	11	Geology and Geophysics
..	..	..	..	..	..	..	..	..	3	..	13	Life Sciences
..	..	..	3	2	9	..	..	1	6	10	80	Mathematics
..	..	..	..	1	1	..	1	..	6	3	3	Meteorology
..	..	..	1	..	..	..	..	..	2	1	1	Oceanography
..	..	..	12	15	18	..	..	..	15	23	139	Physics
..	..	..	**35**	**43**	**52**	..	**1**	**1**	**57**	**72**	**315**	Total
..	..	..	..	..	..	..	..	..	8	8	11	Without Course specification
10	**15**	**58**	**56**	**56**	**75**	**25**	**29**	**33**	**368**	**289**	**1,226**	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 Studies 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:								
Business and Engineering Administration	..	..	..	..	..	142	872	641
Industrial Management	..	..	..	..	..	..	..	..
Total	..	..	..	..	..	**142**	**872**	**641**
School of Science:								
Biology or Natural History (including VII-A)[4]	..	3	11	25	27	49	57	129
Chemistry	2	27	80	154	151	111	141	166
Earth Sciences[5]	..	..	..	..	..	..	..	..
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	..	..	..	..	..	..	..	..
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.
** Prior to 1923 degrees were awarded in Architecture.
† See also Table 11.
‡ 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] Changed to Life Sciences beginning in January, 1962.
[5] Considered Geology and Geophysics until February, 1961.

				Calendar year since 1959 (included in decade total)					
1941–50	*1951–60*	*1961–*	*Grand total*	*1959*	*1960*	*1961*	*1962*	*1963**	
									School of Architecture and Planning:
..	..	..	**865**	..	..	..	..	..	Architecture†
..	..	..	**172**	..	..	..	..	..	Architectural Engineering
..	..	..	**1,037**	..	..	..	..	..	Total
									School of Engineering:
526	340	..	**1,221**	40	..	..	..	..	Aeronautical Engineering
..	55	125	**180**	..	55	44	43	38	Aeronautics and Astronautics
114	131	..	**376**	..	..	..	..	..	Building Engineering and Construction
740	726	184	**3,241**	59	80	73	65	46	Chemical Engineering
95	108	1	**393**	8	6	..	1	..	Chemical Engineering Practice
272	457	90	**3,105**	41	30	37	32	21	Civil Engineering
1,218	1,518	562	**6,241**	178	194	161	202	199	Electrical Engineering (including VI-A)[1]
..	..	..	**301**	..	..	..	..	..	Electrochemical Engineering
230	133	..	**817**	..	..	..	..	..	General Engineering
1,164	1,049	213	**5,471**	103	72	80	73	60	Mechanical Engineering (including II-A)
194	311	64	**621**	38	33	28	15	21	Metallurgy[2]
..	..	..	**5**	..	..	..	..	..	Military Engineering
..	..	..	**880**	..	..	..	..	..	Mining Engineering and Metallurgy
234	139	19	**910**	9	9	12	3	4	Naval Architecture and Marine Engineering
4	..	..	**264**	..	..	..	..	..	Sanitary Engineering
4,791	**4,967**	**1,258**	**24,026**	**476**	**479**	**435**	**434**	**389**	Total
									School of Humanities and Social Science:
61	152	46	**259**	17	17	15	8	23	Economics, Politics, and Engineering or Science
..	49	99	**148**	18	21	25	37	37	Humanities and Engineering or Science[3]
61	**201**	**145**	**407**	**35**	**38**	**40**	**45**	**60**	Total
									School of Industrial Management:[4]
909	732	..	**3,296**	..	..	..	..	..	Business and Engineering Administration
..	172	179	**351**	91	81	64	69	46	Industrial Management
909	**904**	**179**	**3,647**	**91**	**81**	**64**	**69**	**46**	Total
									School of Science:
74	116	16	**507**	10	16	16	..	..	Biology or Natural History (including VII-A)
232	207	78	**1,349**	22	16	29	14	35	Chemistry
..	..	36	**36**	..	..	13	10	13	Earth Sciences[5]
35	62	11	**108**	5	2	5	4	2	Food Technology and Biochemical Engineering
58	62	..	**335**	2	..	..	..	..	General Science or General Course
32	141	..	**248**	16	10	..	..	..	Geology and Geophysics
..	..	40	**40**	..	..	..	27	13	Life Sciences
72	220	199	**558**	34	54	62	67	70	Mathematics
56	38	..	**94**	2	..	..	..	..	Meteorology[6]
306	617	331	**1,548**	92	74	117	92	122	Physics
865	**1,463**	**711**	**4,823**	**183**	**172**	**242**	**214**	**255**	Total
6,626	**7,535**	**2,293**	**33,940**	**785**	**770**	**781**	**762**	**750**	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 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 and Food Science	..	..	..	..	..	..	..	..
Oceanography	..	..	..	..	..	..	..	..
Physics	..	3	2	2	16	40	50	121
Total	**2**	**8**	**12**	**41**	**79**	**185**	**301**	**514**
Without Course specification	..	..	..	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.

¶ Included in Chemical Engineering before 1959.

‡ Considered Engineering until 1950.

§ Considered Engineering until 1956.

1961-	Grand total	1959	1960	1961	1962	1963*	
		Calendar year since 1959 (included in decade total)					
							School of Architecture and Planning: †
..	**84**	..	..	..	..	..	Architecture
..	**19**	..	..	..	..	..	Architectural Engineering
..	**103**	..	..	..	..	..	Total
							School of Engineering:
..	**771**	50	..	..	..	..	Aeronautical Engineering
182	**245**	..	63	83	53	46	Aeronautics and Astronautics
19	**106**	8	6	15	4	..	Building Engineering and Construction
5	**24**	4	2	4	1	..	Ceramics
117	**1,103**	45	40	40	43	34	Chemical Engineering
42	**1,068**	31	23	25	11	6	Chemical Engineering Practice
122	**930**	53	35	40	46	36	Civil Engineering
367	**3,063**	149	125	123	156	88	Electrical Engineering (including VI-A)
..	**28**	..	..	..	..	..	Electrochemical Engineering
..	**26**	..	..	..	..	..	Fuel and Gas Engineering
171	**1,425**	70	65	64	70	37	Mechanical Engineering
83	**449**	19	31	29	36	18	Metallurgy
..	**33**	..	..	..	..	..	Mining Engineering
88	**345**	32	41	34	31	23	Naval Architecture and Marine Engineering
..	**5**	..	..	..	..	..	Naval Construction
..	**478**	..	..	..	..	..	Naval Construction and Engineering
78	**145**	33	34	23	39	16	Nuclear Engineering¶
..	**5**	..	..	..	..	..	Petroleum Engineering
..	**14**	..	..	..	..	..	Railroad Operation
16	**191**	10	7	10	6	..	Sanitary Engineering
1,290	**10,454**	**504**	**472**	**490**	**496**	**304**	Total
							School of Humanities and Social Science:
1	**48**	**1**	**3**	..	..	**1**	Economics and Engineering or Science
							School of Industrial Management: ‡
312	**1,079**	**91**	**94**	**99**	**113**	**100**	Industrial Management
							School of Science:
4	**95**	5	..	2	1	1	Biology and Public Health (including VII-A)
15	**232**	7	5	7	5	3	Chemistry
6	**69**	10	11	4	..	2	Food Technology and Biochemical Engineering
..	**1**	..	..	..	..	..	General Science
19	**126**	5	11	9	5	5	Geology and Geophysics
21	**198**	13	14	9	4	8	Mathematics
24	**276**	8	10	14	7	3	Meteorology§
7	**7**	..	..	..	3	4	Nutrition and Food Science
5	**5**	..	..	1	2	2	Oceanography
31	**265**	12	13	15	9	7	Physics
132	**1,274**	**60**	**64**	**61**	**36**	**35**	Total
54	**1,110**	34	19	20	15	19	Without Course specification
1,789	**14,068**	**690**	**652**	**670**	**660**	**459**	Grand total

Table 11. Number of Degrees Awarded in Architecture and City Planning

	Total by decades						Calendar year since 1959 (included in decade total)				
	1921–30	1931–40	1941–50	1951–60	1961–	Grand total	1959	1960	1961	1962	1963*
Bachelor in Architecture	..	146	126	257	73	**602**	22	26	28	14	31
Bachelor in City Planning†	..	14	13	4	..	**31**	..	..	..	..	..
Master in Architecture	63	81	78	191	53	**466**	19	20	26	25	2
Master in City Planning	..	18	82	114	32	**246**	16	17	16	9	7
Grand total	**63**	**259**	**299**	**566**	**158**	**1,345**	**57**	**63**	**70**	**48**	**40**

* Includes only January and June degrees.

† From 1935 to 1944, Bachelor of Architecture in City Planning.

Table 12. Number of Degrees of Engineer Awarded

	1949–60	*1961*	*Total*	*1961*	*1962*	*1963**
Aeronautical Engineer†	35	18	53	5	9	4
Building Engineer**	5	1	6	..	1	..
Chemical Engineer	17	11	28	7	2	2
Civil Engineer	21	12	33	3	5	4
Electrical Engineer	132	76	208	25	24	27
Marine Mechanical Engineer	7	1	8	1	..	..
Materials Engineer	..	2	2	1	1	..
Mechanical Engineer	102	49	151	22	14	13
Metallurgical Engineer	24	9	33	4	2	3
Meteorologist‡	2	..	2	..	..	..
Naval Architect	11	2	13	..	2	..
Naval Engineer	334	66	400	26	21	19
Nuclear Engineer	..	2	2	1	1	..
Sanitary Engineer	9	3	12	..	2	1
Grand total	**699**	**252**	**951**	**95**	**84**	**73**

* Includes only January and June degrees.
† Engineer in Aeronautics and Astronautics beginning in 1960.
** Degree discontinued after September, 1962.
‡ 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‡	..	..	..	..	..	6	6	**12**
Ceramics	..	..	..	..	..	1	1	**2**
Chemical Engineering	..	..	..	..	..	..	1	**1**
Civil Engineering	..	..	..	..	..	1	3	**4**
Electrical Engineering	..	..	..	..	1	9	30	**40**
Mechanical Engineering	..	..	..	..	..	4	14	**18**
Metallurgy	..	..	..	..	..	5	8	**13**
Naval Architecture and Marine Engineering	..	..	..	..	..	..	2	**2**
Nuclear Engineering	..	..	..	..	..	5	24	**29**
Sanitary Engineering	..	..	..	..	..	2	3	**5**
Total	..	..	..	..	**1**	**33**	**92**	**126**
School of Humanities and Social Science:								
Group Psychology	..	..	..	..	8	1	..	**9**
Industrial Economics*	..	..	..	..	19	99	31	**149**
Political Science	..	..	..	..	..	..	5	**5**
Total	..	..	..	..	**27**	**100**	**36**	**163**
School of Industrial Management:								
Industrial Management	..	..	..	..	..	..	**3**	**3**
School of Science:								
Biology	..	1	10	17	21	38	20	**107**
Chemistry	7	19	59	146	180	342	102	**855**
Geology and Geophysics	1	7	10	22	20	71	28	**159**
Mathematics	..	..	6	25	35	70	44	**180**
Meteorology	..	..	..	..	..	14	4	**18**
Nutrition and Food Science	..	..	..	..	4	28	8	**40**
Oceanography	..	..	..	..	..	..	1	**1**
Physics	..	2	6	48	159	283	87	**585**
Total	**8**	**29**	**91**	**258**	**419**	**846**	**294**	**1,945**
Grand total	**8**	**29**	**91**	**258**	**447**	**979**	**426**	**2,238**

‡ Doctor of Philosophy in Aeronautics and Astronautics beginning in 1960.
* Includes one in 1954 and two in 1956 in Psychology.
† Includes only January and June degrees.

Calendar year since 1959 (included in decade total)					
1959	*1960*	*1961*	*1962*	*1963†*	
					School of Architecture and Planning:
..	..	..	1	..	City and Regional Planning
					School of Engineering:
3	3	2	3	1	Aeronautical Engineering
..	1	1	..	..	Ceramics
..	..	1	..	..	Chemical Engineering
1	..	1	..	2	Civil Engineering
1	7	6	12	12	Electrical Engineering
..	4	5	8	1	Mechanical Engineering
1	3	1	2	5	Metallurgy
..	..	1	1	..	Naval Architecture and Marine Engineering
2	3	7	11	6	Nuclear Engineering
1	..	2	1	..	Sanitary Engineering
9	**21**	**27**	**38**	**27**	Total
					School of Humanities and Social Science:
..	..	..	..	..	Group Psychology
18	16	14	11	6	Industrial Economics*
..	..	2	2	1	Political Science
18	**16**	**16**	**13**	**7**	Total
					School of Industrial Management:
..	..	..	**1**	**2**	Industrial Management
					School of Science:
3	4	4	9	7	Biology
41	44	35	38	29	Chemistry
8	11	10	7	11	Geology and Geophysics
12	2	18	15	11	Mathematics
1	3	1	1	2	Meteorology
1	9	4	2	2	Nutrition and Food Science
..	..	..	1	..	Oceanography
29	22	23	31	33	Physics
95	**95**	**95**	**104**	**95**	Total
122	**132**	**138**	**157**	**131**	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	18	**78**
Ceramics	..	..	7	16	25	7	**55**
Chemical Engineering	..	23	78	114	117	49	**381**
Civil Engineering	..	2	12	23	46	24	**107**
Electrical Engineering	3	12	30	34	141	41	**261**
Electrochemical Engineering	..	1	1	..	..	..	**2**
Materials Engineering	..	..	..	..	..	3	**3**
Mechanical Engineering	..	4	13	35	125	32	**209**
Metallurgy	..	14	25	70	169	47	**325**
Mineral Engineering	1	..	4	..	..	..	**5**
Naval Architecture and Marine Engineering	..	1	..	..	2	1	**4**
Nuclear Engineering	..	..	..	..	9	4	**13**
Petroleum Engineering	..	..	1	..	..	..	**1**
Sanitary Engineering	..	..	2	3	18	1	**24**
Total	**6**	**61**	**178**	**313**	**683**	**227**	**1,468**
School of Science:							
Chemistry	..	2	5	4	3	..	**14**
Geology and Geophysics	1	2	4	5	2	..	**14**
Mathematics	..	2	3	..	1	1	**7**
Meteorology	..	..	6	25	17	1	**49**
Nutrition and Food Science	..	..	..	3	10	..	**13**
Physics	..	5	18	14	7	..	**44**
Total	**1**	**11**	**36**	**51**	**40**	**2**	**141**
Grand total	**7**	**72**	**214**	**364**	**723**	**229**	**1,609**

† Includes only January and June degrees.

* Doctor of Science in Aeronautics and Astronautics beginning in 1960.

	Calendar year since 1959 (included in decade total)				
	1959	*1960*	*1961*	*1962*	*1963†*
School of Engineering:					
Aeronautical Engineering	2	3*	7	5	6
Ceramics	2	3	3	4	..
Chemical Engineering	17	13	18	16	15
Civil Engineering	9	3	8	9	7
Electrical Engineering	15	17	17	20	4
Electrochemical Engineering	..	..	..	..	..
Materials Engineering	..	..	..	2	1
Mechanical Engineering	19	10	7	16	9
Metallurgy	11	10	18	12	17
Mineral Engineering	..	..	..	..	..
Naval Architecture and Marine Engineering	..	1	1	..	..
Nuclear Engineering	7	2	..	3	1
Petroleum Engineering	..	..	..	..	..
Sanitary Engineering	2	..	..	1	..
Total	**84**	**62**	**79**	**88**	**60**
School of Science:					
Chemistry	..	1	..	..	..
Geology and Geophysics	..	..	..	..	..
Mathematics	..	..	..	..	1
Meteorology	..	1	..	..	1
Nutrition and Food Science	1	1	..	..	..
Physics	..	..	..	..	..
Total	**1**	**3**	..	..	**2**
Grand total	**85**	**65**	**79**	**88**	**62**

Table 15. Summary of Degrees Awarded (1868–1963)

Bachelor of Science	33,940
Bachelor in Architecture	602
Bachelor in City Planning (discontinued after 1954)*	31
Master of Science	14,068
Master in Architecture	466
Master in City Planning	246
Master in Public Health (discontinued after 1944)*	104
Advanced Engineering	951
Doctor of Philosophy	2,238
Doctor of Science	1,609
Doctor of Public Health (discontinued after 1944)*	9
Doctor of Engineering (discontinued after 1918)*	4
Grand total	**54,268**

ROBERT E. HEWES

* See the 1959 Report of the Registrar for details.

Foreign Student Office

When an inquiry is received from an American prospective student, we assume that he has considerable knowledge about M.I.T. and its courses, and we therefore send him a set of application material which he will complete and return to us. This degree of sophistication is not to be expected of a foreign student, and therefore his inquiry is handled in a somewhat different way. Instead of sending an application form directly, a set of information material is first sent to him so that he may decide upon a sounder basis whether he in fact wishes to apply for admission to M.I.T. In addition to this, he receives a preliminary application which he can fill out very quickly and which gives us an idea as to whether or not he is eligible for admission to M.I.T. and should continue with the rather complicated application procedure. In 1963 we received from abroad 5,440 inquiries from young men and women who thought they wished to apply to M.I.T. After we had sent them information material and received from many of them preliminary applications, we then sent out final applications to 1,667. The difference of 3,773 represents a further decision on the part of the applicant that he should not apply to M.I.T. and in many cases a judgment by M.I.T. that on the basis of a preliminary application the applicant would not survive the severe competition.

The trend in these figures over recent years is shown below:

	September, 1960	*September, 1961*	*September, 1962*	*September, 1963*
Inquiries received	4113	4716	5274	5440
Applications sent	1645	2214	1713	1667

Foreign student enrollment at M.I.T. from 1959 to 1963 is shown in this table:

	1959-60	*1960-61*	*1961-62*	*1962-63*
Undergraduate	274	220	228	205
Graduate	516	560	565	609
Total	790	780	793	814

The decrease in the number of undergraduates is due, in part, to increased competition from American applicants because of their relatively better preparation in the last decade. The increase in graduate students reflects, in part, the growth of the M.I.T. Graduate

School with its added opportunities for financial assistance.

The annual census of the Institute of International Education for 1962-63 reports a total of more than 64,000 foreign students enrolled in institutions of higher learning in the United States. Forty per cent of these foreign students were concentrated in the thirty-two institutions that reported an enrollment of more than 400 foreign students. The highest enrollment is at the University of California with 3,108 foreign students; M.I.T. is fourteenth in the number of foreign students enrolled. Most of these thirty-two institutions have rather large total enrollments, so that in most cases the foreign student population is about 5 per cent of the total enrollment. Howard University enrolls 942 foreign students, 16.7 per cent of its total enrollment. M.I.T.'s 814 foreign students constitute 12.6 per cent of our total enrollment. The next highest percentage is that of Harvard University, with 1,020 students and 8.7 per cent.

Of increasing importance for many American universities is the large number of foreign faculty and scholars on their campuses. For the last academic year nearly 6,000 foreign scholars and faculty members from ninety countries were reported on academic assignments in the United States, an increase of 5 per cent over the previous year. These scholars were affiliated with 384 American universities. The largest number of such foreign staff, 509, was reported by the University of California, and the second largest number, 317, was reported by M.I.T. These foreign visitors at M.I.T. are listed with the Registry of Guests under the direction of Mrs. Carolyn Cox.

Aside from the necessary registration and legal procedures which are prime functions of the Foreign Student Office, two of the activities which most concern us are housing for foreign students and efforts to make each student acquainted with the American community away from his campus. The Technology Matrons have been organized to provide "home hospitality" for many years; for this academic year, home hospitality is the responsibility of a Student Services Committee under the co-chairmanship of Mrs. Gordon S. Brown and Mrs. J. Francis Reintjes.

One of the most significant developments in recent years in this area is the M.I.T. Host Family Program. This program is now organized and carried on by the Foreign Student Office, but it owes its initiation and organization to the enthusiasm and competence of Mrs. Norman Padelford, Chairman, and Mrs. Glenn Eichenseer, Vice-Chairman.

The Host Family Program is an activity primarily based on participation by the M.I.T. alumni of Greater Boston. Members of the original group argued that there would be a natural bond of interest between a graduate of the Institute and a newly-arrived student. This turned out to be true, and, as an added dividend, it was found that in helping the student to orient to the Institute, the alumnus was also discovering new things about his own *alma mater*.

The prime objective of the Host Family Program is to establish a close relationship between a single foreign student and a host family. The program secures from the Foreign Student Office the names of the newly admitted foreign students, and a hostess writes each student during the summer before he leaves home, inviting him to spend a few days with the host family on his arrival in the United States. The family thus helps the student get acquainted with the Boston area, and develops a close relationship which may last through the student's entire stay at M.I.T.

In the year 1962-63, 123 students were invited by host families to take part in this program. The number of host families concerned was ninety-five, because some of the students wrote that they were not in fact coming to M.I.T. as they originally planned, and in these cases a host family wrote a second student. Not all students felt that they needed this program, and a few declined; but eighty-five students made visits with their host families for the first semester, and for the second semester eighteen students were placed. On the whole this worked very well. Most of the families kept their young people for two or three days at the beginning of the year and were a great help to them in finding their housing, in shopping for home furnishings, and in other ways making the new arrival welcome. The host and student reactions were nearly all favorable, ranging from friendly to ecstatic. Mrs. Padelford is expanding this program for its second year. A number of the host families are continuing with their same student for another year, and a new group of hostesses has been approached and has invited an increased number of students. The program has gone so well, and it fills a great need so admirably that it will no doubt continue to have the strong support of the Foreign Student Office and the Alumni Association.

