1967

NATIONAL SCIENCE FOUNDATION

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Annual Report

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National Science Foundation

Seventeenth Annual Report for the Fiscal Year Ended June 30, 1967

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LETTER OF TRANSMITTAL

Washington, D.C.,
January 15, 1968.

My Dear Mr. President:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1967 of the National Science Foundation for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

Leland J. Haworth,
Director, National Science Foundation.

The Honorable
The President of the United States.

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A listing of grants, contracts, and fellowships awarded in fiscal year 1967 appears in a separate publication entitled National Science Foundation Grants and Awards, Fiscal Year 1967, NSF 68–2. It is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

PREFACE

This 17th Annual Report of the National Science Foundation presents an account of major activities, and reports on funds obligated for support of science and science education in fiscal year 1967. Where it is necessary for understanding the context within which these activities in fiscal year 1967 took place, earlier and later events are also discussed. Unlike previous reports in which the discussion was arranged so as to correspond approximately with the administrative structure of the Foundation, this report attempts to group activities by scientific discipline and function. For example, in support for basic research, national research centers and programs, specialized facilities, and research accomplishments are grouped under the appropriate scientific discipline. In this way, the reader will find it easier to understand the flavor, scope, diversity, and interrelatedness of the basic research undertaken by the Foundation.

The financial statement for the year is presented as appendix B on page 199, and various component or supporting data are included where appropriate in the description of Foundation activities. During the fiscal year ending on June 30, 1967, the Foundation obligated $465.1 million through 9,311 grants and contracts, primarily to colleges and universities. Distribution of funds by program activity and by support for the various fields of science is described in the chapter, Introduction and Summary.

In accordance with the custom of previous years, a listing of grants, contracts, and fellowship and traineeship awards is published in a separate volume entitled "National Science Foundation Grants and Awards, Fiscal Year 1967" (NSF 68–2).

DIRECTOR'S STATEMENT

In previous years the "Director's Statement" in the Annual Report of the National Science Foundation has combined a summary of some of the more outstanding events of the year with discussions on such general topics as Federal support of research and development, the Foundation's history, objectives, organization and programs and so forth. In this, the Seventeenth Annual Report, covering fiscal year 1967, an introductory chapter serves to summarize and highlight the year's activities in considerably more detail than have the Director's Statements of the past. Hence, this Statement will be restricted to a brief discussion of some of the broader issues facing the Foundation and the Federal Government as a whole with respect to science.

On July 5, 1945, Dr. Vannevar Bush, then Director of the Office of Scientific Research and Development, sent to the President his famous report on a program for postwar scientific research entitled "Science, The Endless Frontier." In his transmittal letter he stated:

> The pioneer spirit is still vigorous within this Nation. Science offers a largely unexplored hinterland for the pioneer who has the tools for his task. The rewards of such exploration both for the Nation and the individual are great. Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress.

In the 22 years since Dr. Bush's report, the exploration of the "hinterland" of science has gone forward with unprecedented intensity. New, sometimes unexpected, regions of understanding have been opened up and valuable, sometimes priceless, findings have been made. At the same time, our general capabilities for scientific exploration have also increased substantially. Physical facilities and instrumentation measure what was previously unmeasurable and analyze and communicate information as never before.

Increasingly our era is one in which new ideas and ways crowd one on the other; concepts and methods change quickly and are old before their time; our society and personal lives are tremendously affected by the impact of science and technology—overwhelmingly for betterment even though some aspects of their applications have had undesirable side effects. And yet, in spite of such profound change, the above quotation is as true today as when it was written. The "unexplored hinterland" and the material and cultural rewards it offers will always be there—only our perception and the extent of exploration change with time.

In this country particularly, science is flourishing in an unprecedented way—one that is unequaled elsewhere in the world. American scientists are at or near the vanguard in all areas of science and the fruits of their research have had great impact upon our rapidly developing technology. The nation's commitment to science and technology is well demonstrated by the fact that from 1953 to 1966—the earliest and latest years for which accurate figures are available—the annual, national investment in research and development more than quadrupled, whereas the Gross National Product only doubled. Investments for research and those for development have increased in approximately equal proportions but, significantly, the relative emphasis on the basic component of research has increased most substantially, its financial support having increased sixfold during the 13-year interval.

Fortunately, the growth of scientific manpower has kept pace with the nation's demands. The proportion of scientists and engineers in the total civilian labor force has never been greater. In 1954, approximately 370 of every 100,000 civilian employees were research and development scientists and engineers. Today, this proportion has approximately doubled. In the universities, in industry and in Government far more people with, or working toward, advanced scientific or engineering degrees are engaged in research and development, with greater individual productivity and with more financial support than ever before.

In all of this the impact of Federal investments has been enormous. Partly to meet its own specific needs and partly in the general public interest, the Government has increased its expenditures for science and its applications by leaps and bounds so that today Federal support for research and development represents nearly two-thirds of the total national investment in these activities. As in the total national case, greatest increased emphasis has been on basic research, as evidenced by the fact that in the past 10 years the Government's support for it has increased from approximately 7 percent to 15 percent of total Federal R. & D. expenditures and has increased from less than half to about two-thirds of the total national investment in such research.

Nowhere has the impact of the Federal commitment to science been greater than in the country's academic institutions. From essentially none before World War II (except in agriculture), Federal support for the conduct of research in the academic institutions proper (as distinguished from federally owned "contract research centers" operated by the universities) rose to approximately $1.26 billion in fiscal year 1966, almost two-thirds of the total research expenditures in those institutions; additional funds of the order of $0.11 billion were obligated for research laboratories and research facilities. Although the primary objective of most of this support has been to meet the informational needs of the agencies having specific missions—in defense, health, space, atomic energy, etc.—it has, nevertheless, had a profound impact on education, especially at the graduate level where the conduct of research is vital.

In recent years significant, though smaller, support has also been given to higher education in its own name. Students have been assisted through fellowships and traineeships (as well as through opportunities for employment on research projects); growing support has been given to the classroom teaching function, especially by the National Science Foundation and, at a rapidly increasing rate, by the Office of Education. Still another type of program in several agencies provides special support to assist selected institutions to improve the quality of both research and classroom activities. In total about $2.2 billion was obligated by the Federal Government in fiscal year 1966 for support of research and science education in our universities and colleges.

Unfortunately, the many demands upon the Federal Government's financial resources have recently forced a leveling off in its total support for science. This has inevitably given rise to problems, some new, some merely brought to sharper focus. The rate of acquiring new knowledge will inevitably be slower than it would otherwise have been; certain opportunities for new advances requiring costly equipment will have to be postponed; the needs of higher education will not all be met. I wish to discuss, however, only one aspect of the total problem, namely, Federal support of graduate education in the sciences and engineering.

It is almost universally recognized that one of the most valuable things an individual can strive for, both from his own point of view and from that of society, is a good education—scientific or otherwise. A well-educated individual is better able to adapt to his rapidly changing environment; to be a productive member of society with a higher economic status; and to have a broader range of choices which will add to his enjoyment of life. Our society needs educated citizens for an effective democracy and a vigorous economy; such citizens can participate more actively and effectively in the life of their community and that of the Nation. Also, it has been estimated that "the additional schooling of the labor force would appear to account for about one-fifth of the rise in real national income in the United States." [1] Hence, resources invested in education benefit both society as a whole and the recipients as individuals—in keeping with the very essence of democracy.

This belief is attested to by the fact that the Nation's investment in education at all levels has grown by leaps and bounds and that school and college enrollments, especially the latter, have grown far faster than have the school and college-age populations. Enrollments in colleges and universities have quadrupled since 1940—indeed have doubled in the

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[1] T. W. Schultz, *The Economic Value of Education* (N.Y.: Columbia University Press, 1963) p. 11.

past 10 years. Out of a given number of college-age young people four are now enrolled in college for every three who would have been in 1957.

Not so universally recognized is the crucial nature of the role played by graduate education. The leaders in research—be it in science or in other fields—be it in the universities, in industry or in Government—are predominantly found among those educated to the highest levels. Among these highly educated individuals are those who train the research leaders of the future, and who teach our undergraduates for all walks of life, including that of teaching in the Nation's schools. Thus, the process of graduate education is essential to our progress in every aspect of modern life.

Fortunately, the desirability of a graduate education has been increasingly recognized by the Nation's youth. Total graduate enrollments have doubled since 1960 and are expected to do so again by 1980. Although science and engineering account for only about one-third of the total of such enrollments, approximately two-thirds of the Ph. D.'s are awarded in these fields. This seems to result from two factors. First is the widespread and increasing awareness on the part of industry and the public of the tremendous economic and social benefits which can be derived from the applications of science and technology. This has created a corresponding increase in demand for highly trained personnel which is reflected in the desire of students to acquire training that will qualify them for the new employment opportunities. A second factor is the startling increase in the quality and complexity of scientific and technological knowledge itself. This, in turn, has generated a situation in many areas of science and technology where a student usually cannot acquire the training needed to qualify him for independent professional activity without advanced graduate training. This trend toward acquiring more advanced training is currently most pronounced in engineering, where in recent years the doctorate production has increased at a substantially greater relative rate than in the sciences proper.

There is no question that the recipients of a graduate education will be usefully employed. There is every indication that industry will need ever-increasing numbers of personnel who are highly trained in the sciences and engineering; the colleges and universities will clearly do so in view of their increasing enrollments. Furthermore, in addition to the need for growing numbers of scientific and technical personnel, there is an equal need in all sectors that they be more highly educated. For example, the fraction of the individuals on the faculties of the Nation's universities and colleges who possess the Ph. D. or equivalent degree has always been much lower than desirable. Moreover, although the rate of granting this degree has increased rapidly (doubling since 1960), the growth of undergraduate enrollments and hence of academic faculties has been so great in recent years that the fraction of the faculty possessing Ph. D.'s has, unfortunately, declined from a peak of roughly half in the early 1960's to an estimated 35 to 40 percent at present.[2] Although, assuming past career choice patterns, the fraction of the academic faculties who hold the Ph. D. will shortly start to rise again, it is not expected to reach the 50 percent mark of the early 1960's until at least midway of the 1970's. This shortage of the most highly qualified individuals has, of course, been more seriously felt in the developing than in the well-established universities, still more seriously in the four-year colleges, and most seriously of all in the rapidly burgeoning junior colleges.

An especially acute need, perhaps even more acute in its way than the total national need, is that of regions, States and localities that are endeavoring to develop high-quality academic institutions where such do not now exist. It is generally recognized that a first-class university or, to a more modest extent, a first-class college, has a highly salutory effect on the total life of the locality in which it finds itself. It influences in a positive way the educational systems, the culture, the intellectual life and, in more or less degree depending on the circumstances, the overall economy. Quite apart from the financial support they may receive, institutions endeavoring to better themselves and hence their communities have great difficulty in doing so when there is a shortage of high-quality individuals with whom to build their faculties. In the face of such a shortage they find it hard, if not impossible, to compete for such individuals with those institutions already recognized as having high quality.

The need for higher levels of training of their personnel is also present in industry and in Government laboratories as well as in the universities and colleges. Not only must new personnel be more highly educated but also there is great, and proper, demand on the part of working scientists and engineers for opportunities to extend and update their knowledge by returning to the universities as full- or part-time graduate students.

Thus, from every standpoint—national, local, and individual—it is highly desirable that the growth of graduate education—both quantitative and qualitative—should continue. This is part and parcel of the enlargement of our national objectives in education. As a nation we are asking our educational system to do more than turn-out a greater number of graduates. We are asking our colleges and universities to produce better educated graduates and we want them to come from a larger number of universities and colleges. It is in the national interest that such institutions be present in every region of the land, including every large metropolitan center, and that we give added encouragement to those disciplines that have most direct relevance to our physical and social environments so that the creative and fresh thinking of young graduates can contribute to problems concerning the general welfare.

Unfortunately, the costs are sobering. With the extremely rapid growth of enrollments the colleges and universities have found themselves ex-

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[2] The relative rate of increase in the already large pool of Ph. D.'s is, of course, much lower than the rate of increase in newly available Ph. D.'s.

tremely hard pressed to meet the costs of their undergraduate programs, despite sharply increased tuition fees, especially in private institutions. The graduate institutions are for the most part already at or near present capacity and the cost of developing the facilities and equipment and employing the faculty and others needed to meet the increased enrollments over the next 10 years poses a grave problem to the institutions themselves and to their public and private supporters. The increasing complexity, and therefore costliness, of science adds another factor to the difficulty. Although it would be desirable in the future for the States and local communities to assume a larger fraction of the cost of graduate education, including the research that constitutes so large a portion of it, it seems unlikely that this will be possible at least for some years to come. They will do well to maintain their present proportion in the face of rising enrollments and rising unit costs. In a direct way, therefore, the rate of growth and quality of academic research and graduate education depend on Federal support. It is highly appropriate that this support be forthcoming because, of all levels of education, the graduate level is the most national in character; graduate students at the various universities come from all regions of the land and, after graduation, disperse to every quarter. Furthermore, the Government's own programs are heavily dependent on an adequate flow of the most highly trained personnel.

Graduate education has benefited greatly from the happy circumstance that funds expended for research directly serve the cause of education, whatever the motive for making the investment. Thus, research support provided to the universities by Federal agencies in pursuance of their missions serves the cause of graduate education, even when that is not the primary aim. Indeed, a majority, and until recently a very large majority, of the Federal support for graduate education has resulted from this circumstance. But, especially in the face of ever-increasing needs for graduate education, there is inherent in this situation a potential for difficulties arising from the fact that the research requirements of the various agencies pursuing specific missions do not necessarily coincide, either in quantity or in kind, with the needs of the universities for support of graduate education. For example, there is no inherent reason why the overall need of a given agency for new scientific knowledge should grow at as great a rate as the graduate population. Nor is it inherent that the combined agencies' need for knowledge in any given field will keep pace with the Nation's overall need for new knowledge in, or new scientists trained in, that particular field. Fortunately, these circumstances have not given rise to serious problems in the past, since the overall needs of the combined agencies have kept pace with the growth in graduate education. The plurality of support and the potentiality of balancing adjustments by the National Science Foundation and to a lesser relative degree by others have largely met the needs. However, the recent leveling off in the

Federal Government's support for academic research during a period of increasing enrollments and rising costs has brought about a problem.

It, therefore, seems clear that the policies and programs that worked so well for graduate education in the past should have a reassessment. It seems almost certain that the inevitable increases in Federal support of universities in the years to come should have an appreciably larger fraction directed at graduate education in its own right. In part this could be accomplished by increasing support in categories of costs already supported apart from research awards—e.g., relatively more fellowships and traineeships; larger cost of education allowances in connection with fellows and trainees; greater support for new facilities such as buildings, instructional equipment and computers for educational use as well as for research. In part it could entail supporting directly some categories of costs for which assistance is now given only through research awards, but which are present regardless of the nature and scale of particular research projects—e.g., partial support for faculty salaries; equipment for general use; at least a substantial portion of those indirect costs now supported through research, etc. The research projects themselves would still support those costs directly attributable to the specific research—e.g., faculty salaries in special cases, salaries and wages of other professional and nonprofessional personnel, specific items of equipment and supplies, travel associated with research, cost of publication of research results and so forth. To take such steps would free the universities from a large part of the uncertainties inherent in the inevitable ups and downs of research project support, while still retaining the great virtue of selectivity on a quality basis of the research to be supported by the various agencies. The greater flexibility permitted would also enable the universities to provide more adequately for the research needs of the younger members of their faculties who have not yet acquired sufficient experience and recognition to enable them to succeed in receiving Federal research awards in competition with their seniors.