The second most pressing problem for most of our foreign students is that of housing. Off-campus housing for all of our students at M.I.T. is not of very good quality, and some of our students are necessarily forced into living quarters that are poor, some of them sub-standard. M.I.T. will not have on-campus accommodations for all of its students in the foreseeable future, but it can alleviate the difficulties somewhat by helping our students to find the best quarters available and to pay no more than necessary for them. All M.I.T. students are served in this respect by the Housing Office, under Dean Frederick G. Fassett, Jr. Joining his staff this year is Mrs. Francis Bitter, whose particular charge will be helping newly arrived foreign families to find suitable housing. Mrs. Bitter brings to this appointment many years of experience as a volunteer, and we welcome her excellent assistance.

A new activity, and one which gives great promise for the future, is the Boston Area International Student Seminar. Many agencies have organized orientation programs to help new foreign students adjust to their American university experience. The principal areas of instruction are in the English language, in the salient features of American education, and in the most important aspects of American life. These programs have historically been offered by the State Department to their grantees or by individual universities for their own students. One of the new features of the B.A.I.S.S. is that, probably for the first time in this country, such an orientation program is organized and run by several universities of a region. Cooperating in this venture are Boston College, Boston University, Brandeis University, Harvard University, and M.I.T. The Ford Foundation has generously subsidized the plan for three years. It is hoped that participation by several institutions will strengthen the program and that innovations can be attempted on the basis of the generous financial support of the Ford Foundation.

Of the 814 foreign students now at M.I.T., nineteen are women. This means that in an average year six or seven women students arrive from abroad. They are met and assisted by the M.I.T. Women's Association Foreign Student Committee under the able chairmanship of Mrs. Margaret Freeman of the M.I.T. staff.

Several student groups have contributed to the international program in an organized way. Members of the United Christian Fellowship have acted as welcoming guides to new students and as chauffeurs for room-hunting. The International Students' Council (Atif S. Debs '64, Chairman) is active in a number of ways in the field of student relations, its chief activity being the organization of the program for International Week. The Graduate Student Council has a welcoming committee (Gerald Grams, Chairman) responsible for two programs, writing a welcoming letter to each newly admitted foreign student and sponsoring a get-acquainted dinner at the M.I.T. Faculty Club for all new foreign graduate students. The M.I.T. Dames' Service

Committee (Mrs. Thelma Lyons and Mrs. Carol Taylor, Co-Chairmen) works closely with foreign students' wives. The latest activity is classes in English conversation for foreign students' wives.

M.I.T. has contributed to the support of the International Student Association of Greater Boston and the Boston Council for International Visitors.

Eugene R. Chamberlain, Peter D. Leavitt, and Richard L. McDowell, besides being on the staff of the Admissions Office, serve part-time as Associate Advisers to Foreign Students.

PAUL M. CHALMERS

Educational Council

This report covers the twelfth year of operation for the Educational Council. Membership has continued to grow and now stands at 816—with 778 in the United States and 38 in foreign countries. The Council is active in a total of 187 areas in the United States, of which 160 are fully organized and working directly or indirectly with 2,111 schools. Alumni Regional Scholarship Committees are operating in conjunction with Council groups in 19 areas. No statistics, however, can present the interest, enthusiasm, and dedication of the alumni who serve on the Council, and it is the collective efforts of this group which make this report possible.

During the past year, members of the Council represented M.I.T. at eight convocations, inaugurations, and other occasions at educational institutions throughout the country.

As in previous years, Council members have given invaluable assistance to the Admissions and Student Aid Offices—about 75 per cent of the freshman class had interviews with members of the Council. In addition, members of the Council represented M.I.T. at 141 college night programs and accompanied school visitors from the Institute on 276 visits to local secondary schools.

In September, 1962, 115 Council members returned to Cambridge for the fourth annual Alumni Officers Conference. This Conference plays an important role in keeping the Council members up to date, and the high attendance was reassuring. Since returning to the Council office in September, the Director has had an opportunity to meet with members in 31 areas. These meetings have been most helpful in bringing about further reorganization in the school assignment program designed to keep this effort up to date. The meetings also have served to develop a better understanding of the total Council effort and have provided first-hand knowledge and opportunities to improve our general effectiveness.

Close cooperation and coordination between the Council organization and alumni clubs have proved to be very successful. In many areas, club and Council have jointly sponsored such events as receptions for entering freshmen, Christmas parties to include students, and other activities which make for closer ties between the alumni and students at M.I.T. Strong encouragement has been given to these activities as well as to the practice of inviting local guidance counselors to specially arranged club meetings.

A continuing challenge is that of keeping Council members' impressions of M.I.T. current. It is apparent that this challenge must be met effectively if the Council members are to maintain their broad responsibilities as representatives of the Institute in their communities. An increasing amount of time and effort has been given to this matter, with the hope that we can be of greater assistance to the members of the Council in keeping them well informed.

D. HUGH DARDEN

Medical Department

The past year was again a very busy one for the Medical Department, with a 16 per cent increase in the utilization of our services. During 1960-61 there were 30,378 clinic visits; in 1961-62 there were 34,771 visits, while last year the figure rose to 40,115. As was the case the previous year, the increase occurred in all categories of patients—students, faculty, staff, and employees. The increase in patient load has occurred without a significant increase in the Institute population or a major epidemic. Last year we began to offer medical care to the wives of students, but their visits accounted for only 14 per cent of the increase in patient load. The facilities now available are barely adequate to meet the present demand for medical care. Additional space must be found to enable us to cope with the increasing utilization of our services and the 50 per cent increase in Institute population which is expected to occur during the next ten years.

Two important additions have been made in our program during the year. As already has been mentioned, we began to offer medical care to the wives of students. The care is financed by an optional extension of student health insurance (elected by 442 students) or on a fee-for-service basis. This opportunity for medical care seems to have been welcome, as 278 student wives made a total of 728 visits to the Department. A second important innovation was the addition of a consultant in social work to our professional staff. This was an exploratory program and we were fortunate to have had Miss Jeane I. Murphy, Professor of Social Work at Boston University, undertake the assignment, giving us a day a week of her time. Our experience during the past year has demonstrated that there is a very real need for social work in the M.I.T. community. Professor Murphy has consented to take a leave of absence from Boston University next year and devote her full time to the Medical Department.

PERSONNEL

During the year the Department was served by seven full-time physicians and fifty-one part-time physicians.

The psychiatric service was greatly strengthened by the appointment of Dr. Joseph H. Brenner as a full-time psychiatrist. Dr. Brenner studied at the University of Liverpool, practiced internal medicine for several years, and received his training in psychiatry at the Massachusetts General Hospital and at the McLean Hospital.

Dr. Samuel W. Stein, a graduate of Yale College and Harvard Medical School who had been associated with us on a part-time basis, joined our full-time staff. Dr. Stein is a specialist in internal medicine with an excellent background in the subspecialty of cardiology. He has been placed in charge of our electrocardiographic unit.

Our business manager, Mr. Alan W. Burke, retired at the end of the year; he has made significant contributions to the operation of the Department. Mr. Leo D. Caplice who has had many years of experience in accounting and subsequently in personnel work, will succeed Mr. Burke.

MEDICAL CLINIC

The Medical Department has completed its first full year of coding all diagnoses and recording these diagnoses on cards, using the "International Classification of Diseases" published by the Department of Health, Education, and Welfare. This means that we should have in our files, in proper order, every single diagnosis of each patient who came to the Department. While this desideratum may not have been fulfilled completely, we feel that we are very close to it.

Where three years ago we had only one physician at a time covering the Medical Clinic with a total of 32 available appointments per day, we now have two doctors much of the time making it possible for 50 patients to see an internist between the hours of 8:30 a.m.

and 5:00 p.m. This does not include special appointments that are made with the internists. We anticipate a further increase in coverage for the clinic next year.

We now have two full-time nurses on the first floor—one who sees mostly medical patients and the other who works primarily with the surgeons. This year we have added the services of a third nurse for five hours a day who helps both of the full-time nurses.

The M.I.T. obstetrical clinic at the Boston Lying-In Hospital run in conjunction with a similar group at Harvard continued to attract many young mothers-to-be. The cost was increased slightly last fall from $250 to $260, but this has had no effect on the clinic's enrollment. Last year there were forty-six deliveries and a total of 123 different patients seen. Some of these were prenatal visits only, while others came for both prenatal visits and deliveries.

The Sabin oral polio vaccine was offered to all students, faculty, staff, and employees of the Institute in January, March, and May. Approximately 9,000 persons availed themselves of this opportunity. It is planned to have a clean-up drive in the fall to complete the series for those persons who missed one or two of the three doses this spring.

There was no change in the professional staff of the dermatology and neurology clinics. Both clinics had a significant increase in patient visits.

SURGICAL CLINIC

There was an 8 per cent increase in visits to the general surgical clinic, while visits to the orthopedic and ear, nose, and throat clinics increased by 21 and 10 per cent, respectively, during the year. Four hundred and thirty-seven minor operations were performed, an increase of 17 per cent over the previous year. There were nineteen major operations as compared with ten the year before.

We were fortunate in having very few serious occupational injuries during the year. A partial amputation of a finger and atrophy of the intrinsic muscles of the hand following injury to the ulnar nerve at the elbow were the most serious injuries among our employees.

ATHLETIC INJURIES

Dr. Thomas Boyd has continued to serve as surgeon for the athletic program. There were 233 athletic injuries, an increase of 35 per cent over the previous year; among these were fifteen fractures. As usual, "touch" football was responsible for by far the largest number of injuries. The most serious injury was a rupture of the spleen occurring in a student with infectious mononucleosis who bumped against the side of the rink while engaged in casual skating.

DENTAL CLINIC

There were 5,590 visits to the dental clinic last year, an increase of 9 per cent over the previous year. We have continued the policy of offering dental hygiene and diagnostic service without dental therapy except in emergencies.

HEALTH SURVEY OF NEW STUDENTS

We have continued the practice of the preceding two years in requiring entering students to have a physical examination done before arrival at the Institute. After arrival, all new undergraduates and foreign students are required to have a medical interview, a dental survey, an intradermal tuberculin test, and a photofluorogram; American graduate students are allowed to waive the medical interview and the dental survey. This year we coded all of the unusual conditions appearing on the physical examination forms sent in prior to matriculation. We have made a special effort to interview students with serious conditions, such as diabetes or epilepsy, within a short time after they have registered.

FACULTY HEALTH SURVEY

The Faculty Health Survey is a voluntary program offered to all faculty members and to members of the administrative staff of equivalent rank. The survey consists of a medical interview, a complete physical examination, a chest X-ray, an electrocardiogram, simple pulmonary function tests, and routine laboratory studies of blood and urine. Further diagnostic studies are done if necessary. Those over 40 are advised to have yearly examinations, while the younger group is asked to come every second year unless there is a health problem that should be evaluated more frequently. This year we performed 498 examinations under this program, compared with 429 and 379 in 1961-62 and 1960-61, respectively.

It is evident that the program is popular, and we feel that it is making an important contribution to the health of the Institute faculty and administration.

STAFF AND EMPLOYEE HEALTH PROGRAM

A total of 2,349 physical examinations were performed for members of the staff and employees, representing a slight increase over the previous year; of these, by far the largest number were pre-employment examinations. Others received examinations in connection with retirement, as operators of moving equipment, as individuals with potentially hazardous occupational exposures or because examinations were required for application for fellowships or jobs.

Thirty-two (1.8 per cent) of the applicants for employment were found to have health problems sufficiently serious that their employment required special consideration. Suitable positions were found for seven of these people.

In addition to the problems which were judged to be potentially disqualifying because of the nature or severity of disease in relation to the job being considered, many other abnormalities were found. These ranged from epilepsy (well controlled) to ulcerative colitis in remission. The most common abnormality was anemia occurring in young women.

For the second year the opportunity for a health survey was offered to all employees aged 60 and 63. The first year only twenty of the approximately 100 employees eligible accepted the invitation, but last year, with about the same number eligible, thirty-two came for examination. We hope that the number participating will increase still further.

Seventy-four employees between the ages of 65 and 70 were examined as part of the retirement program. Fortunately, it was not necessary to recommend retirement on medical grounds for anyone who wished to continue working.

We hope eventually to offer health survey examinations to employees at age 45, 50, and 55, in addition to the present program of examinations at 60, 63, 65, and yearly thereafter until retirement. This will provide an extremely valuable longitudinal record of the employee's health and, we believe, will permit the detection of some diseases at an early stage.

The program for the periodic examination of employees engaged in operations where loss of control might be hazardous to others as well as to themselves was continued, and twenty-eight such employees were examined this year. Fortunately, only one individual was found to have a disqualifying health problem. This person was referred for treatment, and his condition is now greatly improved.

We have been concerned about a segment of the Institute community which has no contact with the Medical Department at the time of their employment. These people have various titles but function as research associates. They may have potentially hazardous exposures, and we have had occasion to see quite a few of them at the time of an acute illness when the record of a previous medical examination would have been most helpful. In an effort to close this gap in our health records, we have invited members of this group to have a physical examination when they have reported for the legally required triennial chest X-ray. Twenty-eight of this group were examined during the year.

Massachusetts law requires that teachers and employees of an educational institution have a tuberculin test or/and chest X-ray every three years to rule out active tuberculosis. We have urged every member of the Institute over the age of 40 to have a chest X-ray in connection with this program, even if their tuberculin test is negative, as we feel that this is an important survey program for chest disease. During the year 1962-63, 2,293 chest X-rays were taken in connection with this program. The great value of this program is shown by the fact that three cases of active tuberculosis and two cases of lung tumor were discovered during the year.

PSYCHIATRIC SERVICE

One hundred and eighty five more patients were seen this year than last, in the Psychiatric Service. This represents a 34.5 per cent increase in the case load and a 18.8 per cent increase in the total number of visits. The senior class showed the largest change in the past year, increasing from 5.6 per cent in 1962 to 12.6 per cent in 1963.

The median number of interviews for undergraduate students increased from 2.1 in 1962 to 4.47 in 1963. This reflects a decision by the Psychiatric Service to refer to outside mental health facilities only those students who require extended psychiatric treatment and thus permit greater opportunity for brief therapeutic consultation with students with a wide range of late adolescent difficulties. This does not reflect an increase in the emotional anguish of the M.I.T. undergraduate.

One hundred and twenty-six patients were referred for further psychiatric treatment; fifty were referred to a clinic and seventy-six were referred for private psychiatric treatment. Seven patients were hospitalized for major psychiatric illness during the year; two of these patients were able to return to M.I.T. within a month. The vast majority of students who received intensive psychiatric treatment outside of M.I.T., as well as those seen in consultation by the Service, were able to carry a full academic work load.

Dr. Benson R. Snyder, chief of the psychiatric service, has devoted about one-third of his time to the Student Adaptation Study. He has prepared the following report on the current status of this important research project.

"The pilot phase of the Student Adaptation Study began in January, 1962, with a modest grant from M.I.T. Last September, the Grant Foundation gave three and a half years' support for expansion and continuation of this research. Fundamentally, the project is concerned with studying the dynamics of the interaction between the individual and an educational institution. The hypotheses underlying the project are: (1) that there is a describable range of adaptive and coping patterns characteristic of the undergraduates at this or any institution; (2) that the institution intentionally and unintentionally sets up a variety of cognitive, social, and emotional tasks which the student must master as a central part of his educational experience; and (3) that there is a specific relationship between the individual's characteristic and unique ego adaptive patterns and his ability to master (or cope with) the institutionally defined cognitive, social, and emotional tasks. (This assumes that I.Q., as such, in an elite population does not account solely for academic or scientific excellence.) Certain of these tasks carry with them an implied premium for specific adaptive responses and a penalty for others. Some courses require, for example, the ability to tolerate ambiguity while others require the ability to minutely schedule and organize one's life in order to cover a large amount of relatively routine work.

"The project has four parts. The first is the student movement study. This empirical approach is directed at answering questions about the students and their movement through the educational environment. Which courses serve as a reservoir for students who then move into science, engineering, the behavioral sciences, etc? Which courses have high transfer rates? At what point in time do the largest number of transfers occur? A computer program has been developed which permits the plotting of the routes available to students as they move through four years at the Institute. Combining a number of demographic, sociological, and psychological variables on all of the students in the Class of 1965 with these data from the student movement study will enable us to determine which of these variables characterize groups of students.

"The second part of the project involves psychological testing. This was developed in order to clarify how the M.I.T. population compared with other college student populations and to provide reasonable significant psychological variables for use in the student movement study. It was also necessary to have psychological data in checking the comparability of an interview sample with the total class from which the sample was drawn.

"The Omnibus Personality Inventory, developed by the Center for the Study of Higher Education of the University of California, was given to the entire Class of 1965 in the first week of their freshman year. This procedure has also been repeated on the Class of 1966. The distribution of scale scores on the O.P.I. by course shows a persistent and dramatic difference between engineers and scientists in a number of the mean scale scores. The feasibility of drawing psychological inferences from O.P.I. data is currently being explored. Should this prove to be possible with some assurance, the usefulness of this instrument for the study will have been materially increased.

"The core of the project is the interview study. These semi-structured interviews are intended to provide us with the level and quality of information that will permit reliable inferences about the adaptive patterns and ego functions of the students. A random, stratified sample of sixty sophomores has been selected. These students have had two one-hour taped interviews which have been transcribed. We are currently engaged in a content analysis and coding of these interviews on sociological, demographic, and psychological variables. These interviews are used to develop a psychological description of each of the students and to define the leading themes that characterize the M.I.T. undergraduate. Some of the themes that have emerged are loneliness; reaction to the first experience of failure in an academic setting; the impact on the student of the institution's time demands, for many a major psychological task; the separation from home; the complexity and ambiguity of some science or humanities courses, as a threat for certain students who are uncomfortable without closure; etc. The interview material gives a richness of detail and nuance which obviously would be impossible to expect from the other parts of the project.

"The fourth phase of the project involves some assessment of the faculty's definition of the curricular and extracurricular tasks that they consider crucial for the student's education. This part of the project is the most exploratory and open-ended and will not really get under way before next year.

The overall purpose of this research is to assist in the development of a dynamic understanding of some of the processes involved in educating scientists and engineers."

LINCOLN LABORATORY

The clinic for the care of minor injuries and illnesses at the Lincoln Laboratory has continued to have the part-time services of Dr. Gordon

D. Winchell and Dr. Charles S. Keevil, Jr. There were 9,200 visits to this clinic during the year as compared to 9,931 the previous year. Pre-employment examinations, clinical consultations, and laboratory studies for Lincoln Laboratory people are done by the Medical Department in Cambridge. Major medical and surgical emergencies occurring at Lincoln are brought to the Emerson Hospital in Concord.

INFIRMARY

The infirmary, which contains 23 beds, is kept open from the middle of September until the middle of June. Because of the small number of beds we have continued the policy of limiting admissions to students whenever the infirmary is more than one-half filled. Major surgical procedures are performed in one of the neighboring general hospitals and the students are returned to the infirmary for convalescence. In addition to serving as a unit for bed care, the infirmary is used for emergency medical and surgical coverage during evenings and week ends, when the ambulatory clinics of the Medical Department are closed. This year there were 715 infirmary admissions and 2,393 emergency clinic visits, compared with 690 and 1,962 in 1961-62 and 600 and 1,868 in 1960-61.

In keeping with the nature of the majority of illnesses among young people, the mean duration of stay in the infirmary is short—3.5 days in 1962-63.

LABORATORY SERVICES

The number of clinical laboratory tests performed increased by 20 per cent last year to a total of 19,624 tests. This rise is in keeping with the striking increase in patient visits.

New electrocardiographic facilities were provided last year, increasing the efficiency of this essential service. Nine hundred and one electrocardiograms were taken, an increase of 16 per cent over the previous year.

The activity of the X-ray department increased 23 per cent. A total of 7,776 X-rays were taken during the year, the majority being chest X-rays. In order to cope with this load it has been necessary to employ an additional X-ray technician. Our X-ray equipment is old and will have to be replaced in the near future. We have only one machine and this broke down frequently during the year causing great inconvenience.

OCCUPATIONAL MEDICAL SERVICE

During the past year there has been a striking increase in the demands on the Occupational Medical Service both for routine services and special projects.

The use of the central radioisotope laboratory and storage facility is steadily increasing. This facility is part of the Radiation Protection Service, and, in addition to its use for research with radioactive material by various departments, it provides an appropriate area for such activities as decontamination of equipment, radioactive source preparation, and training exercises in safe-handling procedures.

The Cambridge Electron Accelerator is now in operation and is used by many M.I.T. people. While the safety monitoring of this operation is the responsibility of Harvard University, our radiation protection group meet periodically with their Harvard colleagues to review safety problems at this facility.

The M.I.T. Reactor requires constant surveillance by members of our Radiation Protection Office. At present the Reactor is approved for operation up to 2 megawatts, but plans are being made to increase the power to 5 megawatts.

In addition to the monitoring of toxic hazards and surveillance of exhaust ventilation, the Industrial Hygiene Service devotes a great deal of time to the design of ventilation systems. Arrangements were developed during the year to ensure that the ventilation plans for all new construction and remodeling be submitted to the Industrial Hygiene Service for approval.

Because of our great need for exhaust systems in air-conditioned facilities and the consequent problems of air supply, Frederick J. Viles, Jr., and Richard I. Chamberlin have invented a new type of exhaust hood which they have shown to be superior to conventional hoods. These hoods will be widely used in our new buildings.