Such a transition could obviously not be accomplished overnight; indeed, to avoid undue disruption it should probably be done incrementally as increasing funds are made available for the support of the entire graduate research and education enterprise.

In recognition of the desirability of some such reassessment as that alluded to above, the National Science Board has established a special committee—comprised in part of members, in part of experienced and knowledgeable outside individuals—which, with assistance from the Foundation staff, is studying the opportunities and needs of graduate education in the sciences and engineering with the aim of recommending policies and programs for the long-range future. The conclusions and recommendations of this study, as modified by the Board itself, will result in a Board report to be issued some time in 1968.

PROGRAM ACTIVITIES
of the
NATIONAL SCIENCE FOUNDATION

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INTRODUCTION AND SUMMARY

This chapter summarizes National Science Foundation activities during fiscal year 1967, highlighting those program developments and policy decisions considered most significant, and briefly reviewing the more important changes in Foundation organization and structure. Many of the topics touched on in this section will be described in greater detail in the body of the report.

The activities of the National Science Foundation are carried on within the framework of the National Science Foundation Act of 1950, as amended. The broad overall charge of this Act assigns to the Foundation the responsibility to strengthen basic research and education in the sciences throughout the United States. Although this mandate has remained basically unchanged over the years, additional special responsibilities, such as those for a program of study, research and evaluation in the field of weather modification, have been added. Similarly, as the result of the enactment of the National Sea Grant College and Program Act of 1966, the Foundation is authorized to establish programs, primarily at institutions of higher education, to provide for the training, research, and advisory services necessary to develop, to the fullest extent possible, the Nation's marine resources. Furthermore, with the passage of time, the Foundation's policies and programs, as well as its methods of implementation, have been constantly altered to respond to changes in national needs. Since basic research and higher education constitute closely related and intertwined activities, it has been only natural that the Foundation's programs are concentrated in the country's universities and colleges. However, since science education finds its roots already in the very early stages of the educational process, programs have also been undertaken to improve science teaching in secondary and elementary schools. Furthermore, since one of the responsibilities of the NSF is "to appraise the impact of research upon industrial development and upon the general welfare," continuous and growing efforts related to science policy development and planning and the dissemination of scientific information are being maintained. Indeed certain of the science information responsibilities are specifically spelled out in a 1958 modification to the act.

It is thus clear that two of the major objectives of the National Science Foundation are the production of new knowledge and of the development of a sufficient number of well-trained scientists and engineers to meet the future needs of the country. It is well recognized that the support of basic research at academic institutions provides a unique mechanism for furthering both of these objectives in that research involving graduate students provides the apprentice-type training essential to graduate science education, while at the same time producing significant new knowledge. Superimposed on these major objectives is the recognition of the fact that production of knowledge, as well as of scientific and technical manpower, plays an important part in the cultural, social, economic, and intellectual development of various regions of the United States. Continuous efforts are underway to assess and improve the geographic distribution of science resources.

The broad present program of the Foundation, which is the result of this continuous growth and development, can be described in a number of major categories. In the area of research, activities are supported in essentially all fields of the physical, life, and social sciences. Attempts are made to provide support so as to balance national research activities within all fields of science. In carrying out this balancing function, the Foundation tries to assess not only the extent of support provided by other Federal and non-Federal agencies and institutions, but also the relative needs of various fields of science, the necessity for large research facilities required to open new important areas of investigation, and the various national scientific and technical manpower needs, regardless of whether they are required for research or for other scientific and technical activities. Since it is exceedingly difficult to predict future utilization of basic knowledge, most research is supported for its own intellectual value. However, this is done with the full realization, which is backed up by past experience, that most, if not all, of the research results will sooner or later prove to be of direct practical value to society. Furthermore, if it is clearly evident that research activities in specific areas should be intensified because of present societal needs, attempts are made to stimulate this type of investigation. Examples of such stimulation, accomplished through increased research support, have been in the areas of the atmospheric sciences, physical and biological oceanography, and the social sciences. While most of these research activities are being supported in academic institutions, special National Research Centers are supported when it is evident that they represent the only practical means of making large, complex instrumentation available to the scientific community or of providing adequate focal points in particular fields. Thus, the Foundation supports four of these Centers in the areas of radio and optical astronomy and the atmospheric sciences.

While these research programs maintain and nourish the sources of basic knowledge and scientific manpower, it is also realized that other aspects of science education must be improved continuously if this Nation is to remain an intellectual, political, and economic leader in world affairs. Consequently, the Foundation has been and is a leader in the development of new techniques to improve the teaching of science.

These include programs to develop and implement new and improved curricula, programs to improve qualifications of science teachers, programs to identify and encourage outstanding science students (including direct support of graduate students through fellowships, traineeships, and research assistantship), and programs to provide equipment and facilities required for the teaching of modern science. Furthermore, emphasis is not confined to science education for those who want to pursue a career in science. It is recognized that those who do not intend to enter scientific careers must have an adequate science education to understand properly the role which science and technology play in the daily lives of individuals and of society. Consequently, projects designed to improve science education for all students are also being supported.

Since science education and fundamental research are primarily carried out in universities and colleges, a basic objective of NSF programs is not only the maintenance of existing academic strength in science, but also the improvement of other institutions of the academic community. The latter aspect is of special importance in view of the fact that enrollments for science education in academic institutions will very likely double in the next decade and more than double in graduate schools. Since capacities of well established colleges and universities are limited, it is clear that a considerable fraction of future science students will have to be accommodated at institutions not now among the foremost. It is thus of prime importance to develop in these institutions the capability to provide these large numbers of future students with a good science education. To further this objective, the Foundation has in recent years started a series of science development programs intended to improve institutions within a wide spectrum of quality. Furthermore, programs providing funds for graduate laboratories and research facilities are maintained so that students will not only have space available to carry out their research, but will also be able to learn through the use of modern facilities.

Limitations on available staff, funds, and other resources obviously make it impossible to implement the above programs to the optimum extent. Consequently, the Foundation has tried to maintain a balanced program. On the one hand attempts are made to cope with immediate needs and the maintenance of existing areas of strength; on the other hand efforts are underway to prepare for the needs of the future and to strengthen areas which are underdeveloped at this time. Some of the more significant issues to which the Foundation has addressed itself over the past year and which closely touch on Foundation programs, are examined in more detail in the following section.

The objectives, the role, and the activities of the National Science Foundation have, in the past few years, become the focus of some congressional attention. During fiscal year 1966 the subcommittee on science, research, and development of the House Committee on Science and

Astronautics undertook a comprehensive review of the history and role of the Foundation, and this assessment resulted in the formulation of proposed new legislation (the Daddario bill) aimed at broadening the scope and nature of Foundation activities. Briefly the bill reaffirms the Foundation's responsibility for the support of basic research and education in the sciences—giving, for the first time, specific mention to support of the social as well as the other sciences. (The social sciences, which have received significant and increasing Foundation backing, were not specifically singled out for support in the original legislation.) Other important changes included in the bill provide for the expansion of Foundation programs to cover the support of applied as well as basic research at academic and other nonprofit institutions and for greater participation by the Foundation in international scientific activities, particularly as they relate to international cooperation and foreign policy. The bill also calls for an expansion in the data collection and analysis functions of the Foundation and provides for a number of modifications in the Foundation's internal organization and structure and in the responsibilities and functions assigned to the Director and to the National Science Board. Although passed by the House, the Daddario bill did not reach the Senate floor during the 1966 session of the Congress. In May 1967, with only a technical change, it was reintroduced and again passed in the House. As the fiscal year ended, no action had been taken in the Senate.

MAJOR POLICY CONSIDERATIONS

The Foundation positions on key scientific issues undergo constant internal review and reassessment in an effort to assure that Foundation programs and policies remain responsive to changing national needs and priorities. Discussed below are some of the prime concerns, bearing on Foundation activities, to which consideration was given during the year.

The National Science Effort and Basic Research

Increasing public awareness of the contribution of science and technology to the health and welfare of the Nation has made the national science effort more and more a focus of interest, both in terms of its contribution to increasing the basic fund of knowledge and understanding of natural and social phenomena, and in terms of its potential in the solution or alleviation of some of the immediate, critical problems confronting society. The scientific endeavor has become viewed as a partnership between the pursuit of new knowledge and, where applicable, the translation of the newly accumulated knowledge into practical tools.

This growing recognition of the benefits which can be derived through the development and maintenance of a strong scientific enterprise has indicated the continuing need for large scale support of basic research not only for its own sake and as a proper training ground for the education of future scientists and engineers, but for its development of the underlying foundation for further technological progress and for the national well-being. Advances toward solutions of some of the major present problems—such as pollution of water and atmosphere—are directly dependent on the vast pool of knowledge being accumulated through the Nation's basic research effort, and statements explicitly underscoring this concept have been made both by the President and by his Special Assistant for Science and Technology, Dr. Donald F. Hornig. In a speech before the American Physical Society, in April 1967, Dr. Hornig commented:

> ". . . because we are determined to make use of every bit of available knowledge whose application is feasible, economic and useful, it does not follow in the slightest that this implies a decreased interest in basic research. The two activities are separate and usually done by different groups of people. On the one hand, there are people who feed the pool of knowledge and understanding into which we dip for our practical achievements and on the other hand there are people who recognize human needs and find new ways to meet them. Both are important, both demand creativity, imagination, enterprise and talent, and both will go forward."

In May 1967, the National Science Board approved a policy statement on "Criteria for the Support of Research by the National Science Foundation" (presented as Appendix F, page 212) in order to make explicit the policies of the National Science Foundation concerning support of research in educational institutions and in national centers. The statement is intended to clarify and reaffirm the general philosophy that has guided the Foundation since its inception, and to serve as a guide to the staff and to the advisory groups which assist the Foundation. Also, it was presented as a service to the scientific community, and for the consideration of other bodies and administrators responsible for the support and conduct of scientific research.

The policy document, while taking into account that national needs require a balanced Federal science program, restated the Foundation's commitment to the promotion of basic research and to the management of its non-mission-related, basic research program "in such a way as to permit the development of science along lines dictated by the internal needs of science itself."

In addition, the policy document recognizes that the research strength of academic institutions lies in its individualistic character and relative freedom from constraints outside the intellectual structure of science itself. Accordingly, the criteria for support of academic science "should stress the merit of individual research projects" and "the total constellation of support should permit appropriate research experience for all qualified students and faculty." In assessing merit, many questions must be considered, including but not limited to, "What is the promise of significant scientific results from the proposed project" and "what is the past record of performance of the investigators who will do the work and their potential for future accomplishement"?

In the case of national centers and fundamental research institutes, which are generally funded by block-grant support, decision making involves additional criteria relating to the creation of new research institutions or modification of programs or facilities in existing institutions and national programs that cannot be satisfied by other means.

Institutional Development

Although in some cases support of basic research may have had the effect of fostering institutional development, it has not, however, been the intended primary purpose of basic research project support programs to provide for a general upgrading of science activities at academic institutions.

In recognition of this fact, the Foundation gradually developed programs for the support of institutional activities in the sciences as a complement to its programs in support of individuals within an institution. These programs were devised as a mechanism to provide both for individual institutional needs in science and to increase national scientific capability by providing assistance across a broad spectrum of colleges and universities. Although basic research activity may benefit as part of this activity, Foundation support of individual research projects continues as a separate function.

Several steps were taken during fiscal year 1967 to strengthen and extend the scope of Foundation programs already initiated for support at the institutional level. Two new programs were inaugurated (the Departmental Science Development Program and the College Science Improvement Program) which increased considerably the number of institutions eligible for support, thus contributing to the development of a greater number of high-quality scientific institutions. Each of these programs is described in some detail later in this chapter as well as in the main text of the report. Furthermore, because of the growing importance of this support mechanism, the Foundation, during the year, established a new organizational unit for institutional relations, with its head at the associate director level.

The Role of Social Science Research

The national need for the development of programs which might contribute to the practical solution of current major problems has been discussed above. It is therefore noteworthy that included among the scientific disciplines receiving Foundation support, for both research and educational activities, are the social sciences. Expansion of fundamental knowledge and understanding of the social sciences must underlie solution of many of our major current problems in the long term. At first supported by the Foundation only to a small extent, social science activity has evolved gradually from initial modest efforts at supporting research in "convergent fields" within the the Division of Biological and Medical Sciences and the Division of Mathematical, Physical, and Engineering Sciences, to the establishment of an independent program, to office status, to division status. At the same time expanded coverage has also been given to the social sciences in other units of the Foundation so that the social science related activities are now eligible for support in all NSF institutional and educational programs.

In recent years, the social sciences have been receiving special stimulus in Foundation programs, partly as an outgrowth of recognition by the Foundation of the urgent need to attack specific social ills and the benefit which might be derived by employing social science research as a tool leading to alleviation of these problems. During fiscal year 1967, the National Science Foundation, in a policy document, reaffirmed its commitment to the support of social science research and indicated its intention to expand such support even further. Moreover, in its last meeting of the year, the National Science Board decided to establish a special commission on the social sciences in accordance with the provision of section 3(a)(7) of the National Science Foundation Act.

Additional support for social science research will allow an increase in the support of nonmission related basic social science research, without regard to utility, as well as permit greater emphasis on the support of social science projects which concern critical national issues. The Foundation views its increase in support of social science research as an additional step in strengthening general scientific research on the relation of man to society and in overcoming specific problems such as urban congestion, crime, etc.

SIGNIFICANT PROGRAM CHANGES

During the year a number of program shifts were effected, some in direct response to the policy decisions described above. Several major new programs were introduced, one large-scale venture was concluded, and a change in emphasis was made in a number of ongoing Foundation program activities.

New Programs and Facilities

Institutional Development Programs

In order to assist individual institutions of higher education to upgrade their efforts in science and in order to broaden the base of the Nation's scientific endeavor, the National Science Foundation has established two new support programs for the support of institutional development. These programs complement and extend the scope of assistance previously provided by the University Science Development Program (formerly known as the Science Development Program), and provide additional resources to groups of institutions of varying type, size, and function.

The newly initiated Departmental Science Development Program concentrates on the improvement of specific science departments at graduate level academic institutions which are not yet ready to move into the top rank in science on a broad front but where considerable strength already exists and can be built upon. It is the intent of the program to assist the participating institutions in developing strong centers of quality within the institution which may then provide stimuli for the improvement of other institutional scientific activities. This program falls within the jurisdiction of the Foundation's Institutional Relations program. Although it was not possible to announce the program until the fall of 1966, numerous proposals were received from which, by the end of fiscal year 1967, four had been selected for grants totaling $1.9 million.

The College Science Improvement Program focuses on assistance to 4-year undergraduate colleges. The program is intended to provide undergraduate-level institutions with resources with which to improve undergraduate education in the sciences and to expand opportunities for undergraduates to become interested in scientific careers. This activity is organizationally located in the Foundation's Education program. Fifteen College Science Improvement awards totaling approximately $2.5 million were made during fiscal year 1967.

Research Programs

Some major new research programs were initiated during the year.