Dr. Harriet L. Hardy and her colleagues are anxious to contribute to the M.I.T. teaching program. Staff members have continued to give lectures in various departments, and an undergraduate seminar was given during both semesters. The Occupational Medical Service would like to be given more opportunities for teaching both at the graduate and undergraduate levels.

SANITATION

The Institute food handling services and the swimming pool are inspected regularly by Fred E. Smith, our consulting sanitary engineer. Bacteriological monitoring of cream and milk, food handling equipment, and the swimming pool is performed on a regular schedule. Our sanitary record continues to be very good because of the excellent cooperation of the many employees involved.

STUDENT HEALTH INSURANCE

Except for an increase in benefits to keep up with the rising cost of medical care, the Student Health Insurance Program has not been changed during the past two years as it seems to be meeting the requirements of our students satisfactorily. We review the program critically each year and are prepared to make changes as they seem desirable. Unlike most health insurance programs, which only provide benefits when the patient is hospitalized, our program provides for ambulatory diagnostic and therapeutic service as well as hospital care.

The Student Health Insurance is voluntary, and unfortunately only about two-thirds of our students enroll each year. While some of the others have insurance programs, many gamble on their health and have no insurance coverage. As might be expected, each year a number of the uninsured students encounter major medical expenses and jeopardize their academic future. The Medical Department hopes that eventually enrollment in Student Health Insurance will be made compulsory.

D.S.R. HEALTH SURVEY

Last year 110 senior members of the Division of Sponsored Research were invited to participate in a health survey program similar to the Faculty Health Survey. Fifty-three individuals accepted the invitation and were examined during the year. We assume that the number participating in the survey will increase in future years.

ALBERT O. SEELER

Placement Bureau

STUDENT PLACEMENT

In preceding years' reports such as this, it has been pointed out that the role of the Placement Bureau has changed from that of employment office to that of career counselor.

Our statistics for the year show increased activity once again. A total of 490 companies, government agencies, and graduate schools made reservations to interview through the Placement Bureau. These organizations interviewed 1,522 students in a total of 7,299 interviews. Of the 1,522 students who took their interviews through the Placement Bureau, 277 were underclassmen, 530 were candidates for the S.B., 428 for the S.M., 21 for the professional Engineer degrees, and 266 for the doctorate. The trend to graduate study by Bachelor's degree recipients continues, with 60 per cent of the June, 1963, class continuing their study immediately on a full-time basis.

We have now accounted for 94 per cent of the June, 1963, class. The following table shows the dispersion:

Placement by Fields

	Doctor's		*Professional*		*Master's*		*Bachelor's*		*Total*	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
Academic research										
M.I.T.	16	15.2	3	5.3	15	4.7	20	3.2	54	4.9
Other	7	6.7	0	0.0	1	.3	3	.5	11	1.0
Teaching										
M.I.T.	13	12.4	0	0.0	2	.7	4	.6	19	1.7
Other	22	20.9	1	1.8	6	1.9	13	2.1	42	3.8
Further study										
M.I.T.	1	.9	14	24.5	79	24.5	145	23.2	239	21.6
Other	2	1.9	1	1.8	23	7.2	233	37.2	259	23.4
Industry	36	34.3	11	19.3	122	38.3	160	25.4	329	29.7
Government	3	2.8	1	1.8	9	2.8	8	1.2	21	1.9
Foreign	1	.9	8	14.0	27	8.5	12	1.9	48	4.3
Armed service	4	3.8	18	31.6	33	10.4	25	4.0	80	7.2
Miscellaneous	0	0.0	0	0.0	1	.3	3	.5	4	.4
Total placed	**105**	**100.0**	**57**	**100.0**	**318**	**100.0**	**626**	**100.0**	**1106**	**100.0**
Unknown	5		0		8		56		69	
Total	**110**		**57**		**326**		**682**		**1175**	

The Placement Bureau continues to grow in its importance to the student regardless of the degree he seeks. It can be said modestly that an M.I.T. student has at his command one of the largest collections of graduate study information available anywhere. It is to be hoped that in our new quarters for 1963-64 we will continue to provide a continually improving service to employers, graduate schools, students, and alumni.

ALUMNI PLACEMENT

It has also been a busy and interesting year in alumni placement. The number of companies in touch with us for men has continued to grow. Counting as conservatively as we know how, we have listed

11,417 jobs, an increase of more than 28 per cent over 1961-62. Apparently the only thing which will slow down the influx of positions is our inability to handle any more work.

We continue to place between 21 and 22 per cent of the men who register with us. We know that at least seventy-four of those placed moved from one state to another and that we placed people in thirty-one states and in Canada, England, and Bermuda. Almost exactly half of the men placed had Master's degrees, and over 13 per cent had the Ph.D. or Engineer degree.

For the first time, M.I.T. was our best customer this year. We placed twelve men, six of them in various operations of the Division of Sponsored Research and six in M.I.T. offices or departments.

While the great majority of our positions are for men specifically trained in science or engineering, we hear of an increasing number of executive and administrative openings. This year we placed three men in company presidencies and one as an understudy and successor to an owner-president.

THOMAS W. HARRINGTON, JR.

VICE PRESIDENT, RESEARCH ADMINISTRATION

THE SEVERAL FUNCTIONS of the Institute reporting to the President through the Vice President, Research Administration include the Cambridge Electron Accelerator, the Division of Sponsored Research, the Industrial Liaison Office, the Joint Center for Urban Studies of Harvard University and M.I.T., The M.I.T. Press, the National Magnet Laboratory, the Summer Session, and the Libraries. Reports from the Directors of each of these activities for the fiscal year 1962-63 follow.

The Cambridge Electron Accelerator (operated jointly by M.I.T. and Harvard) and the National Magnet Laboratory are two examples which illustrate one major trend in modern research at M.I.T. as well as at other universities. Both are expensive research tools costing millions of dollars of federal funds and with large operating budgets. They represent expenditures far in excess of university resources. However, they are an essential part of modern research and education in science and engineering and must be available if the universities are to continue to fulfill effectively their essential function of advancing knowledge and education.

At the other end of the spectrum there are still many examples of excellent research and education being conducted by our staff in small laboratories with modest budgets, but the trend is toward more expensive and more sophisticated research tools even in these smaller operations. There has also been a trend for several years toward more assistance in the form of support personnel, which increases the productivity of the staff. These are some of the major factors in the increase in total sponsored research volume which is shown in the report of the Director of the Division of Sponsored Research.

Another major factor in the increase in our total research budget is that the Institute has expanded into new areas of education or is placing increasing emphasis in existing areas; examples are nutrition, food science, experimental psychology, oceanography, and biology. Each of these must be supported by a vigorous research program.

Again, there are areas where we have made commitments to expand in order to fill a national need. For example, our agreement with the Advanced Research Projects Agency of the Department of Defense calls for a progressive increase in the number of advanced degrees awarded in the field of materials science and engineering. Improved materials are vital to the success of most major engineering enterprises of both government and industry, and the universities must make a major contribution to both education and research in this field.

Finally, we have made several commitments to assist in education and development programs overseas, including Latin America, India, and Africa. These activities complement our own programs, and the staff directly concerned with them are enthusiastic about the contributions that are being made. The pressures to expand such activities are great, however, and we are mindful of the dangers of overcommitments.

The report of the Division of Sponsored Research emphasizes the increasing involvement of M.I.T. in federally sponsored research programs. This is not a new situation either at M.I.T. or at other universities. In most instances it is a direct result of pressure from within our own university community, since our research program is primarily generated by faculty demand and is, therefore, a significant mark of the vigor and activity of a competent staff. However, as the magnitude of our support for research from outside sources increases, the need for a careful and continuous scrutiny of the effects of such support upon our total program becomes increasingly important.

The critical state of our library system is emphasized in the report of the Director of Libraries and in a recent report of an *ad hoc* Committee on Long-Range Planning for the Libraries. Our library budget in recent years has increased at a rate in excess of that of any other unit at the Institute, but the increased magnitude of publications, particularly in science and engineering, continues to create major space and acquisitions problems, which, in the long term, can probably only be solved by a major breakthrough in methods of information storage and retrieval.

The Joint Center for Urban Studies, operated by Harvard University and M.I.T., in its report for this year emphasizes the need for attracting capable people from many disciplines into this important field. The Center is faced with a variety of interesting and complex problems including theoretical, practical, and political questions, all of which are involved in the broad area of urban redevelopment. A major concern has been the selection of the most rewarding areas for study with the limited staff and funds available. The Center from its inception has had excellent leadership, and we look forward to a continued record of accomplishment under the new Director, Dr. James Q. Wilson, Associate Professor of Government at Harvard University.

CARL F. FLOE

Cambridge Electron Accelerator

The Cambridge Electron Accelerator, a joint undertaking of Harvard University and M.I.T. with the support of the U.S. Atomic Energy Commission, was brought into operation at the design energy of 6 Bev in August, 1962, and was dedicated in a ceremony on September 14, 1962. Preliminary operation for research started in October, and by December 31 the machine was running nearly every day, with half of the operating time devoted to experiments in high-energy physics and half to tune-up studies of the machine. From January, 1963, through May, 1963, the operating schedule was extended to two shifts, with the daytime shift devoted to machine studies and installation of research experiments and the evening shift assigned to research operation. In June, three-shift operation was initiated with two night shifts for research. Crews of operators and technicians were recruited and trained to support this level of activity.

A total of nine experimental research projects were supported and provided with operating time during the year. These projects were staffed by forty-five scientists and by a number of their students from M.I.T., Harvard, and other New England universities. One research paper was published and two others prepared for presentation at scientific meetings. Two graduate students, one from M.I.T. and one from Harvard, presented doctoral theses based on data taken at the C.E.A. Although requests for operating time exceeded that available, all research projects approved by the C.E.A. Scientific Subcommittee have been scheduled for a significant amount of research operation. Of the total beam-hours scheduled, about one-third were for M.I.T. scientists and students, one-third for those from Harvard, and one-third for those from other universities.

From July 15 to September 1, 1963, operations were suspended to allow several construction and modification jobs to be performed. The temporary control room was moved to a permanent location in the central power building; the target area has been re-shielded to allow construction of a large data-taking center; and improvements were made for more efficient beam handling and beam sharing. Three-shift operation for research was scheduled for the September-December operation period.

M. STANLEY LIVINGSTON

Division of Sponsored Research

For the seventh successive year the sponsored research program on the campus shows a large increase in volume, amounting this year to more than 25 per cent over that for fiscal year 1962. Comparative figures are shown below:

DOLLAR VOLUME	*1961-62*	*1962-63*
Federal government	$21,506,384	$28,393,993
Industrial, foundations and other non-federal government	2,548,999	1,836,147
Grants-in-aid	690,917	1,078,830
Total	$24,746,300	$31,308,970

PERSONNEL EMPLOYED	*June 30, 1962*	*June 30, 1963*
D.S.R. staff	345	411
Academic staff devoting time to research projects	1,224	1,423
Support personnel	686	727
Total	2,255	2,561

In addition to the research funding noted above, the federal government, through grants and contracts, has reimbursed the Institute in the amount of $2,807,745 for facilities and equipment. About three-quarters of this total, $2,168,028, came from the United States

Air Force under a contract providing for the National Magnet Laboratory, which was completed in the spring of 1963. The balance of $619,717 covers the costs incurred in completing the Cyclotron facility (under an Atomic Energy Commission contract), the Psychology Research Building (under a National Institutes of Health grant), and the nuclear laboratories (in the former Ward building) and laboratory equipment purchases (under National Science Foundation grants). All of these expenditures, excepting the Magnet Laboratory, involved cost-sharing by the Institute in the amount of nearly $600,000.

Again this year the large increase in the dollar volume of sponsored research at the Institute is distributed through almost every department and inter-departmental laboratory. Moderate increases averaging less than 10 per cent over 1962 are the rule in the School of Engineering. Activities in the School of Science have increased markedly, averaging 35 per cent over 1962, and every department in the School has shown a large increase.

The National Magnet Laboratory, its facilities completed, moved into essentially full-scale operations, while the Laboratory for Nuclear Science increased its activities by nearly 50 per cent. Two new large computer programs were initiated late in the year, and their full impact will not be apparent until 1964.

The entire increase in the volume of sponsored research came from government agencies, with the National Institutes of Health, the National Science Foundation, and the National Aeronautics and Space Administration supplying most of the additional support. These three agencies, as well as certain defense agencies, use the so-called grant instrument in place of the contract for most of their research. Grants undoubtedly have certain advantages; however, there are many features involved in them that complicate the administration of research. The grant instrument in many cases involves all of the conditions set forth in a contract. In other cases, the instrument itself is a simple document; but the operating conditions and required procedures are set forth in a manual issued by the granting agency from which the grantee has no appeal. Much of what appears in a contract is the result of mutual agreement by the contracting parties, while procedures for operating under a grant are often set unilaterally by the government sponsor. Of the utmost concern to the Institute and all universities is the difficulty of obtaining full costs under government grants, particularly because of the limitations placed upon reimbursement for indirect costs.

Because of congressional action and various reports prepared by special governmental committees, the problems of contracting with the government have increased in complexity during the past year, and the administration of each sponsored research program becomes more intricate. This Division is giving increasing thought to ways in which it can relieve project supervisors of more of the administrative problems involved.

The sponsored research program continues to become more closely integrated with the academic program. The ever-increasing participation of faculty and graduate students is clearly shown by the personnel figures quoted above. This year saw an increase in research assistants (part-time graduate students) working on sponsored research from 590 to more than 750. These figures do not give the complete picture of the integration of the research with the educational program. Samplings from a few laboratories and departments show not only equally large numbers of graduate students working without pay on sponsored research programs but clearly indicate that large numbers of the undergraduates are associating themselves with these activities throughout their four years at the Institute, to their considerable benefit. Many are conducting their Bachelor's theses in these laboratories. It is hoped that more complete statistical proof of the contributions of sponsored research to undergraduate education may be forthcoming in the near future.

F. LEROY FOSTER

Industrial Liaison Office

The Industrial Liaison Program has completed its fifteenth year of providing the participating companies organized communication with and convenience of access to the ever broadening spectrum of M.I.T.'s research and academic programs. The recent successful conclusion of the Second Century Fund afforded an additional stimulus to the Institute's already dynamic expansion. In order to discharge its responsibilities in the face of these developments and to maintain personalized service for each of the research-oriented organizations which comprise the membership of the Program, the staff of the Office was augmented by the appointment of an additional Industrial Liaison Officer, and the space occupied by the Office was increased. In addition to this expansion and a continuing improvement of the customary services, several innovations were introduced. All of the activity statistics increased, indicating that the Program has become a significant and viable adjunct to the Participants' in-house research activities.

At the conclusion of the 1962-63 fiscal year, there were 117 participating firms distributed among the following industrial groups:

Aerospace	21%	Manufacturing	15%
Automotive	3%	Metals	9%
Chemical	15%	Paper	2%
Electronics	17%	Petroleum	9%
Food	3%	Others	4%
Insurance	2%		

During the year *six* companies entered the Program and seven found it necessary to withdraw, primarily for budgetary reasons. Income for the year totaled $2,044,000, slightly greater than last year's record income.

Industrial Liaison Symposia continued to be a very effective means of presenting to the member companies comprehensive status reports on research in progress at M.I.T. and its associated laboratories. The record-breaking attendance for the past year attests to the popularity and utility of these informal research briefings. Attendance totaled 1,805, an increase of 34 per cent over last year's record. Average attendance per meeting increased 20 per cent to 113. The largest number of Symposia presented in one year, sixteen, was offered to the participants. The Program membership consists of a cross-section of American industry, and as the technical interests of these companies expand, it becomes increasingly important that the Symposia present a diverse sampling of the Institute's current research. During this year, Symposia were offered on the following topics: Ships and Hydrofoils; Catalysis and Applied Kinetics; Electromechanical Control Components; Welding; Production and Operations Management; Sensory Coding in the Nervous System; Deformation and Flow in Polymeric Materials; Subsurface Signal Transmission and Processing; Plasma Physics; Thin Shell Structures: Design and Analysis; Ceramics; Financial Decisions; Exploration in Future Food Processing Techniques; Computer-Aided Design; and Inertial Navigation Equipment Evaluation Techniques.

A total of 118 Institute staff members made presentations at these symposia; there were two speakers from other organizations. Attendance at these meetings by M.I.T. staff members increased significantly; 232 attended this year, compared with 126 the year before. Their popularity within the M.I.T. community indicates that these meetings are serving the Institute internally as a means of communication among the departments and laboratories.

The concept of the off-campus meeting was introduced four years ago. The Office's commitment in the Southwest and West Coast areas broadened, and these meetings became an integral part of the Program. This responsibility has continued to expand so that Program services now are extended to approximately seventy major facilities of member companies located in those regions. The continued enthusiastic reception by industry to symposia presented at off-campus locations indicated that the effort and expense involved in preparing these meetings were most worthwhile. Such "away" meetings are held at locations characterized by a concentration of participants interested in the meeting topic. The symposium on Subsurface Signal Transmission and Processes was held in Houston, Texas, and reported on M.I.T.'s effort to apply advanced electronics and communications techniques to the detecting and transmission of signals through the earth's crust. This year, for the first time as an addition to our "off-campus activities," one symposium was presented at two locations; Plasma Physics was certain to be one of the year's strongest and most popular meetings, and in order to give the companies on both coasts an opportunity to send sizeable delegations, this meeting was presented both at M.I.T. and three weeks later in Los Angeles. The response to this experiment was very favorable. Similar arrangements will be considered in the future.

There were 1,078 personal conferences with members of the faculty arranged by the Industrial Liaison Office for company representatives, an increase of 15 per cent over last year. Faculty participation in this phase of our activity has also expanded significantly. The increase in the number of these individual discussions can be attributed to the continuing expansion of both the participants' and the Institute's research programs, which result in more common research interests. Also, the several participants who entered the Program a year ago during the Second Century Fund are now more familiar with the Institute and tend to use the visit privilege more frequently. Visits, in general, have been characterized by top-level company representatives exploring many areas of the company's present or projected interests, rather than the more specific visits of a few years ago. Administering such individual visits to the campus occupied a major share of the attention of each Industrial Liaison Officer. The staff of the Office was enlarged so that this personalized visit activity would not be compromised by the increase in the number of Program participants.

In addition to campus visits by company representatives, sixty-two visits by Institute faculty members were made to company laboratories at the request of the Industrial Liaison Office, an increase of 15 per cent over the number of such visits last year. Both company and faculty response to these visits was favorable; it is anticipated that this activity will continue to expand.

Distribution to the participating companies of publications generated at M.I.T. and its associated laboratories continued as a major means for providing detailed coverage of Institute research. A total of 367 titles were distributed, 10 per cent fewer than last year. After consulting the Program membership it became apparent that, in general, published journal articles written by Institute faculty were readily available either in the journal or in reprint form and that any further distribution of this material was redundant; therefore, it was decided to curtail reprint distribution. Reprints from only the most difficult-to-obtain journals are now distributed. The decrease in the total number of titles distributed is a result of this policy; only five reprints were distributed this year in contrast to fifty-six last year. The remainder of the distribution consisted of technical reports, progress reports, preprints of journal articles, and abstracts of theses from several academic departments; the number of these titles distributed increased slightly. The number of mailing points increased approximately 10 per cent as did the number of copies per title mailed, so that in spite of the decrease in titles distributed the total volume remained the same as last year.

The Monthly List of Publications, a tabulation of publications distributed by the Industrial Liaison Office, was expanded to include a section listing publications available on request. This section indicates reprints which are no longer being distributed as noted above and, more importantly, publications which are not of sufficient general interest to warrant a complete distribution. On several occasions this additional information was of significant value to the recipients. During its first year, this section listed 213 titles. This expansion of our publications coverage was favorably received and will be continued. Operational improvements were effected which permit quicker and more complete response to special publications requests. This improvement, coupled with the introduction of the "available" section, has apparently encouraged the participants to make more use of this service. Over 1,500 such requests were processed during this year, an increase of approximately 20 per cent over those of the previous year.

The Directory of Current Research, a comprehensive compilation of research projects in progress at M.I.T. prepared annually by the

Industrial Liaison Office, was expanded this year to list 1,050 projects as compared with 989 last year. This publication finds widespread use by member companies and also by the Institute staff. This year over 350 copies were requested by and distributed to the faculty, an increase of approximately 25 per cent over the number distributed last year. The utility of the Directory was greatly enhanced by the addition this year of an index. Although it adds considerably to the effort required to prepare this document, the index elicited so many approving comments from the participants that it will undoubtedly be included in future editions. Internal procedures were modified to more closely relate the Directory to our publication function, the goal being a total information service for the member companies regarding M.I.T. publications.

Library Privilege Cards which entitle the holders to borrow books and to use the reading rooms and reference materials, in accordance with usual library regulations, are made available to participants. At the close of this year 459 cards were held by representatives of participating companies, compared with approximately 350 one year ago.

A year-end report such as this can only sample the activity levels in several phases of the formal operation of the Program. The long-term benefits to both the Institute and the participants that result from such a collaborative relationship are impossible to assess over the period of one year, although eventually they might well be of significantly greater importance than the year's accomplishments reported above. There have been many instances during the year when consulting arrangements and research grants have resulted from this organized contact between the Institute and industrial research leaders. Equipment and materials have been exchanged. The faculty were able to become better acquainted with company research programs. Younger members of the Faculty were able to broaden their professional acquaintances in industry. Any of these might well contribute to the overall success of future research programs, either at M.I.T. or in industry.

Gary L. Benton, James E. Donahue, Daniel J. Holland, and Thomas Yonker served as Industrial Liaison Officers throughout the entire year. Lloyd S. Beckett, Jr., and Philip J. Robinson accepted appointments to the Office during July and August, respectively. The accomplishments of this year of intense activity attest to the initiative, ability, and dedication with which these Industrial Liaison Officers discharged the Institute's responsibilities to the participating companies. John F. Maxwell, Jr., and Winston R. Hindle, Jr., left the

Office in July to accept positions in industry. The latter's responsibility as Acting Director was assumed by the undersigned. In conjunction with the Office expansion described above, Frank T. Bauchspies joined the staff in April, 1963, and Jack V. Drake accepted an appointment as Industrial Liaison Officer in May, 1963. It must be borne in mind that the effective functioning and, indeed, the very existence of this Office would be impossible without the continuing support of the faculty.

RICHARD B. FINN, JR.

Joint Center for Urban Studies

Attention to both the scholarly and practical problems of urbanization and urban change has been in eclipse for a generation. At an earlier time, particularly under the aegis of the University of Chicago, much of American sociology and a significant part of political science, geography, and even economics were concerned with urban problems, but the great depression and the second World War made national and international affairs appear more exciting than urban affairs to social scientists. After the War, the interest of technological specialists in the operations of cities dimmed before the glamour of space and other new ventures. Even a field such as urban planning, which by definition deals with the city, has neglected research as a basis for action.

To change this situation, the Joint Center has had to solve three problems. Because of past neglect, it had to discover and stimulate the first-rate talent which had long been absent in urban research. It also had to attract the ablest students who might become the future scholars and practitioners in the urban field. Finally, it had to consider means for approaching the many policy and applied problems now confronting our cities.

Looking back over the past four years, we believe that the Joint Center has won respect for its intellectual tone—for the quality of the scholars and students who are associated with its program. The initial emphasis was deliberately cast along these lines because success here was essential if the other objectives were to be successfully achieved. On the other hand, the Joint Center has not neglected policy issues or applied problems. It has been more energetic and more successful in this respect than originally anticipated.

This report describes the activities and current problems of the Joint Center in relation to these issues.

The ablest men and women in universities today are drawn to fields where they feel that they have an opportunity to solve intriguing theoretical as well as applied problems. The Joint Center has succeeded in creating a program which would yield such opportunities; it has attracted able men and women who would not otherwise have been in Cambridge. It has also attracted students and scholars, already here in a variety of disciplines, who would not otherwise have devoted themselves to urban problems.

The program evolved to realize this objective was not a precisely ordered and predetermined one. Some scholars of great ability thrive in group projects and seek them out; but others—probably most—are at major universities so that they can work by themselves on studies in a field of their own choosing. Thus to follow the aim of bringing together the ablest talent meant having a reasonably permissive program.

A reasonably permissive program can also be structured. By the end of the first two years, after the sifting of a wide range of exploratory studies, we focussed on four areas of concern: comparative analysis, structure, and growth of cities; urban transportation and technology; urban design; and urban and regional problems in developing countries. These four areas continue to reflect the interests of the people drawn to the Joint Center. Our effort has been to make studies in these areas additive by achieving an exchange of ideas, methods, and knowledge among those conducting research. Thus, through the Joint Center scholars learned of the related work being done by others and broadened their own studies. One of the formal devices for this purpose is the review seminar in which drafts of the work of the members of the Center are discussed and criticized. In addition, informal reviews particularly among some of the younger members results in work drawing on insights from many disciplines.

These efforts have begun to bear fruit, as can be seen from the growing catalogue of publications brought out under the auspices of the Joint Center. By the fall of 1963, eight books and seven monographs will have appeared bearing the Joint Center imprint and published for the Center by the Harvard University and The M.I.T. Presses. These include studies of law and land use, urban politics, housing economics, urban ethnic groups, the city in history, visual aspects of city life, transportation and communications, retail trade, and urban renewal. The series of reports on the politics of large cities, initiated and supervised by Professor Edward C. Banfield of Harvard, has now been completed, with twenty-three cities surveyed. One book summarizing these findings has been prepared for the Joint Center book series; a second will appear through a commercial publisher.

Publications issued by the Center during the 1962-63 year are as follows:

City Politics in Washington, D.C., by MARTHA DERTHICK. Monograph. Issued jointly by the Joint Center for Urban Studies of M.I.T. and Harvard and the Washington Center for Metropolitan Studies. Distributed by the Harvard University Press; $4.00; September, 1962.

The Intellectual Versus the City: from Thomas Jefferson to Frank Lloyd Wright, by MORTON and LUCIA WHITE. Published by the Harvard University Press and The M.I.T. Press; $5.50; October, 1962.

Streetcar Suburbs, by SAM B. WARNER, JR., Published by the Harvard University Press and The M.I.T. Press; $6.50; October, 1962.

The Zone of Emergence, by ROBERT A. WOODS and ALBERT J. KENNEDY, edited and with a preface by Sam B. Warner, Jr. Monograph. Distributed by the Harvard University Press; $4.00; November, 1962.

A Communications Theory of Urban Growth, by RICHARD L. MEIER. Monograph. Published and distributed by The M.I.T. Press; $4.50; December, 1962.

A Report on the Politics of El Paso Texas, by MARK K. and GERTRUDE ADAMS. Distributed by the Joint Center for Urban Studies; $6.00; June, 1963.

Although the Joint Center is a research and not a teaching program (it offers no credit courses or degrees), the teaching programs of the two institutions have gained greatly from the research. Close to a dozen new subjects based in whole or in part on the research materials of the Joint Center are now offered. Existing subjects and seminars have had rich raw materials upon which to draw.

In the first four years about forty students, mostly advanced graduate students but some undergraduates, have worked with the senior research staff on Joint Center studies. Since almost all the senior research staff are faculty members of M.I.T. or Harvard working part-time at the Joint Center, students have an opportunity here which is not available at most major universities. In addition a voluntary research seminar for advanced graduate students, drawn from a wide range of departments at both Harvard and M.I.T., has been conducted jointly by Professors Martin Meyerson and Lloyd Rodwin. The focus has been on the dissertation topics pursued by these younger scholars, and these collaborative discussions have helped to enlarge the perspectives within which these specialized studies were pursued.

Each year several students have been awarded Stouffer Fellowships to prepare doctoral dissertations at the Joint Center. These fellowships have helped interest able students at both institutions; perhaps more than any other group, these Fellows have gained from the interchange of approaches provided by the Joint Center. The quality of Fellows and their work is so good that we hope in most cases to publish their findings.

The regional study, undertaken in 1961 to assist the government of Venezuela in developing the resource-rich Orinoco River area of that country, has been our most important applied effort. (The details of this program have been described in our 1962 report.) The materials developed by these studies have been used extensively in the teaching programs of several departments at both Harvard and M.I.T. as well as at other institutions such as the University of Pennsylvania. In the summer of 1963 the first major presentation of the progress of that project was given in Venezuela by the Joint Center staff, now numbering seventeen full-time professionals and their Venezuelan counterparts, on the occasion of the annual meeting of the Visiting Committee of the Center.

The scale of the Venezuelan project with its large number of staff members from city planning, urban design, economics, political science, transportation, and other fields has not been repeated domestically. However, some modest-scale applied projects have been conducted—for example, a study of the relation of highway planning to urban development (performed for the Bureau of Public Roads) and a study on metropolitan planning (underway for the United States Senate). No major action study has been completed in the Boston region, but a quarter or more of the studies of the Joint Center use Boston for their case materials, and one Boston action study—an evaluation of efforts to find housing for low-income minority groups—has been inaugurated.

Meanwhile, members of the Joint Center have become deeply involved in some of the main action programs in urban affairs, nationally, in the Boston region, and through the U.N. and other international organizations. Requests come to the Joint Center constantly for personnel both for research and for action assignments. Often we help find the right person for the job, either from our own staff or through our knowledge of other programs; just as often the shortage of able, trained people makes it impossible for us to make a recommendation.

The Joint Center has continued its weekly luncheon meetings at which guest speakers from a wide variety of disciplines and activities appear. In addition, two major conferences on urban problems were held by the Center during the year: one brought together some of the country's leading librarians with urban sociologists, economists, political scientists, and specialists in the new technology of information handling to discuss ways of meeting the new demands being placed on city library facilities; the other provided an opportunity for some of the country's leading real estate developers to discuss with faculty from the Institute and Harvard the problems of urban design and development. The latter was so successful that the developers have requested its continuance on a regular basis. The problems and possibilities posed by such activities are now being weighed.

The Joint Center is also a magnet for practitioners and scholars from overseas as well as in this country who wish to spend from several months to a year in serious research. Visiting Associates of the Joint Center have included an assistant to the Minister of Housing and Local Government in Great Britain, an American city councilman, a sociologist from Tokyo, and a research administrator from the Argentine. Supported by funds from outside the Joint Center, the Visiting Associates have enriched the activities of the Joint Center and have conducted research studies of their own.

During the past year the Joint Center received an additional grant from the Ford Foundation of $600,000 for a period of three years. This assistance may be extended in the future; nonetheless, the period of the present grant limits the long-term planning and staffing of the Center unless more diversified financial support can be obtained.

Professor Meyerson of Harvard University, who as Director guided the Joint Center from its inception and whose stimulation and judgment did so much to make the Center pre-eminent in its field, left Cambridge in July, 1963, to assume his new post as Dean of the College of Environmental Design at the University of California at Berkeley. The new Director is James Q. Wilson, Associate Professor of Government at Harvard University.

JAMES Q. WILSON, LLOYD RODWIN

Libraries

This year has been dominated by planning for the future. An *ad hoc* committee of the faculty, appointed by the President two years ago, spent last year making a long-range study of the place of the Libraries at the Institute. The group submitted its report early in the fall. They said: "The Library is the most important single administrative unit of the Institute. The quality of the programs in education and research depends directly on the quality of the library facilities." They foresaw a staggering expansion of library accessions: the book collections doubling in thirteen years, the journals in ten, the number of readers in the Libraries in ten.

To cope with this increased activity and bring the libraries into line with the trend of engineering education, the committee suggested combining our Science and Engineering Libraries in one primary unit and combining our Humanities, Architecture and Planning, and Industrial Management and Economics Libraries in a second. In addition, they proposed a "Residence Library, preferably in the Student Center" and "a dozen or more small, specialized reading-document-study rooms in locations convenient to research activities." They felt that 125,000 square feet should be added to the present 105,000 square feet of the Library in the decade ahead, that major development of collections in certain fields should be undertaken, that "machine data processing methods should be introduced to simplify the handling of the contents of the Library," and that a full-time Dean of the Library should be appointed who would be responsible for all Library facilities at the Institute.

During the year these recommendations were discussed by the top academic committees and by the Corporation's Visiting Committee on the Libraries. They were presented to the faculty at its May meeting.

Concerning the first suggestion, that the Institute should combine its Science and Engineering Libraries, there was near unanimity, with the result that Walter Netsch of the firm of Skidmore, Owings and Merrill has been engaged to make a feasibility study, with the assistance of Keyes Metcalf former Director of Libraries at Harvard, as Library consultant, of the conversion of Building 10 for this purpose.

The other recommendations of the *ad hoc* committee have gained general approval as a blueprint for the next ten years. Only one of them is completely unworkable, and this for reasons unknown to the committee when their report was written. For the members were unaware of plans to build a new center including a library of economics and industrial management back of the Sloan Building. Since the construction of the new building for industrial management and economics has been authorized, the second major library conceived by the committee cannot be realized in the foreseeable future.

A report under preparation by the Executive Board of the Faculty Advisory Committee on the Libraries will point out other minor modifications which would be desirable in the *ad hoc* committee report but, in general, they enthusiastically endorse it, as does the Director of Libraries.

CURRENT OPERATIONS

Far from stopping work while we planned for the future, we have had to carry on the daily business of the Libraries at an annually accelerating rate which we have come to accept as normal. More books every year, more journals, more readers; the tables give statistics. We have tried to keep pace by adding new staff where necessary and by simplifying procedures. Substantial accomplishments have been possible in both this year thanks partly to grants from the National Science Foundation. The N.S.F. institutional grant of $50,000, for instance, was given to the Libraries to provide staff and books in such shortage areas as materials science and space science.

As to procedures, a substantial improvement was made by building a new lobby in the Hayden Building and combining book circulation activities for the Science, Humanities, and General Library stacks at a desk in this lobby. A reduction of noise in the reading rooms and more convenient charging out and returning of books made this a welcome move.

The building was also made more attractive by the installation of new drapes, the old ones being badly worn and torn after twelve years in the southern sun.

A further innovation in the lobby was the installation of a Xerox 914 copier, which proved its value by making 77,000 copies of journal articles and pages of books in a little over six months. To a large extent these copies were in lieu of borrowing. At 10¢ a page for M.I.T. people (20¢ for outsiders), many would rather take home an expendable copy than go to the trouble of charging out a book or a journal and having to return it. This benefits other borrowers, too, for it means that the materials remain on the shelf and the frustration index goes down. Circulation from the Science, Humanities, and General Libraries stacks shows a drop from 113,202 last year to 97,254 this year, but the copier may not be the only influence at work. There is also the growth of departmental libraries in chemistry, mathematics, physics, and psychology. While these are generally not open to undergraduates, they do save some professors and graduate students from having to come to the Library. Drops in circulation in Dewey and Rotch can be explained partly by more room use and longer hours at Dewey.

Other simplified procedures are being planned and tried. These include an expansion of machine data processing techniques, such as the annual print-out of our *Current Serials and Journals* from punched cards which we hope in the future to prepare by computer-

Library Circulation (Exclusive of Room Use), 1959 to 1963

	1959-60	*1960-61*	*1961-62*	*1962-63*
Aeronautics and Astronautics Library	13,178	11,319	12,295	16,342
Dewey Library	40,794	45,576	45,079	42,998
Engineering Library	34,334	38,052	40,273	43,372
Hayden (General & Humanities and Science Libraries)	98,361	106,956	113,202	97,254
Music Library	3,128	3,115	3,927	4,857
Reserve Book Room	7,472	8,828	10,422	8,202
Rotch Library	15,682	16,242	16,314	14,917
Totals	212,949	230,088	241,512	227,996

controlled photocomposition. Government reports, coming in at the rate of over 28,000 a year to our Regional Technical Reports Center, have been particularly difficult to handle because of the many different numbering systems used by the originating agencies. The volume is expected to double next year. In cooperation with the University of California at Los Angeles and the University of Washington, we are machine-producing a correlation index of these numbers. The Reports Center is supported by a grant from the National Science Foundation. New personnel were needed to handle the flood of reports on paper and in many forms—microcard, microfiche, microfilm, microprint. Requests for these reports come to us by mail, telephone, TWX, and personal calls from people in New England and even in other parts of the country (though we are one of twelve such centers scattered across the country to make the results of government-sponsored research more accessible). We have been happy to become a Center to help clear up the earlier situation where many government reports were asked for but simply could not be found. The new system still does not include all unclassified government-financed research reports as it should, but it is an improvement.

Under still another grant from the National Science Foundation, an International Union List of Communist Chinese scientific, technical, and medical serials, including 100 social science titles, is in the final stages of preparation by our Chinese Science Project. This list has been prepared with the help of librarians at thirty institutions here and abroad. Its publication will mark a first major application of computer-controlled photocomposition, which we hope to use for our *Current Serials and Journals,* as mentioned above. The Chinese Science Project has also been busy collecting a total of 3,370 issues of journals published on the Chinese mainland since 1949. We now have exchange arrangements with the Academica Sinica, the Institute of

Scientific and Technical Information of China, and the National Library of Peking, but our success in assembling a large collection is due to the energetic assistance of Kay Kitagawa of the National Science Foundation, to the Library of Congress and the National Agricultural Library, and more recently to the highly successful efforts of the National Federation of Science Abstracting and Indexing Services.

Still under the heading of simplification is our decision to convert to the Library of Congress classification system. The M.I.T. Libraries since the beginning have used the Dewey Decimal System but with numerous special adaptations which have become more and more difficult to continue as the Libraries have grown. The Library of Congress system, while not perfect, is more nearly up to date and more suitable for large libraries. So beginning on January 1, 1963, all new books were given Library of Congress numbers and went to new sections of the shelves set aside for them. The transition period of the next few years will be difficult, for we shall have two places to look for books on any one subject—the older books in one and new ones in another. By next fall, all journals will be fitted into the new system. Later on those books which are taken out frequently will be reclassified and shelved with the new books. In this way the period of inconvenience to our readers will be made as short as possible.

Before setting the date and making plans for the changeover to the Library of Congress system, we experimented with classification of new books in the Dewey Library beginning in September. Our experience in this busy library made it possible to anticipate the difficulties and set up a realistic schedule for the rest of the system. In January Miss Mary D. Herrick of Boston University was engaged to conduct workshops which were a great help to our librarians in converting to the new classification.

Crowding in the Dewey Library is severe, as it is in the Rotch Library of Architecture and Planning and in the Music Library, but in Dewey the situation will be relieved in two years by the new building for management and the social sciences. There seems to be little hope of alleviating the situation in the Rotch and Music Libraries for the present, though they are both full of books and neither has enough reader space.

In a sense, the problems of the Engineering Library are just the reverse. Its collections are far from satisfactory but it does not get the use it should. Located on the fifth floor, it is serviced by slow elevators which do not run at all Saturday afternoon or Sunday. It is physically relatively unattractive, particularly on the upper floors. But improvements have begun this year and will continue under the energetic leadership of the new head of the Engineering Libraries, Miss Rebecca Taggart. She has already brought about increased interest in the Library on the part of the faculty, with improved cooperation in the selection of books. She has rearranged reserve and reference books, and dingy work areas have been painted and relighted. This is only a beginning. Office space is urgently needed for more staff to modernize the collections and provide better service. Industrial science and engineering libraries have led the way in recent years in bringing literature, especially reports, to the attention of their researchers. Small libraries and document rooms at the Institute do much of this type of service, and we believe that the Engineering and Aeronautics and Astronautics Libraries should develop more activities of this kind for the members of the departments they serve.

Library Collections, 1961 to 1963

	Annual Growth		*Total*
	1961-62	*1962-63*	*Volumes*
Dewey Library	9,015	12,272	135,363[1]
Engineering Library	3,067	5,873	127,217
Aeronautics and Astronautics Library	3,275	4,275	41,675[2]
General & Humanities Library	14,298	10,117	402,197
Music Library	1,012	647	5,908
Rotch Library	2,349	2,557	47,303[3]
Science Library	4,211	4,800	74,874
Archives	973	1,110	14,233
New England Deposit Library	78	327	910
Totals	38,278	41,978	849,680[4]

Though the Engineering Library is not used as heavily as it should be by our own community, all the libraries, especially Engineering and Science, have heavy use from outside the Institute. This year 1,033 cards, as compared with 724 last year, were issued to members of the industrial community around us. Many of these contributed directly or indirectly to the support of the Libraries. Participants in the Libraries' Membership Plan for Industry accounted for 292 cards and income of $8,250. There were 55 individuals paying $50 per year for the privilege of using our facilities, and 576 staff

[1] Of which 72,521 are pamphlets.
[2] Of which 34,563 are technical reports.
[3] Of which 18,385 are pamphlets.
[4] In addition the libraries have: 34,673 microcards/fiche, 2,306 microfilm reels, 44,204 slides, 3,508 sound recordings, 16,334 photographs, and 39,169 maps and plans.

members of industrial firms which contribute substantially to the support of the Institute through the Industrial Liaison Plan and the Associates Program received free cards. In addition, cards were held by 104 representatives of government agencies.

But the number of cards by no means indicates the extent to which industry uses our Libraries. We loaned them 1,777 volumes on inter-library loan as opposed to 1,059 last year. And the large story of outside use is told in the figures of the Microreproduction Service; of the year's total production of half a million black-on-white prints, half a million negative microfilm exposures, and hundreds of thousands of other kinds of copies, over 50 per cent went to industry. The orders for the many services rendered by the Laboratory also shows a substantial increase over last year, particularly in orders from the Institute.

Microreproduction Service Operations, 1961 to 1963

	1961-62	*1962-63*
Orders from industry	5,382	5,760
Orders from U.S. government agencies	52	81
Orders from educational institutions	1,369	1,382
Orders from M.I.T.	1,999	3,569
Total orders	**8,802**	**10,792**

In addition to the above services, which are billed at cost, Peter Scott, Head of the Laboratory, has been active in advising members of the faculty and staff on many special photographic problems.

SPECIAL PROJECTS

The service rendered by the Libraries has been generously recognized again this year by a substantial increase in the budget and by three special appropriations to buy materials to support new doctoral programs: $1,000 for political science, $5,000 for linguistics, and $5,000 for mathematics. There was also the transfer to the Library of the $50,000 institutional grant from the National Science Foundation mentioned earlier. And the Foundation supported still other projects which have not yet been mentioned. One was a study by Boris Gorokhoff of Soviet information activities, with particular attention to the organization of the system and recent changes in it: Soviet engineering and scientific societies, abstract and bibliographic services, the extent of Soviet publication in various fields of science and technology, and compilation of a Russian-English glossary on information. A preliminary directory of Soviet technical information agencies was prepared, containing over 500 entries and including data, when available, on the sponsoring body, address, history, operations, and publications of each agency. In the spring, a supplementary grant was made extending the work for another year.

Another N.S.F.-supported project was that of Dr. Myer M. Kessler, who has been accumulating data and designing several automatic processing schemes for possible inclusion in a pilot model of a mechanized system for the selective dissemination of scientific information. The preliminary design of the model is now well advanced and it is planned to have an operational system during the next year. The results of the past year's work were published in seven reports and four journal articles. Support of the work has been renewed.