As the result of enactment of the National Sea Grant College and Program Act of 1966 the Foundation was authorized to establish programs, primarily at institutions of higher education, to provide for the training, research, and advisory services necessary to develop, to the fullest extent possible, the Nation's marine resources. In direct response to this charge, the Foundation established two programs: (1) The Sea Grant College support program which will provide block-grant support to a limited number of colleges and universities having the appropriate scientific competence to engage in training and research related to the development of marine resources and to undertake marine advisory programs; and (2) the Sea Grants Project support program which will support activities related to the exploitation of marine resources on a project-by-project basis.

Also announced during the last year was the decision that the National Science Foundation and the Ford Foundation will jointly fund, through the Association of Universities for Research in Astronomy, Inc., the design and construction of a 150-inch optical telescope at Cerro Tololo Inter-American Observatory near La Serena, Chile. This instrument, one of the largest in the world, will complement the 150-inch telescope planned for the Kitt Peak National Observatory in Arizona by enabling scientists to investigate astronomical phenomena in the Southern Hemisphere skies, which have not previously been accessible with instruments of this size, and to correlate the results with studies made in the Northern Hemisphere. This undertaking marks the first time that a major U.S. private foundation and the National Science Foundation have collaborated in providing support for a major scientific instrument.

International Programs

Two new international programs for scientific cooperation were established in fiscal year 1967.

An agreement was signed by the United States and Italy providing for a broad program of scientific cooperation, through joint scientific ventures and the exchange of information, and naming the National Science Foundation as the executive agency for coordinating and implementing the terms of the agreement on behalf of the United States.

The Foundation was also designated as the agency responsible for executing the terms of a U.S.-India agreement for the exchange of scientists and engineers. The purpose of this arrangement is to promote increased communication between the scientific communities of the two countries on problems of mutual interest.

In addition, a formal agreement between the U.S. Agency for International Development and the Government of India, for a project initiated in fiscal year 1966 and for which the Foundation was assigned administrative responsibility, was signed and implemented during fiscal year 1967. Designed to upgrade science education in India, the program sponsored a series of summer institutes for teachers of science in Indian secondary schools and colleges and universities.

Programs Concluded

Project Mohole, the scientific venture to drill through the earth's crust and into the mantle beneath it, was terminated in fiscal year 1967. Effort on the project was stopped by congressional action which discontinued financial support for the undertaking. The prime contract with Brown & Root, Inc., was only partially terminated in order that the best interests of the Government would be served in completing those subcontracts for designs and fabrication of equipment which were more than 95 percent completed. Also final technical effort was authorized to complete various reports and engineering summaries in order to preserve as a final project legacy the research and development which had been accomplished since the project's initiation in 1962. The closeout of the project proceeded expeditiously during fiscal year 1967. All continued subcontracts were completed, the majority of terminated subcontracts were settled, all material and equipment were disposed of, and the final technical summaries were completed. The final settlement with the prime contractor should take place in the early part of calendar 1968.

Other Program Changes

Several ongoing Foundation programs received increased support or emphasis during the year and also deserve special mention.

Research Programs

Foundation support for its Weather Modification Program increased substantially in fiscal year 1967. In part the increased support represents a response to the recommendations set forth in two relevant reports, one issued by the Foundation's Special Commission on Weather Modification, and one by the National Academy of Sciences/National Research Council Panel on Weather and Climate Modification. Both studies indicated the ability of man to exercise some control over and to change some aspects of weather and climate, and both called for steps toward establishing a greater understanding of this area.

Support for basic research projects in physics and in the social sciences was also expanded during the year. The physics program undertook to fill the gap created by the withdrawal of Department of Defense support from the large accelerator centers at the University of Chicago and at Columbia University. The growth of funds for social science research reflects, as previously indicated, Foundation interest in encouraging basic research in this area which, in turn, might contribute to the elimination of some of the more critical and urgent problems of society.

Education Programs

A number of Foundation education programs are being strengthened.

The decision was made during the year to provide greater support for the Cooperative College-School Science Program as a means of adapting new materials, approaches, and techniques—developed to improve the quality of instructional programs—to the specific needs of school systems as determined by local educational authorities. This program permits the school system responsible for the implementation of new or improved curricula to obtain professional assistance and advice on curriculum change and teacher training from subject-matter experts at the college level. The Cooperative College-School Science Program serves as a complement to other Foundation programs designed to improve science instruction at the pre-college level.

In an effort to stimulate highly innovative science education activities more dollars were channeled to the Foundation's program for Special Projects in Education at the pre-college level. This program provides assistance for proposed ideas which reveal new and imaginative approaches to problems in science education but which fall outside the bounds of other formally established programs. Some examples of the types of activities covered by this program include experiments making use of new educational technical resources such as computers, television equipment, video tapes, etc., and the mobilization of community resources (museums, for example) for the enrichment of school curricula.

Additional funds were also provided during the year to strengthen the Course Content Improvement Programs, which enable scholars and competent teachers and educators to create new instructional materials for the teaching of science, and to strengthen programs for the supplemental training of college teachers.

Computing Activities

Increased attention and support were also given to computing activities during fiscal year 1967, and a discussion of the Foundation's computer program may be found in a later section of this chapter.

Science Information

Another change in program orientation, which took place during the year, provides for increased stress on the development of discipline-based information systems as part of the Foundation's science information activity. The decision was made that the Office of Science Information Service should concentrate a much greater portion of its future effort on the growth of comprehensive information systems, within the major scientific disciplines, based upon the discipline's own appraisal of its requirements and of the most appropriate means of meeting them. Fiscal year 1967 obligations reflected this change in emphasis, with a significant increase in support being given to scientific societies with the capability for developing information systems for their specific discipline.

The prototype of this concept has been the chemical information system. The American Chemical Society is converting all its publications to production by a single computer-based system which will also provide for automatic search and retrieval of chemical information. This conversion was begun with the Chemical Abstracts Service (CAS) and it is expected that CAS publications will be completely computer produced by 1970.

Science Planning and Policy

A significant development took place in Foundation activities in the area of science planning and policy. In order to strengthen national capability in this increasingly important area, the Foundation proposes to expand its program to develop science planning and policy centers through a series of grants to academic institutions with some established potential.

MAJOR PROGRAM ACCOMPLISHMENTS

Important progress was made during the past year in a number of research and science education programs and activities receiving Foundation support, and some of the more significant accomplishments are highlighted below.

Cornell 10 BeV Electron Synchroton

Construction of the Cornell 10 BeV electron synchroton, developed with Foundation support at the Cornell University Laboratory of Nuclear Studies, is now nearing completion. The electron beam first made a complete circuit around the accelerator on March 4, 1967; acceleration of an electron beam to 2 BeV was achieved in May, using the temporary acceleration system. With one-half of the final acceleration system in operation, an energy of 7 BeV was achieved on October 10; final completion is expected by the end of year, several months ahead of the target date of April 1, 1968. Experiments to be performed at the accelerator are already being planned by groups of scientists not only at Cornell but at several other institutions as well.

Line Islands Experiment

During fiscal year 1967, the Line Islands (Christmas, Fanning, and Palmyra Islands in the Central Pacific) were the focus of an extensive series of land, sea, and air observations coordinated by the National Center for Atmospheric Research (NCAR) and involving groups from nine academic institutions and various Federal agencies. Purpose of the experiment was to measure vertical energy transport due to tropic convection. The Foundation supported this activity for the academic institutions as well as NCAR. The experimental data collected will provide greater understanding of the contribution of tropical ocean areas to the global atmospheric circulation and will increase the amount of meteorological information available from these regions. The experiment was the first in a series of Tropical Meteorological Experiments (TROMEX) that are now being planned. The next experiment is scheduled for the summer of 1969 near Barbados. All of the TROMEX are part of a larger group of experiments known as Global Atmospheric Research Project (GARP). GARP is the research portion of the international programs known as the World Weather Program (WWP).