Two projects financed by grants from the Council on Library Resources were continued: the microfilm reader finder, for which a prototype has been completed and is being tested, and the catalog card replicator, which has been designed but not yet constructed. A request for renewal of the latter grant is pending.

GIFTS

This year again we have benefited from the generosity of many friends. M.I.T. authors have contributed autographed copies of their works to the Tech Collection, and a large number of others have given books or other articles. We cannot mention all the names here but we thank them all.

A special word of appreciation should be said to Mrs. Alta M. Saunders for a collection of books from her late husband's library; to Henry C. Menzies, Australian Government Senior Trade Commissioner, for a set of the "Australian Encyclopedia" which he presented in a special ceremony at the Library; and to the Embassy of the Czechoslovak Socialist Republic for a substantial quantity of recent technical and scientific books, presented by Jaroslav Petr and Antonin Simecek who personally delivered them.

VISITORS

Other visitors came in large numbers throughout the year. Miss Indira Sukhtankar, Librarian of the Indian Institute of Management at Calcutta, spent the spring term studying our operations, especially those at Dewey Library. In April we received a Soviet Book Delegation, and in May and June a number of medical librarians from abroad came to the Institute in conjunction with attending an international congress of medical librarians in Washington.

STAFF ACTIVITIES

Our own staff have been active in many ways outside the Institute. In addition to attending professional meetings, a number have been elected officers of professional societies or held other honorary and responsible positions; these are tabulated elsewhere in this volume. Of particular interest is the fact that Mrs. Irma Johnson, Reference Librarian, was one of eighteen Russian-speaking Americans who accompanied the U.S. Technical Book Exhibit on a six-months' tour of Russian cities.

WILLIAM N. LOCKE

The M.I.T. Press

Technology Press, as we were known for thirty years, was a distinguished imprint. During most of this period it was provided with publishing services on contract by John Wiley and Sons, Inc. This year formal cooperation between the two organizations was amiably terminated, and, renamed, The M.I.T. Press became an independent, full-fledged university press seeking to serve the research and pedagogical missions of the Institute through book publication.

Throughout this transitional year, changes—more of scale than of purpose—consisted chiefly of adding new publishing services to well-established existing ones. The strain of these changes was sometimes visible to the naked eye.

Ideally The M.I.T. Press would publish research monographs and treatises deriving from and properly completing many of the Institute's varied research commitments; experimental texts and materials for the Institute's classrooms and laboratories; and as many good generalized books on highly technical subjects as it could find, for the benefit of those who would be generally educated—indeed, for the specialist who is in our time a layman in every field other than his own. Colloquially stated, the purpose of The M.I.T. Press is to be as useful to the Institute as a book publishing facility on the campus serving M.I.T. faculty and staff can be, and still stay in business.

During the past year total sales increased 25 per cent.

The Press published eighteen books independently and two in conjunction with the Harvard University Press. These titles are:

An Introduction to COMIT *Programming,* by VICTOR H. YNGVE. 1962. 62 pages, $2.00.
The purpose of the COMIT system for automatic digital computers is to minimize

or eliminate the delays inherent in the use of an intermediary programming specialist, by providing the user with a programming language that is so simple to use that he can prepare the programs himself.

COMIT *Programmer's Reference Manual,* by VICTOR H. YNGVE. 1962. 61 pages, $2.00.
This companion manual to *An Introduction to* COMIT *Programming* presents conventions for writing programs in COMIT and a description of how the computer interprets the instructions.

Varactor Applications, by PAUL PENFIELD, JR., and ROBERT P. RAFUSE. 1962. 623 pages, $15.00.
This book is a theoretical examination of the way in which series resistance affects varactor performance in many applications. It indicates the fundamental limits on performance and leads to the circuit conditions which must be met to achieve this optimum performance.

Synthesis of Optimum Nonlinear Control Systems, by HARRY L. VAN TREES. 1962. 102 pages, $4.00.
This study applies to Volterra functional expansion of the synthesis of nonlinear feedback systems. It specifies the optimum nonlinear filter for a given ensemble of random inputs or a particular fixed input and designs a compensator which will make the entire closed-loop control system stimulate this filter. (*An M.I.T. Press Research Monograph.*)

A Decision Structure for Teaching Machines, by RICHARD D. SMALLWOOD. 1962. 122 pages, $4.00.
This book describes a flexible and sophisticated decision structure which will endow the teaching machine with two highly significant capabilities of a human tutor: (1) it can adjust its presentation to the specific knowledge and capacities of the individual student, and (2) it can improve its own teaching technique with each new tutorial experience. (*An M.I.T. Press Research Monograph.*)

A Communications Theory of Urban Growth, by RICHARD L. MEIER. 1962. 192 pages, $4.50.
Professor Meier employs information-theory concepts to point out the intimate relationship between urban growth and increased capacity for communication.

Communication: A Logical Model, by DAVID HARRAH. 1963. 128 pages, $4.00.
This book shows how symbolic logic and semantic information can be used to analyze certain aspects of human communication. (*An M.I.T. Press Research Monograph.*)

Universals of Language, edited by JOSEPH H. GREENBERG. 1963. 269 pages, $6.00.
The papers deal with three main areas—phonology, grammar, and semantics—and represent both synchronic (distribution) and dischronic (historical) approaches. They consider the nature of language universals, methods for deriving them, and specific candidates for adoption.

Magnetohydrodynamic Shock Waves, by J. EDWARD ANDERSON. 1963. 226 pages, $6.50.
Any waves found to occur in nature must: (1) possess steady-state structures

and (2) be stable in the presence of small-flow disturbances. In this monograph the author examines these criteria in relation to plane shocks for which the collision frequency is large compared with cyclotron frequency.

Waves in Anisotropic Plasmas, by WILLIAM P. ALLIS, SOLOMON J. BUCHSBAUM, and ABRAHAM BERS. 1963. 280 pages, $7.50.
The many published researches on the propagation of waves in plasmas have resulted in a confusion of terminology and a variety of special assumptions applicable only to limited domains. This book tries to bring order out of this diversity, using phrase velocity diagrams and carefully indicating the resonances and cutoffs that bound the areas wherein each diagram is applicable. (*An M.I.T. Press Research Monograph.*)

Albania and the Sino-Soviet Rift, by WILLIAM E. GRIFFITH. 1963. 423 pages, $7.95.
The first full-scale analytical and documented treatment of Albania's break with the Soviet Union and alliance with Communist China.

Domestic Airline Efficiency: An Application of Linear Programming, by RONALD E. MILLER. 1963. 172 pages, $6.00.
This study applies linear programming methods to the examination of the efficiency of aircraft flight allocations in an important segment of the airline industry. (*A Regional Science Study.*)

Community and Contention: Britain and America in the Twentieth Century, by BRUCE M. RUSSETT. 1963. 252 pages, $7.00.
This careful study analyzes the bonds and the strains underlying the Anglo-American alliance, whose maintenance is vital to the free world. The author presents substantial evidence that, contrary to general belief, Britain and America are today less responsive or "close" than they were a few decades ago, that the bonds of the alliance are less strong than generally supposed and are probably growing weaker. Russett recommends specific policies for reversing this trend.

Ice and Snow: Properties, Processes, and Applications, edited by WILLIAM D. KINGERY. 1963. 684 pages, $16.00.
Chemists, ceramicists, metallurgists, physicists, and geologists join glaciologists in building a body of knowledge that will enable the more extensive and effective utilization of these widely available materials whose engineering potentialities remain generally unexplored.

Conflict and Conformity: A Probability Model and its Application, by BERNARD P. COHEN. 1963. 208 pages, $5.00.
The Asch experiments measuring the social pressures to conformity are well known. In the present monograph Dr. Cohen examines in detail the behavior which occurs in those experiments and describes the construction, testing, and application of a probability model for conformity—the "conflict model." (*An M.I.T. Press Research Monograph.*)

The Natural Resource Content of U.S. Foreign Trade, by JAROSLAV VANEK. 1963. 160 pages, $4.00.
Proposing a new mode of economic analysis for international trade, the author identifies and measures the economic forces that have shaped our foreign trade in natural resources since 1870.

Vice President, Research Administration

Impact Phenomena in Textiles, by W. JAMES LYONS. 1963. 208 pages, $5.00.
This is a summary of a half-century of study of textile behavior under impact loading.

The Communist Foreign Trade System, by FREDERIC L. PRYOR. 1963. 304 pages, $7.50.
To make more meaningful to the West the trade statistics and the rapid changes in trade policies of the Communist-bloc countries, the author describes and analyzes the process of planning and decision-making in the agencies controlling the foreign trade of the satellite countries. He relates the foreign trade of these nations to their domestic economies and their economic planning systems and explains how Communist-bloc countries have conducted trade among themselves and with the West.

Judged against its stated purpose, the record of the Press this year was one of partial achievement. Good procedures for editorial selection yielded books of high quality, albeit highly specialized works. Though monographic in character, they were useful—as their sales testify. But for the future, broader procurement and more selective construction of the publishing schedules must be undertaken to gain a better balance of monographic, text, and general books.

The Press has as a further ideal the full representation of the wide-ranging substantive and intellectual concerns of the Institute. The list this past year, as in previous years, reflects service to this ideal rather than its achievement, and in future years we hope that more comprehensively representative lists can be constructed—from linguistics and philosophy to mathematics, from history to the biological and physical sciences, and from economics to engineering.

The Research Monograph Series was augmented by seven volumes, bringing the number of these useful contributions, rapidly published, to a total of nineteen. The Press plans to expand the series substantially.

Obviously, experience is important to high standards of performance. The Press enjoys good experience in editorial and production services. As in the past five years, the Press continued to grant painstaking and expensive editing to its manuscripts destined for publication. It also designed and produced all of its books.

Among scholarly publishers, the Press has championed the marriage of suitable modes of production to varying subject matter. This year it was proud to make extensive use of typewriter and other "cold type" techniques for composition.

This year, also, a new colophon was created and its use begun.

Undertaken for the first time as Press functions were the promotion and sale, domestically and abroad, both by mail and by field representatives, of new and backlist titles. Commissioned sales agreements were drawn to provide sales representation for The M.I.T. Press books to roughly 800 book stores in the United States and to more abroad. Domestic sales held firm under new arrangements, but the historically high percentage (30 per cent last year) of Press books sold overseas fell during the year, and corrective measures will take at least another year, possibly two. Heavy routine promotion of Press books overseas, including advance information sheets on each new title to seven hundred foreign book stores, will be augmented so that nearly 3,000 foreign college and university libraries and more than a thousand booksellers gain early information about new titles.

If the Press is preoccupied at any given time with new books, it is also mindful at all times of its backlist. Among the books reprinted last year were:

Wavelength Tables, by GEORGE R. HARRISON. First published in 1939. M.I.T. Electrical Engineering Series Volumes. *Electric Circuits and Magnetic Circuits and Transformers*. 1943.

Index Fossils of North America, by HERVEY W. SHIMER and ROBERT R. SHROCK. 1944.

Methods of Operations Research, by PHILIP M. MORSE and GEORGE E. KIMBALL. 1951.

Aerodynamic Measurement, edited by ROBERT C. DEAN, JR. 1953.

The simple mechanics of starting to do business has high inertial costs in time and money. The path of sudden growth is not easy. To accommodate an increase in daily orders from ten a day in July, 1962, to well over one hundred a day during the spring peak order season required great energy on the part of the Press's business staff. Warehousing was contracted satisfactorily with Publishers' Shipping Company at Clinton, Massachusetts, and direct-line TWX creation of customers' invoices and shipping labels at Clinton, typed in the Press office, insured same-day order service to orders from Press customers throughout the world. For those who preferred to pay for M.I.T. Press books in sterling, a warehousing arrangement was contracted with The Book Centre in London, and continental and United Kingdom orders were shipped and billed from there. In short, the business transition was strenuous but satisfactory, in spite of the further disruption of an essential relocation from Building 20 to the Kendall Square Building at 238 Main Street.

A university press that measures its performance on any basis other than service to its parent institution is misguided, for its quantitative records may be significant but can never be critical. The following summaries are offered in this spirit:

M.I.T. Press Sales Summary, 1962-63

	Domestic		*Foreign*		*Total*	
New Titles (20)						
New units sold	17,738	85.1%	3,106	14.9%	20,844	36.7%
New titles, dollar sales	$91,275	86.7%	14,088	13.3%	105,363	36.2%
Backlist Titles (162)						
Backlist units sold	29,602	82.5%	6,295	17.5%	35,897	64.3%
Backlist dollar sales	$151,357	81.8%	33,823	18.2%	185,180	63.8%
Total units sold	**47,340**	**83.4%**	**9,401**	**16.6%**	**56,741**	**100%**
Total dollar sales	**$242,632**	**83.6%**	**47,911**	**16.4%**	**290,543**	**100%**

CARROLL G. BOWEN

National Magnet Laboratory

The third year of operation has been devoted to the occupancy of the new National Magnet Laboratory building, the installation and testing of the 10-megawatt power supply, the construction of high-field solenoid magnets, and the expansion of the solid-state research program. In the meantime, the relatively small 1.7-megawatt magnet facility that has been situated in Building 4 for many years has continued to function at its fullest capacity and will be used for solid-state research work during the next academic year. In the new building, the system testing of the new generators, control equipment, and magnets has extended through the summer of 1963. Operation of the facility is planned for the fall.

The formal dedication of the Laboratory building was held on April 30, 1963. The ceremony was attended by members of the M.I.T., Greater Boston, and Washington scientific communities. The sponsors of the Laboratory were represented by Major General Don R. Ostrander and members of his staff from the Air Force Office of Aerospace Research and representatives from the Air Force Office of Scientific Research. The Honorable Brockway McMillan, Under Secretary of the Air Force, made the dedication address. Dr. Eugene G. Fubini, recently selected as Deputy Director of Defense Research and Engineering, spoke in the evening at the dedication dinner.

Just preceding the dedication, the first meeting of the Scientific Advisory Committee of the National Magnet Laboratory took place.

This group, consisting of nine distinguished scientists representing universities, government, and industrial laboratories, will meet semi-annually to discuss technical and policy problems related to the operation of the Laboratory. The Committee will serve in an advisory capacity to the Director of the Laboratory and to its sponsors, and the Committee will devote its attention particularly to the role of the Laboratory as a national research center.

The fundamental research program on solid-state physics and the development of new magnet designs pursued by the Laboratory have progressed satisfactorily. Twelve technical articles have been published and twenty-six meeting papers have been presented on the solid-state research projects. The topics have included high-field antiferromagnetic resonance, cyclotron resonance, Zeeman effects and stress effects on the spectra of paramagnetic ions in optical maser crystals, operation of optical masers in high magnetic fields, oscillatory interband Faraday rotation and Voigt effects in semiconductors, high field Mőssbauer studies, magnetic-field influences on electroluminescence in gallium arsenide, and the search for the Dirac monopole. Theoretical papers have appeared on electronic polarizabilities, on the quantization of elementary particle masses, and on the dispersion in magneto-optical effects in semiconductors. Progress in high-field magnet design on both water-cooled magnets and superconducting solenoids has also been reported in several articles and meeting papers.

The cooperative program with outside institutions and other laboratories of the Institute has also been productive. The research has included the investigation of the energy-band properties of bismuth and mercury-cadmium telluride by magneto-optical methods, the magneto-tunnelling effect in lead selenide, and the high-field magnetoresistance in silicon. There was a program initiated to study the magnetic properties of the metals and compounds of the rare earth group in order to understand the interactions in ferromagnetic and antiferromagnetic materials more fully. This also included experiments on radiation-induced ionization in iron oxides. Large magnetic effects were found in the optical reflectivity of silver and graphite, and now the correlation of these findings with existing theoretical models of the energy bands is under way. The thermo-magnetic and thermoelectric properties of the semimetals bismuth and bismuth-antimony have been studied in high magnetic fields with the objective of developing more efficient refrigerating devices. The properties of superconducting alloys and elements for use in the development of high magnetic fields have been extensively investigated.

Vice President, Research Administration

These cooperative programs have been carried out by scientists from the M.I.T. Metallurgy Department and Lincoln Laboratory, the General Electric Research Laboratory, Minneapolis-Honeywell Research Center, Raytheon Research Laboratory, Bell Telephone Laboratories, and the I.B.M. Watson Research Center. Measurements of superconducting materials have also been made by faculty from McGill University and the universities at Lausanne and Giessen.

BENJAMIN LAX

Summer Session Office

The scope of activities during the 1962 Summer Session followed the pattern of previous years with the three principal components consisting of a series of Special Summer Programs, a limited number of regular academic subjects for undergraduate and graduate students, and professional conferences or symposia.

The specialized one- and two-week Special Summer Programs are designed to give professional people outside the Institute opportunities to keep pace with advances and trends in their fields. The total registration has varied in recent years as follows:

	1959	*1960*	*1961*	*1962*
Number of Programs	26	25	26	29
Total registration	1641	1838	1412	1763

It will be noted that the yearly fluctuation in enrollment is not related to the number of Programs offered. Rather, the variation is more dependent upon the timeliness of the individual Programs which comprise the series in any given year. For example, in 1962 a Program was offered in the exciting field of Optical Masers, and it was attended by 162 registrants. In addition, the popularity of the Special Summer Program series appears to follow the general level of economic activity, but at a lag.

In 1962, the principal change in the general character of the registrants in the Special Summer Programs was the distinct increase in the proportion of faculty members from other institutions. Through the School of Engineering we were able to offer Ford Fellowship grants to engineering faculty of other American universities and colleges. The plan was a flexible one, whereby available funds were used to defray those expenses which were not covered by the home institution. In most instances the grant paid only half of the total tuition fee which was due. For thirty men, however, we covered part or all of the travel and living expenses at M.I.T. A total of 112 individual awards were made from the grant. The recipients represented seventy-three different colleges or universities, and there were fellowship holders in twenty-five of the twenty-nine programs. The Summer Session Office received many favorable comments and letters from the recipients, so it would appear that the fellowship plan was highly successful.

The total registration of regular students has increased from 1,600 in 1960 to 1,748 in 1962, even though the number of individual subjects has remained constant. Approximately 75 per cent of the registrants are graduate students who are devoting part or all of their time to research. The Summer Session enrollment has thus increased with the expansion of the Graduate School.

Harvard University and M.I.T. were joint hosts for the Ninth International Congress of Linguists during the week of August 27 to 31. Professor William N. Locke served as Secretary General, and Kresge Auditorium was used as the headquarters. Many of the 800 conferees were housed in the dormitories.

Professor Arthur C. Smith of the Department of Electrical Engineering conducted a five-week program on Solid State Physics for academic staff of other institutions from June 25 to July 27. This program was supported by the Ford Foundation, and its attendance was limited to 24 persons.

Professor Robert W. Mann conducted, under the sponsorship of the National Science Foundation, a two-week summer conference in Engineering Design and Graphics Education from August 13 through 24, attended by 85 faculty members from other institutions. Also, the National Science Foundation and the Research Laboratory for Electronics sponsored a research training conference in Computer Techniques for Biological Scientists.

A one-week conference of the Council for Advancement of Small Colleges was conducted at Kresge Auditorium from August 6 to 10. M.I.T. provided housing for approximately 150 of the 200 conferees.

Each summer the Institute offers three functions of an entertainment nature for the summer session students. This past year we presented Jerome Kilty and Cavada Humphrey in *Dear Liar* on June 27, a program of folk songs by Richard Dyer-Bennet, on July 18, and an organ recital by E. Power Biggs on August 28. These events were received by large and enthusiastic audiences.

JAMES M. AUSTIN

VICE PRESIDENT

THERE FOLLOW the annual highlight reports of the directors of M.I.T.'s two largest associated research operations, commonly called the defense laboratories. These are the Lincoln and Instrumentation Laboratories, managed by M.I.T. in the national interest.

The national importance of these programs will be indicated to some extent by the brief accounts below. Their increasing contribution to the Institute's educational activities will also be noted.

JAMES MC CORMACK

Instrumentation Laboratory

The activities of the Instrumentation Laboratory for the past year can be best characterized as a continuing advancement of the state of the art in the fields of navigation, guidance, and automatic control. The application of these technologies to the changing requirements of spacecraft, missiles, aircraft, and ships has necessitated the development of new inertial components with even higher performance and reliability while operating in the most severe environments. The development of these components has lead to an intensification of activities in the basic fields of metallurgy, strength of materials, lubrication, and high vacuum phenomena.

The broad scope of these activities has provided productive fields of research for graduate students. During the past year the Laboratory has supported fifty-two theses in four departments, including five doctoral theses.

PROJECT APOLLO

The largest single effort in the Laboratory continues to be Project Apollo. The National Aeronautics and Space Administration's program to place a man on the moon by the end of this decade represents the greatest scientific, engineering, and industrial challenge ever undertaken, and it is one of this country's major space exploration efforts. N.A.S.A.'s principal contractor for the development and production of the Apollo Spacecraft is the Space and Information System Division of North American Aviation, Inc., which also has the final integration responsibilities for all systems associated with the Apollo Spacecraft. The Grumman Aircraft Engineering Corporation, as an associate contractor, has the responsibility for the development and production of the Lunar Excursion Module, the vehicle that lands two men on the moon. The M.I.T. Instrumentation Laboratory, also an associate contractor, is pursuing for the second year its task of design and development of the guidance and navigation system for the spacecraft and the Lunar Excursion Module. Each of the above participants is obligated to assist and coordinate its efforts with the others in order to achieve the best possible spacecraft system.

The effective integration and coordination of the Laboratory's research efforts in a program of such complication and sophistication in itself requires an extensive effort, in which the Laboratory is assisted by three participating contractors who are under contract directly to N.A.S.A. but under the technical direction of the Instrumentation Laboratory. The AC Spark Plug Division of General Motors Corporation has the responsibility for the construction of the inertial measurement unit and associated electronics and for integration of the system. The Raytheon Company will construct the digital computer that will translate the system's data into commands to keep the space vehicle on course. The Kollsman Instrument Corporation has the manufacturing responsibilities for an optical tracking system consisting of a sextant and telescope to perform the navigation functions of the mission. It should be noted that although these contractors are the primary manufacturing sources, the initial systems will be constructed by the Instrumentation Laboratory. These contractors have also substantially participated in the design and development effort in a close working relationship with the M.I.T. core effort.

The time schedule of the program has required that all aspects of the development of the Apollo Guidance and Navigation Equipment be worked on simultaneously with the theoretical problems of the mission. However, during this second year of effort on Apollo, it was felt that sufficient background research had been accomplished to permit concentration on the actual design and fabrication of the navigation and guidance system.

OTHER LABORATORY ACTIVITIES

The development of advanced systems and concepts for ballistic missiles is continuing. Research work supported by the Air Force Ballistic Systems Division has resulted in the development of a system involving new concepts and components which will meet the requirements of advanced types of ballistic missiles. It is anticipated that a program involving the use of this system as part of a complete weapons system will evolve in the near future. In addition, components developed under this program are being incorporated into a current weapons system.

The Laboratory continued the development of the guidance system for the 2500-mile Polaris missile under sponsorship of the Special Projects Office of the U.S. Navy. This effort is tapering off but will continue at a lower level during the next fiscal year. During the past year the Laboratory assisted the Navy in establishing Minneapolis-Honeywell and Hughes Aircraft Company as additional sources for producing these systems. This team will supplement the capabilities of the General Electric Company and Raytheon Manufacturing Company, which have been designated as the primary production source by the Navy.

The Laboratory continued the development of improved ship navigation systems for the Polaris program with industrial support from Nortronics, a division of the Northrop Corporation. In connection with this effort, a new miniaturized inertial navigation system was successfully tested at sea this year, demonstrating improved accuracy and the capability of operation for extended periods of time without external monitoring.

In addition, the Laboratory will continue research on new guidance equipment and techniques for the Navy. These efforts will be directed primarily towards improving the capabilities of the Fleet Ballistic Missile System, but several offshoots of this work have already shown potential application in other areas.

The PACE system previously developed by the Laboratory as an accurate navigation and guidance system for a hypersonic glide vehicle has been flight tested in a conventional aircraft. The results of this program were very encouraging, and an extension of the program to develop an accurate lightweight navigation system for inhabited aircraft is actively being considered by the U.S.A.F. Additional efforts in the field of military space applications involve the study of possible Titan III missions and studies related to the development of a standardized space guidance system.

Work is actively proceeding on advanced types of flight control systems for VTOL aircraft under sponsorship of the U.S. Army. Many VTOL aircraft are divergently unstable in one or more modes of operation, particularly at low speed. This requires extremely high level of pilot proficiency and limits operation to visual flight conditions. The purpose of this program is to develop flight control systems capable of providing optimum control characteristics under all operating conditions so that the full military potential of VTOL aircraft may be realized. The results of analytical studies indicate that it is possible to design a pilot-commanded automatic flight control system using inertial techniques which will increase the control precision of the aircraft to a point where flight under the worst weather conditions should be easier than flight under optimum conditions with present-day manual control systems. A turbine-power tandum-rotor helicopter is employed in the flight test of this system.

CHARLES S. DRAPER

Lincoln Laboratory

As we enter the year 1963-64, the pattern of the Laboratory effort is becoming more sharply focused on two major fields, re-entry technology and space communications. Our work in these fields rests on a broad foundation provided by our general research program in the fields of solid-state physics, chemistry, and metallurgy; radio physics and astronomy; radar; communications; and data systems. This general research program is pursued at a level corresponding to one-third of our technical staff. We are also continuing a small program for N.A.S.A. on the electronic environment for Project Apollo.

The most noteworthy recent event at Lincoln Laboratory was in space communications—the initiation in May of the Project WEST FORD experiment, to evaluate the feasibility of using radio signals scattered back to earth from a thin orbital ring of tiny microwave dipole fibers. The orbital scatter communication technique being investigated offers great promise for providing a hard core of long-distance communication, immune to accidental or intentional interruption. The successful results of the experiment to date indicate that all of the essential objectives of Project WEST FORD will be met.

The preparatory work for this experiment has stimulated progress in radar and communications technology. The California WEST FORD transmitter produces average power of 40,000 watts, many times as much as could be generated in the 8,000-megacycle range only a few years ago; and the Massachusetts terminal, with its maser receiver, can detect moon-reflected signals sent from California with a transmitted power of only 0.005 watt; performance of this character is essential to the WEST FORD experiment in which the receiving antenna will intercept only about one part in 10^{20} of the transmitted energy. Time-delay and frequency distortions introduced by the scattering medium have required the development of new modulation techniques for teletype, voice, and high-speed digital communication. In a popular practical demonstration about a month before the experiment began, clean, clear teletype copy was sent from the California site to the Royal Aircraft Establishment at Farnborough, England, some 5,300 statute miles away, using the moon as a passive communication satellite.

A new technique for error-free transmission of digital data at unprecedented high rates was demonstrated over an 800-mile toll-grade telephone circuit from Lincoln Laboratory to Syracuse, New York, and back. The basic concept, sequential decoding, was proposed in an M.I.T. doctoral thesis in 1957; its electronic implementation at Lincoln Laboratory was stimulated by WEST FORD communications developments. The recent telephone-circuit test is particularly significant in that it was the first demonstration in practice of a truly adaptive electronic system for communication, a system that constantly senses the prevailing condition of the communication medium and continually adjusts its performance to utilize the medium with unusually high efficiency.

Several important steps were taken toward making available the generous bandwidths at optical frequencies. A gallium arsenide diode that acts as a simple, efficient, easily modulated source of intense infrared light was used to send voice and video signals over a distance of thirty nautical miles. Last fall a diode of this type was made to produce a coherent optical radiation and became one of the first of a new type of optical masers. This spring, coherent radiation at a wavelength about four times that of gallium arsenide was obtained from indium arsenide. Intermediate wavelengths have been obtained with mixed crystals of these compounds. Fine tuning has been accomplished by means of an externally generated magnetic field.

Our re-entry technology program also spans the broad range of the electromagnetic spectrum from microwaves to optical radiation. It encompasses three areas of current research activity—re-entry physics and Project PRESS, radar discrimination technology, and ballistic missile re-entry systems. Many of the findings are applicable to the improvement of our strike capabilities as well as to the problems of defense against ballistic missiles.

Field measurements of re-entry phenomena play an important role in this program. Two such programs have come into operation on a substantial scale this year. Radar and optical measuring equipment at Kwajalein Atoll in the Marshall Islands, designed and installed for Project PRESS, has been used to observe a number of exercises on the Pacific Missile Range; the PRESS operations are directed by a Lincoln team that has been in residence at Kwajalein, many with their families, for more than a year.

On almost the opposite side of the world from Kwajalein, at Arbuckle Neck near Wallops Island, Virginia, a large spectrometric telescope with unusual capabilities for tracking and for optical analysis and measurement was added to the existing array of radars and camera equipment. We are also preparing to participate on a substantial scale in a third field measurement program getting under way at White Sands, New Mexico. All of these efforts are guided and supported by theoretical and experimental work in the Laboratory, which provides the scientific foundation for the design of the field experiments and the interpretations of results.

In radar astronomy, Venus was observed by our solar radar at El Campo, Texas, at a frequency of 38 megacycles per second, almost ten times lower than any radar observations previously reported. The first observations of lunar reflectivity at 35,000 megacycles per second, almost four times as high a frequency as any previously reported, were made with a new radar on the roof of the Laboratory in Lexington. Highlight radar reflections from a localized region of the lunar surface, observed in data taken last year at Millstone Hill, were identified as coming from the crater Tycho, which is only 55 miles in diameter.

Interactions between the Laboratory and the campus continue to broaden at both faculty and student levels. Nothworthy during this past academic year was the establishment of research assistantships at Lincoln for a modest number of graduate students.

During the academic year of 1962-63 approximately 60 per cent of our budget was used to purchase research and development work, goods, and services from outside suppliers and contractors.

In February, Professor Wilbur B. Davenport, Jr., rejoined the Laboratory as Assistant Director, after serving for two and a half years on the faculty of the Department of Electrical Engineering and as Associate Director of the Research Laboratory of Electronics. He is working closely with Professor Radford and me on the management of all aspects of our technical program. Dr. John V. Harrington, Head of our Radio Physics Division, left the Laboratory to become Professor in the Departments of Electrical Engineering and of Aeronautics and Astronautics and Director of the Institute's new Center for Space Research.

CARL F. J. OVERHAGE

VICE PRESIDENT AND TREASURER[1]

The introductory statement to the financial report for 1962-63 includes sections on operations, gifts, funds, plant facilities, and investments. Immediately following, on pages 490 and 491, the balance sheet as of June 30, 1963, presents the resources of the Institute, and on page 494 the revenues and funds used to meet current operating expenses in 1962-63 are summarized. The exhibit on pages 492 and 493 showing the changes in fund resources during the year and the funds at the beginning and close of the year illustrates the main financial developments in 1962-63 and the position of M.I.T. on June 30, 1963.

Operations

The operations of the Institute in 1962-63 and in 1961-62 are set out in the exhibit at the top of the next page.

The greater part of the direct expenses of the departmental and interdepartmental research is under the supervision of the academic

[1] The complete report of the Vice President and Treasurer, including schedules supporting those printed on the following pages; the list of gifts, grants, and bequests received during the year 1962-63; 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.

	1962-63	1961-62
Educational and general activities:		
Revenues and funds:		
Tuition and other income	$10,726,000	$ 9,246,000
Endowment investment income	2,014,000	1,887,000
Gifts, investment income, and other receipts	6,592,000	6,957,000
Allowances for indirect expenses	12,224,000	10,847,000
Dining and student housing	2,201,000	2,096,000
Total	$33,757,000	$31,033,000
Expenses:		
Academic departments	$13,016,000	$11,876,000
General and administration	13,599,000	12,648,000
Plant operations	4,941,000	4,413,000
Dining and student housing	2,201,000	2,096,000
Total	$33,757,000	$31,033,000
Direct expenses of general departmental and interdepartmental sponsored research met in the same amount with revenues from sponsors	$25,014,000	$19,440,000
Direct expenses of major laboratories and special departmental research met in the same amount with revenues from sponsors	$72,558,000	$57,480,000

departments, and some but a lesser part of the direct expenses of the major laboratories is similarly supervised. To provide a more complete statement of operations for the Institute as a whole, the expenses and corresponding reimbursement for the major laboratories and special departmental laboratories are included in the foregoing summary and in the exhibit on revenues and funds and expenses on page 494. While inclusion of these activities is proper financial and accounting treatment, the effect tends to distort the research related to graduate education at the Institute.

General and administration expenses of $13,599,000 for 1962-63 apply to all of the operations of M.I.T. including sponsored research activities. For example, of the total general and administration expenses, $6,095,000 was represented by retirement, insurance, and other benefits applicable to all of the employees of the Institute. Research general and administration expenses of $2,715,000 not included in Institute-wide general and administration expenses were financed entirely in 1962-63 by research revenues and consisted in large measure of vacation allowance accrued expenses related solely to sponsored research. Plant operations of $4,941,000 in 1962-63 provide for the expense of total plant facilities, including those facilities devoted in whole or in part to sponsored research, with the exception of Lincoln Laboratory housed in government-provided buildings. The direct expenses of sponsored research were met from revenues received from the government agencies, industrial companies, and others supporting this research during the year.

As in previous years, the Institute used the "income availed-of" method of accounting in the statement of revenues and funds and expenses for 1962-63. Under this procedure, all tuition receipts, the total of receipts for the direct expenses of sponsored research, essentially all of the total allowances for indirect expenses, and dining and housing receipts are applied against the current expenses of the year. In contrast, endowment income and gifts, investment income, and other receipts represent in part receipts from prior years used in the year under review, with part of the receipts from these sources remaining for use in subsequent years.

In addition to endowment investment income as included in revenues and funds, 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.

Gifts

The gifts for 1962-63 are compared to 1961-62 in the following table.

	1962-63	*1961-62*
Gifts for endowment	$ 1,245,000	$ 2,764,000
Gifts for buildings	2,990,000	375,000
Gifts for current use — invested	8,684,000	9,595,000
Industrial Liaison Program	2,044,000	2,043,000
Other funds for current use	2,516,000	2,914,000
Total gifts	$17,479,000	$17,691,000

Contributions to the Second Century Fund received in 1962-63 were $13,252,000 included in the total of $17,479,000 of gifts, contributions, and bequests for the year. In 1961-62 the gifts received for the Second Century Fund were $13,175,000. Endowment gifts were largely for the support of faculty salaries and increased student aid. Gifts were received during the year for part of the cost of a building for chemistry, for the women's residence, and for the structure now being planned for the School of Industrial Management and Department of Economics and Social Science. Contributions for current use provided for major support of the educational programs of the academic departments.

The gifts directly to the Alumni Fund of $429,000 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 will be found in the Treasurer's Report Issue (September, 1963) of the *Massachusetts Institute of Technology Bulletin.*

Funds

Endowment and other funds increased by $15,133,000 during 1962-63.

	1962-63	*1961-62*
Endowment for general purposes	$ 38,759,000	$ 38,243,000
Endowment for designated purposes	34,124,000	32,861,000
Total endowment funds	$ 72,883,000	$ 71,104,000
Building and expendable funds	41,140,000	34,212,000
Other funds	35,985,000	29,559,000
Total funds	$150,008,000	$134,875,000

The increase in building and expendable funds was attributable to gifts and grants received during the year for future additions to educational plant and operating expenses. The year-to-year change in other funds in the foregoing table represents largely the results of investment operations during 1962-63.

On June 30, 1963, investment income set aside for 1963-64 was $6,030,000, and unallocated investment income was $3,833,000. The general investments gain and loss account on the same date was $11,464,000, increased from $7,923,000 on June 30, 1962. Including retirement funds, the total book value of the funds on June 30, 1963, was $184,518,000.

Plant Facilities

During the year the educational plant increased from $51,856,000 to $59,334,000, due primarily to further construction progress on the earth sciences building, the women's residence, and the married student housing project on the West Campus. Since the National Magnet Laboratory is government property, the construction cost does not appear in the plant account. Construction of the Center for Materials Science and Engineering was underway at the end of the year.

Continuing the trend of recent years, some plant assets added in 1962-63 are being financed on a long-term basis from future sources of income and contributions. Major additions to plant facilities during the year were financed from resources provided by the federal government and matched in substantial measure by funds provided to the Institute from private sources. The married student housing development, on which construction continued during 1962-63, was financed with government funds, and a loan of $3,000,000 was negotiated during the year with the Federal Housing and Home Finance Agency for further additions to student facilities at the Institute. Construction in process or contracted for is covered by funds on hand, grants to be made to the Institute, or pledges to the Second Century Fund.

Investments

The investments of the Institute on June 30, 1963, and June 30, 1962, 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, 1963		*June 30, 1962*	
	Book Value	*Market Value*	*Book Value*	*Market Value*
General investments:				
Bonds	$ 68,399,000	$ 68,378,000	$ 62,528,000	$ 61,869,000
Stocks	35,100,000	107,697,000	34,241,000	86,070,000
Real estate	13,478,000	13,478,000	13,505,000	13,505,000
Commercial paper	4,213,000	4,213,000	1,482,000	1,482,000
Special interest bank accounts	10,385,000	10,385,000	6,056,000	6,056,000
Total	**$131,575,000**	**$204,151,000**	**$117,812,000**	**$168,982,000**
Special investments	10,110,000	20,391,000	10,995,000	13,828,000
Student notes receivable	4,434,000	4,434,000	3,912,000	3,912,000
Total	**$146,119,000**	**$228,976,000**	**$132,719,000**	**$186,721,000**

The investment portfolio of the Institute reflects to an important degree the substantial part of the funds of the Institute that are expendable and temporarily invested with the permanent funds of M.I.T. Funds sharing in the income from the general investments earned 6.51 per cent on the average book value of the funds, and 5 per cent was allocated to the endowment funds in 1962-63. Of the total investment income of the year, $2,013,000 was used directly for current expenses; $1,507,000 was added to balances of expendable funds which in turn were used for current operating expenses to the extent of

$2,429,000; and $794,000 was added to funds for scholarships, loans, and buildings.

The increase in the market value of the special investments as related to book value was due in part to the revaluation of a substantial common stock holding where a market value was established.

The investments of the M.I.T. Pension Association, the Supplementary Retirement Plans, and the Retirement Plan for Employees on June 30, 1963 and June 30, 1962 are presented in the following exhibit.

	June 30, 1963		*June 30, 1962*	
	Book Value	*Market Value*	*Book Value*	*Market Value*
Pension Association	$17,926,000	$24,613,000	$15,752,000	$20,082,000
Supplementary Retirement Plan — Fixed Benefit Fund	9,264,000	10,595,000	8,030,000	8,628,000
Supplementary Retirement Plan — Variable Benefit Fund	1,347,000	1,440,000	574,000	532,000
Retirement Plan for Employees	5,440,000	5,816,000	4,023,000	4,129,000
Total	$33,977,000	$42,464,000	$28,379,000	$33,371,000

General

At the close of the fiscal year 1963, the invested funds and plant of the Institute together were $207,000,000 as compared with $183,000,000 at the end of the previous fiscal year, $132,000,000 five years ago, and 93,000,000 ten years ago.

On June 30, 1963, over two-thirds of the gifts related to the Second Century Fund had been received in the form of securities, cash, or other property, and these assets make up an important part of the total resources of the Institute.

Gifts and bequests received during the five years 1959 through 1963 were $77,000,000, due largely to the success of the Second Century Fund, compared with $39,000,000 during the five years ended in 1958 and $31,000,000 during the period 1949 through 1953.

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, 1963.

Schedule B—Sources of Revenues and Funds Used to Meet Expenses of Current Operation for the Year Ended June 30, 1963.

Schedule C—Statement of Funds for the Year Ended June 30, 1963.

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, 1963, 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 6, 1963

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, 1963, and their certificate is submitted herewith.

Respectfully,

THEODORE V. HOUSER
WILLIAM WEBSTER
GILBERT M. RODDY, *Chairman*

Schedule A: Balance Sheet, June 30, 1963

INVESTMENTS			
General investments:			
U. S. Government bonds		$29,585,500	
Other bonds		38,813,572	
Preferred stocks		1,330,005	
Common stocks		33,769,863	
Real estate (including $4,930,968 devoted to Institute use) and mortgages		13,478,612	
Commercial paper		4,212,515	
Special interest bank accounts		10,385,195	
		(A-1)	$131,575,262
Investments of funds separately invested		(A-2)	10,109,714
Students' notes receivable		(A-13)	4,434,300
Total investments			$146,119,276
Uninvested cash			477,804
			$146,597,080
CURRENT AND DEFERRED ASSETS			
Cash:			
General purposes		$ 2,833,383	
Restricted to certain contracts		672,633	
Students' safe-keeping deposits		77,474	$ 3,583,490
Accounts receivable:			
U. S. Government	(A-14)	$ 5,781,799	
Other	(A-14)	1,394,895	7,176,694
Contracts in progress, principally U. S. Government		(A-15)	16,780,512
Deferred charges and other assets		(A-16)	4,551,075
Advanced for educational plant			569,534
			$ 32,661,305
EDUCATIONAL PLANT			
Land, buildings, and equipment		(A-20)	$ 59,334,344
Temporary investment — cash and U. S. Treasury Bills			806,881
			$ 60,141,225
			$239,399,610

INVESTED FUNDS:

Endowment funds:			
Income for general purposes	(A-3)	$38,758,920	
Income for designated purposes	(A-4)	34,123,590	$ 72,882,510
Student loan funds	(A-5)		6,125,686
Building funds	(A-6)		3,343,044
Other expendable funds			
General purposes	(A-7)	$ 9,986,606	
Designated purposes	(A-8)	27,810,493	37,797,099
Unexpended endowment income for designated purposes	(A-4)		2,000,842
Agency and annuity funds	(A-9 and A-10)		3,120,770
General investments — gain and loss account	(A-11)		11,463,939
Investment income for distribution to funds	(A-12)		6,030,000
Unallocated investment income	(A-12)		3,833,190
			$146,597,080

CURRENT LIABILITIES AND FUNDS

Accounts payable		$ 4,338,543	
Accrued wages and vacation allowances		1,521,467	
Withholdings, deposits, and other credits	(A-17)	1,682,311	
Students' advance fees and deposits	(A-18)	386,359	
Students' safe-keeping deposits		77,474	
Advances by the U. S. Government for certain research contracts		15,250,000	
Total current liabilities			$ 23,256,154
Grants for sponsored research			5,994,538
Gifts and other receipts for current expenses	(A-19)		3,410,613
			$ 32,661,305

EDUCATIONAL PLANT CAPITAL

Note payable to bank		715,000
Dining facilities bonds, 3⅛% due 1962-1999 ($655,000 U. S. bonds are in escrow as collateral)		394,000
Married student housing mortgage bonds, 1961, 3½% due 1964-2001		3,000,000
Advanced from general purpose cash		569,534
Endowment for educational plant	(A-12)	55,462,691
		$ 60,141,225
		$239,399,610

Schedule C: Statement of Funds for the year ended June 30, 1963

		Balance June 30, 1962
Endowment funds:		
Income for general purposes	(A-3)	$ 38,242,796
Income for designated purposes	(A-4)	32,860,781
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
Unexpended endowment income for designated purposes	(A-4)	2,008,399
Agency and annuity funds	(A-9, A-10)	2,927,139
General investments — gain and loss account	(A-11)	7,922,733
Investment income for distribution to funds	(A-12)	5,250,000
Unallocated investment income	(A-12)	2,880,284
Total invested funds		$131,501,597
Gifts and other receipts for current expenses	(A-19)	3,373,550
		$134,875,147

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 operation .....
Gifts, investment income, and other receipts used to meet expenses of current

Scholarship and fellowship awards ....
Expenditures for buildings added to educational plant ....
Direct research costs charged to gifts designated therefor ....
Expenditures of service activities and other charges to funds not representing

* Investment income on endowment funds for designated purposes is included under the caption "Unexpended endowment income for designated purposes."