Antiquity of Life on Earth

Although scientists generally agree that the earth is about 4.5 to 5 billion years old, very little is known about the time at which the first and most primitive forms of life appeared, and about the conditions which led to their development. Extensive evidence has been uncovered concerning the existence of later, more complex organisms which date back to the Cambrian Period, about 500 million years ago, but few clues have been found relating to conditions in the vast pre-Cambrian period, which represents about 90 percent of the earth's history. Some new light has been shed on the problem of ancient life by a Harvard University scientist who, working under a grant from the National Science Foundation, has identified ancient bacteria which date back 2 and 3 billion years. These findings have implications for understanding not only the time period during which some form of life has existed on earth but also understanding the conditions which led to the creation and development of life.

Course Content Improvement Program—Madison Project

The four largest cities in the United States, New York, Chicago, Los Angeles, and Philadelphia, and, in addition, San Diego, are revising mathematics instruction in their elementary school systems through the introduction of new teaching techniques developed by the Madison Project, an undertaking sponsored by the Foundation's Course Content Improvement Program. The project, headquartered at Webster College, Webster Groves, Mo., will, with Foundation support, provide consultative assistance to each city's school system to put the new system into operation.

Ion Cyclotron Resonance Spectroscopy

A new technique, ion cyclotron resonance spectroscopy, developed with Foundation support, promises to be of considerable significance in the understanding of certain chemical reactions. A commercial ion cyclotron, double resonance spectrometer is now being produced, and Dr. John D. Baldeschwieler, of Stanford University, one of the developers of this technique, has been selected as the 1967 winner of the American Chemical Society's Award in Pure Chemistry in part for his contribution in ion cyclotron resonance spectroscopy research.

Space-Age Polymers

Research conducted at the Case Institute of Technology, with principal support from the National Science Foundation, has led to the development of polyphenyl, a new plastic material. This material is now being produced commercially in limited quantities for use as a heat shield for re-entry of space vehicles and for use as an insulator in electronic equipment which operates at high temperatures.

Laser Communications Receiver

Foundation sponsored work at the University of Texas has resulted in the development of a new method for receiving television signals transmitted by means of a laser light beam, and a laser television transmitter has been constructed which sends out a beam of invisible infrared light. Although additional development work is required this method could ultimately lead to a means of sending information now carried by radio and television transmitters and could thus result in relieving the congested radio wave spectrum.

NATIONAL SCIENCE FOUNDATION PARTICIPATION IN GOVERNMENT-WIDE ACTIVITIES

In addition to its regular functions as part of the Federal scientific community, certain focal agency responsibilities rest with the Foundation in connection with programs and policies which cut across all Federal agency lines.

Committee on Academic Science and Engineering

The Committee on Academic Science and Engineering (CASE) was established in fiscal year 1966 by the Federal Council for Science and Technology as a direct response to a Presidential memorandum and with the purpose of coordinating some of the academic science activities of Federal agencies. The Director of NSF serves as chairman.

During its first year of operation numerous projects were initiated, and, during fiscal year 1967, considerable progress was made in several important areas. An interagency reporting system, known as the CASE Reporting System, was developed to make available compatible data and information on Federal financial contributions to research and other scientific activities conducted at academic institutions. Federal agencies report to the Foundation, which serves as the central Federal body for the administration and operation of the system, information on their support of all academic science activities. Such information will provide assistance and guidance to Federal officials involved in the administration and planning of Federal science and engineering support programs. The Foundation, which is responsible for the compilation and analysis of the incoming information, will prepare a comprehensive report annually.

The first of these reports, *Federal Support for Academic Science and Other Educational Activities in Universities and Colleges, Fiscal Year 1965,* was issued during the year. Prepared by the Foundation for the Office of Science and Technology, the publication presents detailed information on Federal science activities in colleges and universities. A second report, covering fiscal years 1963 through 1966 and providing greater detail, was also prepared during fiscal year 1967.

A Task Force on Facilities, established to develop methods of achieving greater uniformity in policies and procedures affecting requests for support for the construction and renovation of facilities, also made significant progress over the year. A report was drafted, accepted by CASE, and transmitted to the Federal Council for Science and Technology. In addition, the recommendations of a CASE Subcommittee on Institutional Development, aimed toward establishing greater coordination and cooperation among Federal agencies in their institutional level support programs, were approved both by CASE and by FCST, and work is underway on devising means of implementing these recommendations.

Computing Activities

During recent years, computers have become an increasingly important tool for academic science and their use by colleges and universities has grown rapidly. As a result academic institutions have been forced to apply an increasingly large part of their resources to computer investments. In recognition of this growing burden the Foundation has been expanding its support of academic computational facilities and operations to help maintain the quality of academic computer capabilities where they already exist and to establish needed computers where there are none available. As part of this effort to assist academic institutions in the development and maintenance of campus computing facilities, the Foundation has been concerned with devising methods for applying computer technology to the educational processes.

The potential which computers may have within the educational process was emphasized in a report of the President's Science Advisory Committee entitled "Computers in Higher Education" (Pierce Report). Prior to the publication of this report the Foundation undertook a survey of the current and projected costs for computing services by academic institutions. The results of this survey and the recommendations presented in the Pierce Report indicated that substantial new Federal support would be required if the potential uses of computers in education are to be realized early in the next decade. In his health and education message to Congress on February 28, 1967, the President specifically directed the Foundation to work with the U.S. Office of Education in establishing an experimental program for developing effective methods for utilizing computers at all levels of education.

After a review of its current activities related to computers, the Foundation decided that the establishment of a new Office of Computing Activities early in fiscal year 1968 would provide a more suitable framework for meeting future requirements for computers in education and research. At the same time, it was planned to establish an interagency Committee for Educational Uses of Computers to help insure the effective coordination of Federal programs in support of the objective of developing educational uses of computers.

Through the membership of its director on the following committees, the Foundation participates in a number of other Government-wide activities:

Interagency Committee for International Meteorological Problems of the Department of Commerce;

Defense Science Board of the Department of Defense;

Federal Council for Science and Technology;

Federal Council on the Arts and the Humanities;

Interdepartmental Committee for Atmospheric Sciences of the Federal Council for Science and Technology (Vice Chairman);

International Committee of the Federal Council for Science and Technology;

Interagency Working Committee on Science and Urban Problems of the Department of Housing and Urban Development;

National Council on Marine Resources and Engineering Development;

President's Committee on Manpower;

President's Science Advisory Committee (Consultant);

Science Liaison Group of the Department of State.

SUMMARY OF FINANCIAL, PROPOSAL, AND AWARD ACTIVITIES

The fiscal year 1967 congressional appropriation for the operation of the National Science Foundation totaled $480.0 million, the same amount as was authorized for fiscal year 1966. Foundation obligations for fiscal year 1967 amounted to $465.1 million. This figure covers all Foundation external support programs, its intramural activities, and all attendant operating expenses.

The distribution of Foundation obligations according to major program category, for both fiscal years 1966 and 1967, is summarized below. A more detailed breakdown of the fiscal year 1967 obligations may be found in the Financial Report in appendix B.

The summary table reveals some change in the standing of a number of Foundation programs in both absolute and relative terms. The Foundation's research programs, in total, received reduced dollar support and accounted for a smaller share of all Foundation obligations in fiscal year 1967 than in fiscal year 1966. This decrease is mainly due to the termination of Project Mohole. Institutional support programs, on the other

Table 1.—*Net Obligations of the National Science Foundation, Fiscal Years 1966 and 1967*

	Fiscal year 1966 [1]		Fiscal year 1967	
	Amount (in millions)	Percent	Amount (in millions)	Percent
Scientific research	[2] $235.0	50.4	[2] $220.9	47.6
Science education	124.3	26.7	123.4	26.5
Institutional support of science	69.5	14.9	79.7	17.1
Computer activities	10.0	2.1	12.7	2.7
Planning and policy studies	2.0	.4	2.4	.5
Science information activities	11.6	2.5	10.0	2.2
International science activities	.9	.2	2.0	.4
Program development and management	13.1	2.8	14.0	3.0
Total obligations	[2] 466.4	100.0	[2] 465.1	100.0

[1] Figures shown here for fiscal year 1966 do not completely match those presented in the NSF Annual Report for Fiscal Year 1966 due to changes in program classification.