Statement of Funds

Gifts and Other Receipts	*Investment Income*	*Transfers In-(Out)*	*Expenses*	*Other Charges*	*Balance June 30, 1963*
$ 67,013	$1,915,792	$ (200,994)	$1,265,678	....	$ 38,758,920
1,180,034	*	83,025	....	$ 250	34,123,590
562,642	68,708	329,080	30,795	1,700	6,125,686
2,989,757	59,384	1,084,271	125,204	2,611,870	3,343,044
4,484,630	307,162	(2,217,218)	303,959	169	9,986,606
6,220,956	1,200,262	1,997,078	2,125,147	4,031,504	27,810,493
2,555	1,817,375	(463,026)	747,791	616,670	2,000,842
168,455	143,706	(1,024)	....	117,506	3,120,770
3,541,206	....	....	....	....	11,463,939
....	(4,901,637)	5,681,637	....	....	6,030,000
....	6,634,543	(5,681,637)	....	....	3,833,190
$19,217,248	$7,245,295	$ 611,192	$4,598,583	$7,379,669	$146,597,080
6,907,004	....	(611,192)	4,007,322	2,251,427	3,410,613
$26,124,252	$7,245,295	....	$8,605,905	$9,631,096	$150,007,693

$17,479,124
1,230,173
3,873,551
1,119,775
2,421,629
$26,124,252

....	$2,013,478
operation	6,592,427
	$8,605,905

....	$2,142,499
....	5,768,219
....	504,262
operating expenses	1,216,116
	$9,631,096

Schedule B: Sources of Revenues and Funds Used to Meet Expenses of Current Operation for the Year Ended June 30, 1963

EDUCATIONAL AND GENERAL

Sources of revenues and funds used:		
Tuition and other income	(B-1)	$ 10,726,037
Endowment investment income	(B-2)	2,013,478
Gifts, investment income, and other receipts	(B-2)	6,592,427
Contract allowances for general and administration expenses and plant operation expenses (see below)	(B-3)	12,223,873
Dining and student housing	(B-7)	2,201,173
		$ 33,756,988
Expenses of current operation:		
Academic departments	(B-4)	$ 13,015,663
General and administration	(B-5)	13,599,079
Plant operation	(B-6)	4,941,073
Dining and student housing	(B-7)	2,201,173
		$ 33,756,988

SPONSORED RESEARCH

Revenues:		
General departmental and interdepartmental research		$ 31,183,970
Major laboratories and special departmental research:		
Lincoln Laboratory		53,045,920
Instrumentation Laboratory		29,277,395
Other research:		
Operations Evaluation Group		127,329
	(B-3)	$113,634,614
Expenses:		
Salaries and wages	(B-3)	$ 40,990,964
Materials and services	(B-3)	41,618,914
Subcontracts	(B-3)	14,961,777
Research general and administration expenses	(B-3)	2,715,392
Allowances for general and administration expenses and plant operation expenses	(B-3)	12,223,873
Allowance for use of facilities and other reserves	(B-3)	1,123,694
		$113,634,614

VICE PRESIDENT, OPERATIONS AND PERSONNEL

THE SUCCESS of the Second Century Fund is increasingly felt in M.I.T.'s operations and personnel activities. The translation of these new resources into physical terms has had a profound effect on the whole Institute community. The quickening tempo of detailed planning decisions, the disruptions occasioned by a host of construction activities, and the staffing of and movement into new facilities have called for and received a high degree of cooperative effort. Our environment will continue to seethe in such respects for the next several years as we adjust to our current physical expansion; throughout the brief summaries that follow, the effects of this can be observed.

Personnel

Employment of personnel exclusive of faculty and academic staff increased 11 per cent during the fiscal year to a total of 6,132 employed; of these, more than 4,500 were engaged in sponsored research activities at the Lincoln Laboratory, the Instrumentation Laboratory, the interdepartmental laboratories, and the various academic departments. The greatest growth occurred at the Instrumentation Laboratory, where employment increased 29 per cent to more than 1,500, largely as a result of the Laboratory's commitment to the National

Aeronautics and Space Administration. To meet the expanding needs of the Institute and to replace those who terminated during the year, more than 1,500 new personnel were added to the non-academic staff.

More than 2,000 hourly-paid personnel, represented by four different labor unions, received 4 per cent wage increases on July 1, 1962, under the terms of two-year contracts which also provided for 3.5 per cent increases on July 1, 1963. Appropriate changes were also made in the salary structures of other groups at the Institute, and individual salaries were adjusted on a merit basis. As a result of a study of the rates charged by hospitals in the area, the allowance for hospital room and board under the hospitalization and medical insurance program was increased.

Major emphasis was given to the problems of maintaining equitable compensation standards among the Institute's diverse and expanding activities, since a wide variety of skills are employed under varying administrative and organizational arrangements. A committee with Professor Douglass V. Brown of the School of Industrial Management as chairman was appointed to study and make recommendations upon the levels and inter-relationships of salaries and benefits provided to administrative personnel throughout the Institute. A joint committee was established with the M.I.T. Employees' Union to study classification descriptions and promotional procedures applying to the more than 1,400 personnel represented by the Union. The committee is being assisted by Professor Donald White of the Boston College School of Business Administration and Professor Lon Fuller of the Harvard Law School. A similar arrangement was made with the Building Service Employees' International Union, A.F.L.-C.I.O., to study wage differentials applying to personnel represented by that Union.

The Personnel Policy Committee met regularly during the year to review wage and salary levels, benefit plans, and other personnel policies and practices. This Committee, which includes representatives from the faculty, the administration, and the Defense Laboratories, is responsible for policy recommendations which aid the Institute in maintaining an effective and appropriate personnel program.

Planning

During the last year the Planning Office has concentrated on implementing the Institute's long-range plans, developing programs for new projects, and coordinating within the M.I.T. community and with the City of Cambridge the thirty-five projects currently under planning and execution.

To be completed this fall are two residential projects, the Women's Dormitory and Married Student Housing. Related to these two West Campus projects is the creation of a new mall extending from Burton House to Westgate. This mall, part of a long-range landscape plan for West Campus, utilizes trees removed from the site of the Student Center.

Planning is now complete on a number of projects, including the Center for the Life Sciences, the Student Center, and facilities in the recently acquired Daggett properties for a number of administrative services; these will be under construction in the fall. Planning is underway for a number of other important projects, including another M.I.T. parking facility, a new building for the social sciences and management, the Center for Space Research, a Center for Advanced Engineering Study, a new chemistry building, a Center for the Communications Sciences, a Graduate Center, a High-Energy Center, a new Boathouse, additional Married Student Housing, a new Linear Accelerator, additions to the East Campus dormitories, a new undergraduate house, and a number of important space changes within the Institute's existing buildings.

This year, in connection with its new responsibilities to the Vice President for Academic Administration and the Provost's Committee on Research and Space Planning, the Planning Office has begun to conduct studies in floor space utilization and allocation. In addition, the Planning Office and the *ad hoc* Faculty Environment Committee have undertaken a major study of faculty and staff housing. It is hoped that the information provided by this study will ultimately improve housing conditions for the M.I.T. community in Cambridge.

Construction Activities

There follows a brief description of the major projects on which construction was completed or in progress during the past year.

Psychology Building. The reconstruction of the former Central Scientific Company property on Ames Street was completed in October, 1962, at a cost of approximately $650,000. This building provides 36,000 square feet of space for teaching and research in the behavioral sciences and includes graduate and undergraduate laboratories, seminar rooms, observation, testing, and office facilities.

Cyclotron. A new Cyclotron building was begun in May, 1962, and was completed and put into operation in February, 1963. The structure, which houses the original cyclotron and vault, increases available research space by 9,000 square feet.

Nuclear Engineering Facilities. The renovation of 20,000 square feet of floor area in the former Ward Building on Albany Street is approaching completion. This project, involving approximately $300,000, will provide additional facilities for the Institute's nuclear engineering activities.

Magnet Laboratory. In November, 1961, a contract was awarded for the complete renovation of 140,000 square feet of floor space in the building at 140 Albany Street. The project provides facilities for the National Magnet Laboratory and includes a power plant, magnet research areas, preparation laboratories, assembly areas, and administrative and faculty office space. An extensive cooling system, capable of handling 25,000 gallons of Charles River water per minute, was a major construction project. Initial occupancy of the building took place in September, 1962; the completed facility was dedicated in the spring of 1963.

Radiochemistry Facility. Renovation of 13,000 square feet of floor space in the former Ward Building on Albany Street to provide laboratory and office space for research in radiochemistry began in April, 1962, and was completed late in the fall of that year.

Dormitory for Women. Construction work on the seven-story dormitory for women began in February, 1962, and will be completed in the summer of 1963. This facility accommodates 116 women students in 70,000 square feet of floor space which includes lounges, a master's suite, guest rooms, and administrative facilities. It is scheduled for dedication and initial occupancy in the fall of 1963.

Married Student Housing—Westgate. In January, 1962, construction began on a sixteen-story tower and four three-story buildings which together will provide 210 apartment units for married students in 90 efficiency, 60 one-bedroom, and 60 two-bedroom units. The tower contains 120,000 square feet of space and the low-rise buildings contain an additional 49,000 square feet. The entire project, located at the west end of the campus, is financed by a self-liquidating, low-interest government loan and will be completed in the fall of 1963.

Green Center for the Earth Sciences. Current schedules indicate that this twenty-story structure will be topped out early in the fall of 1963. Completion and occupancy of the building are anticipated early in 1964. This $5,000,000 facility will provide 125,000 square feet of floor space allocated principally to geology, geophysics, meteorology, and oceanography and includes laboratories and specialized supporting facilities, a library, an auditorium, offices, seminar rooms, and classrooms.

Parking Garage Number 2. In February, 1963, work began on the second of several structures planned to alleviate the Institute's critical parking shortage. This $1,000,000 facility, scheduled for use early in 1964, is of open design and will provide 188,000 square feet of floor area for parking and associated services. One parking level below grade and four levels above grade will accommodate 425 cars.

The Daggett Buildings. Remodeling of the former Daggett buildings on Main and Ames Streets began in the spring of 1963 and is scheduled for completion late in 1964. Ultimately, the facility will house a number of administrative activities, including the Bursar's Office, the Accounting Office, the Payroll Office, the Personnel Office, and the Department of Physical Plant; certain academic and research activities, including Toxicology and Pathology Laboratories and a Clinical Research Center associated with the Department of Nutrition and Food Science; and appropriate commercial occupants in areas not currently assigned to specific Institute use.

Center for Materials Science and Engineering. Construction work began in April, 1963, on a five-story Center for Materials Science and Engineering which will provide more than 150,000 square feet of floor area for laboratories, offices, seminar rooms, shops, and associated services. This structure, scheduled for occupancy early in 1965, is located north of Buildings 3, 10, and 4 in the former main parking lot.

Plant Operations

The demands on the operating sections of the Department of Physical Plant have increased steadily during the past year. During this period the Heating and Ventilating Section has been reorganized to accommodate the rapid increase in air conditioning and ventilating requirements resulting from major construction and renovations. As new space is created and existing space is modernized, service demands of all kinds are increasing rapidly.

A number of new buildings and facilities have come onto the line during the past year as outlined above. These have all been organized and staffed and are under full building operation management.

The new facilities will require an increase in our power plant steam capability; new boiler capacity is planned to be ready for the heating season of 1964-65.

The number and diversity of special events taking place at the Institute continue to increase. This proliferation of M.I.T. activities calls for additional effort in handling the housekeeping and operational details necessary to their success.

Plant Safety

The Safety Office reports that figures for both occurrence and severity of accidents are down for the 1962-63 period, with marked reductions in the number of injuries reported and in the severity of these injuries.

The fire safety features of the dormitory system were upgraded, with fire alarms installed in East Campus and the Burton House sprinkler system extended to include two additional wings. An automatic sprinkler was installed in the Building 14 basement stack area. Modernization of the Institute fire alarms and fire detection systems continues.

A hazardous waste chemical pick-up service was instituted. The utilization of this service by laboratories continues to grow.

"Safe Talk," a safety bulletin distributed periodically to all personnel, was started on a trial basis last year. It seems to have been well received and will continue.

The deficiency in water pressure in our fire mains has been alleviated with the installation of an automatic 500-gallon-per-minute fire pump which, along with a small booster pump, maintains yard pressure at 80 pounds, in contrast to the city water pressure of approximately 42 pounds.

Student Services

HOUSING

The Institute residence system, which now accommodates approximately 2,000 undergraduate and graduate male students, continues to benefit from the physical improvements made possible by the Alumni Fund and the Second Century Fund. Students returning to campus last fall found a dozen new single and double rooms at Baker House; senior tutor accommodations were also provided for the first time. Conner Hall's remaining outdated washrooms were renovated, and all public areas were redecorated. A new House Library was installed in Burton House through the gift of an alumnus.

The Talbot Lounge within the East Campus dormitory complex was completely redecorated and refurnished. In the Senior House, badly in need of communal and recreation space, Crafts basement was renovated into a pleasant panelled meeting and social room. Graduate House, likewise, benefited by the renovation of outdated basement facilities into new recreation-communal space; and extensive renovation of the Graduate House master suite welcomed Dr. and Mrs. Francis Bitter upon their assumption of the Master's responsibilities.

This year we look forward to the new on-campus residential facilities mentioned above—the Institute's first residence for women and the new Westgate apartments, both scheduled for occupancy this fall. The former will provide outstanding residence and social facilities for 116 undergraduate and graduate women, more than half of M.I.T.'s present enrollment of women students; the new Westgate married student apartments provide 210 apartments, in contrast to the present enrollment of married students of more than 1,500.

DINING

The Institute dining service, under the management supervision of the Stouffer Corporation, continues to provide quality meals at economical rates to students and employees at Walker Memorial, Graduate House, Baker House, and Burton-Conner Hall. Since its completion in the summer of 1961, the Burton-Conner dining room has enabled 560 residents to dine together within their own house. An additional campus dining facility in the new women's residence will open this fall. Its food services, in contrast to those of the men's dormitories, will operate seven days a week rather than five. Planning for the Student Center, soon to be constructed, includes extensive communal and private dining facilities for the Institute community, with continuing emphasis on providing the widest range and variety of quality food services at economical rates.

Administrative Services

THE GRAPHIC ARTS SERVICE

Continued expansion has characterized the operations of the Graphic Arts Service at 211 Massachusetts Avenue during the past year. With the transfer of the Illustration Service on July 1, 1962, Graphics Arts now has available complete reproduction facilities from drafting to addressing and mailing. The addition of automatic equipment in the press room and bindery has increased production and provided better service at a lower cost.

Vice President, Operations and Personnel

AUDIO-VISUAL SERVICE

The Audio Visual Service has had a most successful year with continued improvements in both equipment and reliability. Its most notable acquisition is a complete closed-circuit television system including projection equipment as well as standard monitors for picture viewing. Many departments have been using this equipment very successfully.

TELEPHONE SERVICE

The growth in the Institute community has inevitably created pressures for increased communications facilities through our Telephone Service. New switchboard positions have been added to the Institute's central telephone exchange in each of the past two summers, and an additional position is to be installed this fall. A commensurate increase in trunk and other lines has also taken place.

Telephone information service was improved this year with the addition of two new information consoles which helped to lighten traffic on the central board. Present plans call for provision of two toll position consoles to handle the ever-increasing long distance activity. The continued interest and experience of Professor Carlton E. Tucker of the Electrical Engineering Department remains an invaluable service to the Institute in regard to our telephone systems.

Installation of the internal dormitory telephone system purchased from the John Hancock Insurance Company last year is to be completed in the summer of 1963; a large percentage of the system was in operation during the past academic year. This independent system provides convenient, automatic service to the dormitory rooms and alleviates dormitory traffic on the Institute's central exchange.

PHILIP A. STODDARD

OTHER ACADEMIC AND ADMINISTRATIVE OFFICES

Department of Air Science

During the school year we further refined content of all subjects offered by the Department under the "new specialized program" adopted in 1960. The changes made were the direct result of critiques presented by the cadets of the respective classes at the end of the previous school year.

We were very pleased to enroll 53 freshmen for the largest freshman class since the inauguration of the new program. Likewise, of the 36 sophomores who had completed the previous freshman year and returned to M.I.T., 34 elected to enroll in our sophomore program. Similarly, our junior class was larger than the previous year. Consequently we believe the students have enthusiastically accepted the "new" program.

Among innovations this year were two panel discussions planned to help familiarize the cadets with the type of duty they may expect upon the completion of our program. The first consisted of four R.O.T.C. graduates, two of whom were M.I.T. alumni, who had been on active duty about ten years. They briefly described their careers and expectations, then freely answered questions asked by the cadets. The second panel discussion consisted of four lieutenants, two of whom were M.I.T. graduates, who had been on duty less than a year. They described their initial reactions to active duty and answered the cadets' questions. All of the officers were stationed at L. G. Hanscom Field.

DEPARTMENT OBJECTIVES

The Department continued its emphasis on increased academic content for all credit subjects offered.

Also, for the first time we used the junior cadets in staff positions to increase their development of leadership qualities. This new procedure was adopted on the recommendation of our cadets who had attended summer training during the previous summer. Parenthetically, we had one cadet rated number one in his flight at summer training camp. Over half of our cadets were rated in the upper half, and we did not have any rated in the lower third of their respective training camps. But as long as there is room for improvement, we will continue to emphasize the leadership training.

All of the officers assigned to the Department conducted numerous individual student interviews and worked in every way to improve the student-teacher relationship.

Another motivational innovation was the inauguration of a "Cadet of the Month" program, whereby each month the officers and N.C.O.'s selected the cadet who had contributed the most to the development and morale of the Corps during that particular month, and due recognition was accorded these individuals.

CADET ACTIVITIES

We repeated our annual cadet familiarization visits, which this year were made to Wright-Patterson Air Force Base, primarily to visit the Aeronautical Systems Division and the new nuclear reactor at that installation; Otis Air Force Base, primarily for the students to see a typical operational base including the Air Early Warning and Control Wing, A.D.C., F-101 Fighter Squadron, and Bomarc Missile Squadron; and L. G. Hanscom Field, primarily to visit various laboratories.

Our Rifle Team continued to achieve satisfactory progress.

On Military Day, twenty-two Air Science cadets received honors 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

All of our graduates who reported to active duty during the past year have been assigned to one of the laboratories at L. G. Hanscom Field or have volunteered for flight training and have reported to Craig Air Force Base, Alabama, for pilot training.

JACK D. ALEXANDER

Department of Military Science

Registration in the Army's basic R.O.T.C. course at the beginning of the year was the same as the preceding year. Registration appears now to have stabilized under the voluntary program.

	1961-62		1962-63	
	Beginning of the year	*End of the year*	*Beginning of the year*	*End of the year*
Basic course				
Freshmen	55	38	55	26
Sophomores	44	35	27	17
Advanced course				
Juniors	28	28	19	19
Seniors	26	27	32	30

Reserve commissions were granted as follows: four in the Corps of Engineers, three in the Signal Corps, nine in the Ordnance Corps, four in the Chemical Corps, one in Army Intelligence, one in the Transportation Corps, and one in the Quartermaster Corps. One student was commissioned in the Regular Army, Corps of Engineers.

The record of our graduates at the orientation courses at the various service schools continues to be excellent. Of a total of eighty-five M.I.T. graduates who completed such courses at six different Army service schools between June, 1962, and June, 1963, 72 per cent finished in the upper third of their classes.

The proposed new R.O.T.C. legislation outlining the two-year program still has not been acted upon by Congress. As a result, our action to revise the R.O.T.C. curriculum is still being held in abeyance. As a first step in preparing for the new two-year program, action was taken to convert from the branch material program to a general military science curriculum in the Advanced Course. This change will be fully implemented at the start of the 1963-64 academic year and will have the advantages of (1) allowing the M.I.T. graduate to serve in any branch compatible with his academic curriculum, (2) reducing the personnel required to administer the program, and (3) reducing the amount of classroom space required.

Student activities continued at a high level with such functions as the Military Ball in March; visits by cadets and others to West Point, Fort Monmouth, Fort Belvoir, and Aberdeen Proving Ground to witness construction, planning and operations, and research activities; a visit to the St. Lawrence Seaway to gain background information on its construction and operation; continued interest in Pershing Rifles and the Scabbard and Blade Society; and the Military Day Review in May, at which some twenty-five Army cadets were presented awards for their exemplary scholarship and military achievements.