[2] Note that fiscal year 1966 totals include $17.0 million for Project Mohole, which was discontinued in fiscal year 1967.

hand, increased between fiscal years 1966 and 1967 in both relative standing and in the amount of funds obligated. Part of this increase is associated with the introduction of new institutional program activities which themselves include some support for research activities; part of this increase stems from the obligation of funds in fiscal year 1967 to cover commitments made in earlier years for the second stage of two-stage awards for graduate science facilities.

Foundation obligations for each program category according to major field of science are shown in table 2 for both fiscal years 1966 and 1967. Support of the biological sciences, the earth sciences, and astronomy was somewhat lower in fiscal year 1967 than during the previous year primarily because of different emphases in the institutional support program. Furthermore the marked decline in funds for oceanography occurred as the result of the phasing out of Project Mohole. The other scientific disciplines received increased dollar support in fiscal year 1967, particularly chemistry which rose from $43.6 million in fiscal year 1966 to $54.5 million in fiscal year 1967. Much of the increase in chemistry, however, results from the aforementioned fiscal year 1967 obligation for prior year commitments for graduate science facilities in the Foundation's institutional support program.

Table 2.—*National Science Foundation Net Obligations, by Discipline, Fiscal Years 1966* [1] *and 1967*

[Dollars in thousands]

FISCAL YEAR 1966

Discipline	Total	Scientific research	Science education	Institutional support of science	Computing activities	Science information activities	International science activities [2]	Planning and policy studies	Program development and management
Mathematics	$46, 104	$11, 773	$27, 809	$5, 033	$1, 140	$270	$79	....	....
Physics	52, 723	26, 630	13, 650	12, 139	....	229	75	....	....
Chemistry	43, 565	18, 828	15, 658	8, 322	....	666	91	....	....
Biology	82, 908	45, 323	20, 417	16, 711	....	282	175	....	....
Social sciences	31, 879	12, 995	11, 048	6, 040	....	816	43	$937	....
Engineering	48, 681	19, 203	20, 247	7, 716	....	1, 439	76	....	....
Astronomy	24, 457	20, 616	752	3, 063	....	15	11	....	....
Atmospheric sciences	25, 569	23, 620	768	1, 031	....	124	26	....	....
Earth sciences	21, 602	9, 969	7, 275	3, 104	....	1, 178	76	....	....
Oceanography	47, 120	46, 032	645	435	....	....	8	....	....
All other [3]	41, 820	....	6, 036	5, 883	8, 899	6, 601	240	1, 072	$13, 089
Total	466, 428	234, 989	124, 305	69, 477	10, 039	11, 620	900	2, 009	13, 089

FISCAL YEAR 1967

Mathematics	$48, 794	$13, 053	$25, 969	$8, 050	$1, 396	$292	$34	....	....
Physics	58, 485	29, 467	13, 873	14, 192	....	903	50	....	....
Chemistry	54, 547	20, 327	14, 798	18, 222	....	1, 114	86	....	....
Biology	76, 999	44, 395	18, 953	11, 743	....	1, 053	855	....	....
Social sciences	35, 376	14, 724	11, 198	8, 131	....	362	39	$922	....
Engineering	51, 249	20, 188	20, 560	9, 556	....	893	52	....	....
Astronomy	21, 281	19, 902	666	637	....	....	76	....	....
Atmospheric sciences	27, 672	25, 740	348	1, 365	....	161	58	....	....
Earth sciences	18, 562	9, 840	6, 703	710	....	1, 205	104	....	....
Oceanography	24, 401	23, 231	686	456	....	....	28	....	....
All other [3]	47, 738	....	9, 606	6, 661	11, 295	4, 042	619	1, 471	$14, 044
Total	465, 104	220, 867	123, 360	79, 723	12, 691	10, 025	2, 001	2, 393	14, 044

[1] Figures presented here for Fiscal Year 1966 do not completely match those presented in the NSF Annual Report for Fiscal Year 1966 due to changes in classification.

[2] These data are not entirely comparable for the 2 years due to classification changes.

[3] All other includes those obligations in support of programs which cut across disciplines and, therefore, are not attributed to any single discipline.

Of the $465 million in fiscal year 1967 obligations, an estimated $235 million was earmarked for the support of basic research programs. (This figure includes all Foundation basic research obligations, whether supported by its Scientific Research program or by other Foundation programs such as those for Institutional or Computer Support activities.) Foundation obligations for basic research in fiscal year 1967 represented about 11 percent of all Federal agency basic research obligations for the year. The Foundation's basic research programs have accounted for approximately the same share of Federal basic research activities in recent years—varying between 10 and 12 percent between fiscal years 1963 and 1967.

Basic research support by the Foundation is concentrated primarily in the Nation's institutions of higher education. Of the $235 million total Foundation obligation for basic research in fiscal year 1967, an estimated $191 million was assigned to the support of basic research programs in colleges and universities, accounting for approximately one-fourth of total Federal obligations for this purpose. An analysis of the data for the 5-year period covering fiscal years 1963 through 1967 shows that the proportion of total Federal basic research support at academic institutions provided by the Foundation has fluctuated somewhat, being slightly higher in fiscal years 1966 and 1967 than in the earlier 3-year period.

Foundation support of colleges and universities is not, of course, restricted solely to basic research; other facets of academic science activities also fall within the jurisdiction of its programs. In fiscal year 1967, Foundation support for all academic science programs (including basic research, R. & D. plant, science education, and science information activities) equaled $394 million. A review of the information compiled for fiscal years 1963 through 1967 reveals that the proportion of total Federal support for academic science programs represented by Foundation funds declined slightly over the period, from about 20 percent in fiscal year 1963 to about 17 percent in fiscal year 1967 (although the absolute amount increased from $256 to $394 million). This downward trend may be attributed to relatively large growth rates for the support of academic science in the Department of Health, Education, and Welfare, which includes the Office of Education and the National Institutes of Health.

The number of grants and contracts awarded by the National Science Fundation in fiscal year 1967 for its external support programs [3] equaled 9,311, slightly fewer than were awarded the previous fiscal year (9,387). For each year awards reflected an acceptance rate of 61 percent based on the total number of proposals on which final action was taken by the Foundation (15,364 in fiscal year 1967, 15,490 in fiscal year 1966).

In terms of dollar obligations,[4] grants and contracts awarded amounted

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[3] Does not include fellowships; for total award data including fellowships, see table 3.

[4] These data do not match the obligation figures shown in tables 1 and 2 which include funds for the administration of Foundation programs, for Project Mohole, and for fellowship support and which reflect net, rather than gross obligations.

to $441.4 million in fiscal year 1967, an increase of 4 percent over the comparable figure of $424.1 million for fiscal year 1966. Obligations for the Foundation's "operational" programs [5] should more properly be viewed on an annual rate of use basis with the influence of the duration of the award not a factor in the obligation total.[6] Adjusting the dollar amounts for the operational programs, to take into account award duration, funds awarded on an annual rate of use basis totaled $233.8 million in fiscal year 1967, representing a support rate of 70 percent on the basis of the annual-rate dollars requested in the successful proposals ($333.5 million). However, the annual-rate dollars awarded in fiscal year 1967 were 1 percent lower than the fiscal year 1966 figure of $236.3 million. Thus, fiscal year 1967 dollar support by the Foundation was insufficient to maintain the previous level of science support since it did not keep pace with growth requirements arising from inflationary pressures and from the increased costs associated with changing, more sophisticated, and more complex methods of carrying out the work. In the case of research projects, for example, a 5- to 7-percent annual increase would be necessitated by inflation-complexity factors in order for the same amount of research to be supported in fiscal year 1967 as in fiscal year 1966. Moreover, this leveling of support occurred during a period in which the number of science students and faculty was increasing markedly.