IRVING W. FINBERG

Department of Naval Science

There were twenty-three N.R.O.T.C. seniors in the graduating class this year. Eighteen received their ensign commissions in the U.S. Naval Reserve in Commissioning Exercises at Kresge Auditorium in June, 1963. Two more seniors will received their commissions upon completion of the summer cruise in August, 1963, and two others will receive commissions in September when they will have completed their degree requirements. One senior was physically disqualified in June and discharged from the program.

The freshman class this year was required to accept an obligation of three years' active duty, which was an increase from the previous two-year requirement. The three-year requirement has had a very adverse effect on the N.R.O.T.C. Unit, and there were only thirteen freshmen in N.R.O.T.C. at the end of the academic year. There were twenty-six sophomores and fourteen juniors—making a total of seventy-seven students in the Unit at the end of the school year. This Unit also administered ninety-four postgraduate officers of the U.S. Navy, U.S. Coast Guard, U.S. Marine Corps, and four foreign countries, plus twelve Naval Enlisted Scientific Education Program (NESEP) students. Two NESEP students were graduated, one of whom received both Bachelor's and Master's degrees under the Honors Program in Aeronautics and Astronautics. The total strength of the unit was 191 persons, including eight staff members.

Eleven of the eighteen newly commissioned ensigns from the N.R.O.T.C. program were granted deferments from active duty to complete graduate education. Four of these graduates will remain at M.I.T. The others will attend universities as far away as the University of Paris and the University of California. One of the new ensigns was selected for the Navy Nuclear Power and Submarine Training Program. Another graduate was selected for the Naval Aviation Observer Program at Pensacola, Florida.

Captain Lewis E. Larson, Jr., the Commanding Officer and Professor of Naval Science, retired from the Navy on May 31, 1963. His relief will be Captain Harry M. Pugh, U.S. Navy, who will arrive for the fall term. During the summer the undersigned will be relieved by Commander Joseph A. Matthews, U.S. Navy, as the Executive Officer.

ROBERT B. GIBLIN

Alumni Association

On September 7 and 8, 1962, the Fourth Alumni Officers' Conference formally opened the Association's 1962-63 season. The Conference was attended by 273 alumni representing 61 classes and coming from 23 states, the District of Columbia, and Canada.

A census of our membership rolls taken March 31, 1963, showed a total of 68,379 names, 52,804 or 77 per cent living and 15,575 or 23 per cent deceased.

During 1962-63, recognition was granted the newly established M.I.T. Club of San Diego. Thus the present total of 96 such geographical groups is subdivided as follows: 70 within the continental United States, 14 elsewhere in the Americas, and 12 overseas in the other hemisphere.

In the twelve months ended April 30, 1963, 69 members of the Institute staff and Alumni Council attended 113 meetings of 51 different M.I.T. clubs and 16 meetings of the three associate clubs.

The officers and directors of the M.I.T. Club of New York, Inc., terminated their Club's lease of space in the Hotel Biltmore, effective May 31, 1963. The Board's plan for reorganizing alumni efforts in Greater New York calls for two complementary organizations: a Center which will be the focus of contacts between the Institute and alumni in that area; and a self-supporting social facility.

The Alumni Fund Board recognized that during 1962-63 more than 3,250 alumni would still be paying on Second Century Fund pledges, and hence could not appropriately be solicited by the Alumni Fund, and that other alumni might be reluctant to respond to Alumni Fund appeals so soon after they contributed to the S.C.F. Consequently, it is heartening to observe that the amount contributed to the

1963 Alumni Fund totaled $460,294 from 12,573 alumni, compared with $663,515 from 15,682 alumni in the Fund's best year, 1959-1960.

Even before the May 9 announcement of the successful completion of the S.C.F. campaign, plans were being formulated for the 1964 Alumni Fund with its million-dollar goal. Toward this end, Kenneth S. Brock '48 was appointed Director for Special Gifts for the Alumni Fund to be associated with Henry B. Kane '24, Director of the Fund since its establishment in 1940, and Douglas F. G. Haven '52 Director for Regions since 1960.

Plans have been completed for an experimental Alumni Seminar, scheduled for September, 1963, and designed as an educational opportunity for M.I.T. alumni and their wives, and for an Alumni Fund conference to be held in the same month.

DONALD P. SEVERANCE

Development Office

This past year has seen the final efforts marking the completion of the most successful fund drive in the history of higher education. On May 7, 1963, at a Victory Dinner at the Waldorf-Astoria, it was announced that the Institute had received a total of some $98 million from private sources; $77 million of this total came directly through the efforts of Second Century Fund campaign workers.

Since it is more appropriate to include campaign statistics in the final Second Century Fund report, they will not be given here, with one exception. Since this office was responsible for managing the campaign and was directly responsible for its costs, we report with pride that costs were less than those of any other major campaign on record—about 2 per cent of the total raised.

Many studies have been and are being made by this office to discover the patterns and dynamics of the campaign, the strengths and weaknesses of our support, and the achievements and mistakes of our programs. Studies in depth are made feasible by M.I.T.'s computer facilities, which we hope will provide qualitative and quantitative appraisals of the campaign results.

The Development Office has now reduced its personnel to two staff and eight non-staff from a campaign high of approximately twenty-two staff and forty-six non-staff. Scott D. Lothrop, who provided outstanding staff support throughout the campaign to the Leadership Gifts Committee under Walter J. Beadle '17 and to the Secretary of the Institute, has joined the Alumni Fund of the Harvard Business

School. Now working in other departments at the Institute are Mrs. Adelle Fallows and Mrs. Marianne Norman, who for many years and through two major campaigns devoted their talents and energy to running the office, keeping records, and performing those duties which mean the difference between success and failure. The Institute owes them—and their colleagues—its deepest gratitude and appreciation.

With the disbanding of the area organization in 1962, the continuing Second Century Fund campaign was conducted by a few dedicated volunteers and staff members, one of whom was Robert M. Kimball, Secretary of the Institute. His loss will be sorely felt in many ways. He was a warm and friendly colleague, and his wise counsel and tireless efforts played a vital part in the success of the Second Century Fund and the growth of M.I.T.

JOHN W. SHEETZ, III

Office of Public Relations

Completion of the Second Century Fund campaign brought to a climax activities to which we had devoted much of our effort during the past three years, but opportunities and demands for public relations and publications services have not shown an abrupt decline. On the contrary, the expansion of M.I.T.'s programs indicates a growing need for staff support in areas of communication within and outside the Institute.

The question of whether our present publications are effective in reaching audiences that M.I.T. should reach was the focus of a study by a special committee appointed by the President, with Samuel R. Groves '34 as Chairman and with administrative staff members and other representatives of the Alumni Association participating. During the coming year we shall undertake to examine our publications further in the light of the report made by this committee.

M.I.T. publications produced under the leadership of John I. Mattill, Director of Publications, continued to receive recognition for their excellence. They were chosen for display in most of the national exhibitions of outstanding printed matter and graphic design, including those of Campus Graphics, Creativity on Paper, the Type Directors Club of New York, Design and Printing for Commerce (American Institute of Graphic Arts), and the American College Public Relations Association. The A.C.P.R.A. chose five M.I.T. entries for exhibit and gave national citations to three, and the 1963 Design and Printing for Commerce exhibition will include five M.I.T. entries. Credit for such honors, which probably have not been matched by any other university, belongs chiefly to Mrs. Jacqueline S. Casey and Ralph M. Coburn, who during the year were appointed to staff positions as Graphic Designers. W. John Lees, a recent Yale graduate, served as an assistant designer for part of the year.

"The Science Reporter," M.I.T. television program produced by WGBH, maintained a professional level of excellence, with John T. Fitch '52 as host. Grants from the National Aeronautics and Space Administration and National Educational Radio and Television Center will make possible its distribution to some seventy-two N.E.T. stations during the coming season.

The Office of Public Relations continued to respond to the needs of television and radio stations for assistance in interpreting science, engineering, and education, and the increase in foreign visitors clearly pointed to the approach of world-wide communications on the scale to which we are now accustomed in domestic communications. British, German, and Japanese television teams visited M.I.T., and we assisted in the production of a film for a Brazilian station, now to be adapted for use in Japan. Assistance was repeatedly given to the United States Information Agency—for example, in the making of a pioneering film on education for use in Africa. Nelson C. Lees, who provided liaison with such groups, also modified the Second Century Fund film, "To Greater Strength," for use in high schools, as we had planned when the motion picture was produced.

Robert M. Byers continued to have chief responsibility for the informational problems concerned with M.I.T. activities in space and defense research, and he devoted particular efforts to establishing satisfactory relations with government agencies and with industries. At the end of the first year since the resumption of publication, "M.I.T. Reports on Research," edited by William T. Struble, had been enthusiastically accepted by industrial friends of the Institute.

FRANCIS E. WYLIE

Registry of Guests

The Registry of Guests has had its most active year to date, with 828 scheduled short-term foreign visitors. This number does not reflect accurately the total at the Institute during the year, for several large conferences, such as that in linguistics, brought many more foreign visitors for brief periods of time.

Notable among these visitors were the Ambassador from Pakistan, the Crown Prince of Liechtenstein, the Governor of Limbourg, the Minister of Education in Malaya, the Under Secretary of State of Yugoslavia, and the Deputy Prime Minister of Singapore, as well as the presidents of a variety of foreign universities. The majority of the visitors, however, were professors and department heads who came to discuss a definite field of interest at M.I.T.

There were over 300 foreign staff members resident at M.I.T. for varying periods in 1962-63; increasingly, the trend is for these visitors to be appointed for a full term or a complete calendar year. Approximately two-thirds of the foreign staff required some assistance from the Registry in visa and immigration matters.

In addition, the Registry arranged for Honorary Secretaries, Educational Counselors, and other alumni to represent M.I.T. at inaugurations, anniversaries, and similar functions at thirty-six other colleges and universities in the United States and abroad; and we assisted the Chairman of the Committee on Commencement in graduation affairs.

CAROLYN B. COX

Office of Student Personnel

During 1962-63 the Office of Student Personnel placed 2,282 students in 2,284 jobs on the M.I.T. campus and fifty-two students in off-campus jobs. Gross earnings of the students in on-campus jobs was $1,350,000 which, with the $23,000 grossed by the students in off-campus positions, makes a total of $1,373,000 earned by M.I.T. students in the past year. Average gross earnings per student were $588.

In the nine-month academic year, M.I.T. expended $938,000 for the services of 1,724 undergraduates, whose average earnings for the period were $544. Approximately $752,000, or 80 per cent, of this was paid out by D.S.R. accounts, special research projects, laboratories, administrative offices, and department services.

It is estimated that our August survey of project supervisors and laboratory directors will develop approximately 140 new student jobs for the fall term of 1963, contributing to the expected ten per cent increase in total job opportunities for 1963-64 over 1962-63.

On file for reference in our office are approximately 8,000 alumni personnel records and 3,100 active personnel records; these are available for confidential reference to assist students, alumni, employers, and other universities.

WILLIAM H. CARLISLE, JR.

PRINCIPAL PROFESSIONAL HONORS AND ACTIVITIES OF THE STAFF

School of Architecture and Planning

DEPARTMENT OF ARCHITECTURE

ALBERT G. H. DIETZ
Director of the American Society for Testing and Materials.
Director of the Building Research Institute.

MARVIN E. GOODY
Fulbright Lectureship to the Royal Academy of Fine Arts, Denmark.

HENRY A. MILLON
Member of the Board of Directors, Society of Architectural Historians.

ROBERT B. NEWMAN
Honorary degree of Doctor of Science, Lawrence College.

JOSEPH J. SCHIFFER
Architectural Award of the Boston Arts Festival, 1962.

DEPARTMENT OF CITY AND REGIONAL PLANNING

BERNARD J. FRIEDEN
Editor of the *Journal of the American Institute of Planners.*

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

HOLT ASHLEY
Associate Editor of the *Journal of the American Institute of Aeronautics and Astronautics.*
Member of the Research Advisory Committee on Aircraft Structures, National Aeronautics and Space Administration.

LAWRENCE E. BECKLEY
Member of the School Committee, Town of Winchester, Massachusetts.

RAYMOND L. BISPLINGHOFF
Honorary degree of Doctor of Science, University of Cincinnati.
Langley Medal of the University of Pittsburgh.
Technical Director of the American Institute of Aeronautics and Astronautics.

CHARLES S. DRAPER
1962 Space Flight Award of the American Astronautical Society.
Louis W. Hill Space Transportation Award of the Institute of Aerospace Sciences.
Honorary Member of the Instrument Society of America.

JOHN L. GROPPER
Chairman of the *ad hoc* Committee on Manned Interplanetary Technology.

RENE H. MILLER
Fellow of the Institute of Aeropsace Sciences.
Chairman of the Aviation Advisory Panel, U.S. Army.
Member of the Scientific Advisory Board, U.S. Air Force.
Member of the Committee on Aircraft Aerodynamics, National Aeronautics and Space Administration.

GORDON C. OATES
Director of the American Institute of Aeronautics and Astronautics.

DEPARTMENT OF CHEMICAL ENGINEERING

HOYT C. HOTTEL
Member of the National Academy of Sciences.

CHARLES N. SATTERFIELD
Member of the Committee on Chemical Kinetics, National Academy of Sciences—National Research Council.

THOMAS K. SHERWOOD
Chairman of the Engineering Section, National Academy of Sciences.

HAROLD C. WEBER
Honorary doctorate, Suffolk University.

DEPARTMENT OF CIVIL ENGINEERING

NORMAN H. BROOKS
Rudolph Hering Medal of the American Society of Civil Engineers.

JAMES W. DAILY
Member of the Board of Government, Boston Society of Civil Engineers.

Chairman of the Section for Hydraulic Machinery, Equipment, and Cavitation, International Association for Hydraulic Research.
Fellow of the American Society of Mechanical Engineers.

ALBERT G. H. DIETZ
Director of the American Society for Testing and Materials.
Director of the Building Research Institute.
John W. Derham International Award of the Plastics Institute of Australia.

ARTHUR T. IPPEN
Degree of Doctor *honoris causa,* University of Toulouse.
Special lecturer at the Technical University of Berlin.
Vincent Bendix Award of the American Society for Engineering Education.

JOHN F. KENNEDY
J. C. Stevens Award of the American Society of Civil Engineers.

T. WILLIAM LAMBE
Wellington Prize of the American Society of Civil Engineers.

FREDERICK J. MC GARRY
Chairman of the Nineteenth Annual Technical Conference of the Reinforced Plastics Division and Chairman of the Filament Winding Committee, Society of the Plastics Industry, Inc.

RONALD T. MC LAUGHLIN
Collingwood Prize of the American Society of Civil Engineers.

PAUL O. ROBERTS
Member of the Executive Committee, Boston Section, American Society of Civil Engineers.

A. CHANDRA SINGHAL
First award for a technical paper, International Association of Shell Structures.
Carnegie Research Fellowship of the Carnegie Trust for the University of Scotland.

ROBERT V. WHITMAN
Research Award of the American Society of Civil Engineers.
Chairman of the Publications Committee, Soil Mechanics and Foundations Division, American Society of Civil Engineers.

DEPARTMENT OF ELECTRICAL ENGINEERING

JOHN S. BARLOW
Research Career Development Award of the Massachusetts General Hospital.

JORDAN J. BARUCH
Fellow of the American Academy of Arts and Sciences.

LEO L. BERANEK
Honorary Member of Phi Beta Kappa.
Member of the Board of Directors, American Standards Association.

MARY A. B. BRAZIER
President of the International Federation of Societies for Electroencephalography and Clinical Neurophysiology.
Woman of the Year in Science Award.

JACK B. DENNIS
Secretary of the Boston Section, Professional and Technical Group on Electronic Circuits, Institute of Electrical and Electronics Engineers.

MURRAY EDEN
Editor of *Information and Control.*
Vice Chairman of the Professional Technical Group on Bio-Medical Electronics, Institute of Electrical and Electronics Engineers.

HAROLD E. EDGERTON
Honorary Member of the Boston Camera Club.
Man of the Year Award of the Industrial Photographers Association of America.
E. I. du Pont Gold Medal Award of the Society of Motion Picture and Television Engineers.

HARRY C. GATOS
Chairman of the Electronic Materials Committee, the Metallurgical Society (A.I.M.E.).

Chairman of the Corrosion Division and Member of the Board of Directors, The Electrochemical Society.
Editor of *Surface Science.*

JAMES W. GRAHAM
Secretary of the Student Activities Committee and Student Affairs Coordinator, Boston Section, Institute of Electrical and Electronics Engineers.

ERNST A. GUILLEMIN
Medal in Electrical Engineering Education of the American Institute of Electrical Engineers.

EDWARD M. HOFSTETTER
Chairman of the Boston Section, Professional Technical Group on Information Theory, Institute of Electrical and Electronics Engineers.

DAVID A. HUFFMAN
Fellow of the Institute of Radio Engineers.

YUK-WING LEE
Degree of Doctorem Scientiarum Applicatarum *honoris causa,* Catholic University of Louvain.

GEORGE C. NEWTON, JR.
Vice Chairman of the Education Committee, American Automatic Control Council.

PAUL PENFIELD, JR.
Secretary-Treasurer of the Boston Section, Professional Technical Group on Microwave Theory and Techniques, Institute of Electrical and Electronics Engineers.

ROBERT P. RAFUSE
Outstanding Paper Award of the International Solid-State Circuits Conference.

ROBERT H. RINES
Member of the National Inventors Council.
Member of the Technical Advisory Board, U.S. Department of Commerce.

DOUGLAS T. ROSS
Prize Paper Award of the American Federation of Information Processing Societies.

CLAUDE E. SHANNON
Mervin J. Kelly Award in Telecommunication of the American Institute of Electrical Engineers.
Gibbs Lecture of the American Mathematical Society.

HERBERT M. TEAGER
Associate Editor of *Computing Reviews.*

JOHN G. TRUMP
Public Service Award of the Alumni Association, Brooklyn Polytechnic Institute.

JOHN E. WARD
Member of the National Administrative Committee and Delegate to the American Automatic Control Council, Professional Technical Group on Automatic Control, Institute of Electrical and Electronics Engineers.

DAVID C. WHITE
Fellow of the American Academy of Arts and Sciences.

JOHN M. WOZENCRAFT
Member of Commission 6, United States National Committee, International Scientific Radio Union.

VICTOR H. YNGVE
Editor of *Mechanical Translation.*
President and Chairman of the Program Committee, Association for Machine Translation and Computational Linguistics.
Chairman of the Sub-Committee on Common Programming Languages, Working Group on Language Theory, American Standards Association.

HENRY J. ZIMMERMAN
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 Projects, National Science Foundation and Commission on Engineering Education.

STANLEY BACKER
Vice President of the National Council for Textile Education.

STEPHEN H. CRANDALL
Midwest Mechanics Lecturer of the Associated Midwestern Universities, Inc.

NORMAN C. DAHL
Program Director of the Kanpur Indo-American Program, Indian Institute of Technology.

PHILIP G. HILL
Fellowship of the John Simon Guggenheim Foundation.

ROBERT W. MANN
Talbert Abrams Award of the American Society of Photogrammetry.

WILLIAM M. MURRAY
Honorary President of the Society for Experimental Stress Analysis.

RONALD F. PROBSTEIN
Fellow of the American Rocket Society.
Chairman of the Fluid Dynamics Committee, American Institute of Aeronautics and Astronautics.

GEORGE S. REICHENBACH
Secretary of the Research Technical Committee and Vice Chairman of the Rolling Elements Sub-Committee, Lubrication Division, American Society of Mechanical Engineers.

WARREN M. ROHSENOW
Chairman of the Heat Transfer Division, American Society of Mechanical Engineers.

MIKLOS SAJBEN
Junior Award of the American Society of Mechanical Engineers.

ASCHER H. SHAPIRO
Chairman of the National Committee for Fluid Mechanics Films.

THOMAS B. SHERIDAN
Editor of *Transactions on Human Factors in Electronics,* Institute of Electrical and Electronics Engineers.
Chairman of the Education Committee, Human Factors Group, American Society of Mechanical Engineers.

C. FAYETTE TAYLOR
Special Award of the American Society of Mechanical Engineers.

TAU-YI TOONG
Testimonial of appreciation of the Office of Scientific Research, U.S. Air Force.

DEPARTMENT OF METALLURGY

JOHN CHIPMAN
Benjamin F. Fairless Award of the American Institute of Mining, Metallurgical, and Petroleum Engineers.
Fellow of the Metallurgical Society (A.I.M.E.).

THOMAS R. CLEVENGER
Fellowship of the Ford Foundation.

MORRIS COHEN
Fellow of the Metallurgical Society (A.I.M.E.).

JOHN F. ELLIOTT
Howe Memorial Lecturer of the American Institute of Mining, Metallurgical, and Petroleum Engineers.

NICHOLAS J. GRANT
Chairman of the Research Advisory Committee on Materials, National Aeronautics and Space Administration.

CYRIL S. SMITH
James Douglas Medal of the American Institute of Mining, Metallurgical, and Petroleum Engineers.
President of the Society for the History of Technology.

DAVID A. THOMAS
Vice Chairman of the Committee for the New England Regional Conference, American Institute of Mining, Metallurgical, and Petroleum Engineers.

DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENGINEERING

MARTIN A. ABKOWITZ
Fulbright Lectureship to the Technical University of Denmark.
Chairman of the Committee on Steering and Maneuverability, American Towing Tank Conference.

J. HARVEY EVANS
Member of the Committee on Ship Structural Design, National Academy of Sciences—National Research Council.
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