Foundation grants and contracts were awarded to 796 academic institutions representing all 50 States, the Virgin Islands, Guam, and Puerto Rico. In addition, a modest total of 38 grants and contracts were awarded to institutions in 16 foreign countries.

The distribution of all Foundation awards during the past 2 years according to major program category is shown in table 3 in terms of numbers, in terms of total dollars granted, and in terms of dollars granted on an annual basis. As can be seen, the operational programs decreased over the period in the number of awards made and on the basis of annual rate dollars. This pattern varies among the individual programs. The facilities and institutional awards, on the other hand, increased between fiscal year 1966 and fiscal year 1967 both in number and in amount granted. However, once again it should be noted that the growth in dollar support for facilities is largely accounted for by inclusion, in the total, of funds committed in previous years for the second stage of two-stage facility awards but not obligated until fiscal year 1967.

The Foundation's numerous fellowship programs are designed to make available to outstanding students of science and engineering opportunities for advanced training, and the Foundation provides direct support to individuals for this purpose. The number of fellowships awarded during

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[5] For the operational program categories, see table 3.

[6] For example, an award of $100,000 for 2 years may be translated into an award of $50,000 on an annual rate of use basis.

Table 3.—Summary of Grants, Contracts, and Fellowships Awarded, by Program Category, Fiscal Years 1966 and 1967 [1]

[Dollars in thousands]

	Fiscal year 1966			Fiscal year 1967		
	Number awarded	Total amount awarded	Total annual rate awarded	Number awarded	Total amount awarded	Total annual rate awarded
Scientific research...	4,070	$196,502	$122,200	4,204	$200,793	$122,895
Science education...	8,407	131,776	121,407	6,471	129,869	114,820
Science information activities.........	166	12,543	9,900	142	10,710	7,691
International travel .	383	707	3,215	548	971	4,306
Planning and policy studies..........	59	2,148	2,680	55	2,410	2,689
Subtotal—"Operational" programs..	13,085	343,676	259,402	11,420	344,753	252,401
Facilities' support [2]..	278	51,672	....	330	61,800	....
Institutional support of science........	411	50,893	....	532	52,711	....
Subtotal.....	689	102,565	....	862	114,511	....
Total—All programs..	13,774	446,241	....	12,282	459,264	....

[1] These data do not match the obligation figures shown in tables 1 and 2, which include funds for the administration of Foundation programs and for Project Mohole and which reflect net, rather than gross obligations.

[2] Does not include funds from science development programs which might be used for facilities construction, expansion or renovation. These are included in the institutional support category.

fiscal year 1967 was considerably lower than during fiscal year 1966 (2,971 against 4,387, a drop of one-third.) This decrease, however, stems in large part from a change of program emphasis, with support in some science education programs shifting from the fellowship to the traineeship mechanism. Traineeships are awarded to academic institutions granting doctorates and demonstrating the capability for providing adequate training for science graduate students. The institutions select the graduate trainees. In fiscal year 1967, 665 traineeship awards were made to universities and colleges for the support of 5,973 graduate students. In fiscal year 1966, 461 awards provided support for 4,193 students. Thus, the number of students supported through traineeships and fellowships increased from 8,580 in fiscal year 1966 to 8,944 in fiscal year 1967.

ORGANIZATIONAL DEVELOPMENTS

During fiscal year 1967 there were a number of organizational developments relating both to the internal Foundation structure and to the National Science Board.

Personnel appointments at the associate director level announced during the year include:

Dr. Charles E. Falk, Planning Director.

Dr. Thomas D. Fontaine, Associate Director, Education.

Dr. Louis Levin, Associate Director, Institutional Relations (newly created).

Other major appointments are listed below:

Mr. Robert B. Abel, Head, Office of Sea Grant Programs (newly created).

Dr. Neville L. Bennington, Director, Division of College Education in Science.

Dr. Wilbur W. Bolton, Jr., Contracting Officer.

Dr. Geoffrey Keller, Deputy Planning Director.

Dr. Keith R. Kelson, Deputy Associate Director, Education.

Dr. Howard D. Kramer, Director, Division of Graduate Education in Science.

Dr. J. Richard Mayer, Head, Office of Data Management Systems (newly created).

Dr. Howard E. Page, Deputy Associate Director, Institutional Relations.

Dr. Sidney G. Reed, Jr., Head, Office of Planning and Policy Studies (newly created).

Dr. Milton E. Rose, Head, Office of Computing Activities (newly created).

Mr. Howard S. Schilling, Head, Office for Equal Opportunity (newly created).

Dr. William E. Wright, Division Director, Mathematical and Physical Sciences.

In total, 942 full-time personnel were employed by the Foundation at the end of the fiscal year, about the same number as employed at the end of the previous year, with 14 located abroad in branch offices of the Foundation.

As indicated, some of the above-listed appointments were made in connection with the establishment of new Foundation offices. The establishment of new organizational units resulted both from internal assessments which indicated a need for some reorganization based on changing program emphasis as well as from external action which placed additional responsibility on the Foundation. In total, seven new units were created:

The Office of Sea Grant Programs was established to implement the provisions of the National Sea Grant College and Program Act of 1966, described above.

The Oceanography Section in the Division of Environmental Sciences was created to carry out the oceanographic activities previously conducted in the Earth Sciences Section of the same division.

The Office of Computing Activities was formed to provide a framework within which all Foundation computer-related activities, exclusive of those associated with research grants, might be supported and coordinated.

In recognition of the importance of maintaining support at colleges and universities at the institutional level, the Foundation reorganized its institutional program activities by abolishing the existing Division of Institutional Programs and placing these activities instead under an associate director, Institutional Relations.

The creation of the Office of Equal Opportunity represents Foundation implementation of the Executive directive providing for nondiscrimination in Government employment, nondiscrimination in employment by Government contractors and subcontractors, and for nondiscrimination provisions in federally assisted construction contracts.

The Office of Planning and Policy Studies is a merger of two previous Foundation units—the Office of Program Development and Analysis and the Office of Science Resources Planning. By combining the two offices into one unit a more effective way has been found to interrelate planning and policy studies and activities relating to internal Foundation needs with those concerned with national science resources and requirements.

Establishment of the Office of Data Management Systems was a response to the growing need within the Foundation for a focal unit to plan, develop and implement standardized data systems for the operational data needs of the Foundation and for the data requirements which form the basis for policy and planning activities.

National Science Board Changes

During fiscal year 1967 no changes took place in either the membership or the organization of the National Science Board. However, in fiscal year 1968 Dr. Roger W. Heyns, Chancellor, University of California, Berkeley, will replace Dr. Julius A. Stratton, Chairman of the Board, the Ford Foundation, who resigned from the Board due to the pressure of other duties.

With the reelection of Dr. Philip Handler and Dr. Ralph W. Tyler as Chairman and Vice Chairman respectively, and with the continuation of the standing committees, the organization of the Board will remain the same over the next fiscal year. A complete list of National Science Board members is provided in appendix A to this report.

RESEARCH SUPPORT ACTIVITIES

While the totality of all National Science Foundation programs is devoted to strengthening national capability in the sciences, direct support for scientific research can be divided into four major areas of activity:

- Basic research project grants to institutions, primarily colleges and universities, for scientific investigations conducted by individual scientists or groups of scientists;
- Support of cooperative national and international research programs;
- Assistance provided to institutions for acquisition of specialized research facilities and equipment;
- Support of National Research Centers maintained and operated for the Foundation by associations of universities.

These major research programs are discussed in this chapter, mainly in connection with related scientific disciplines.

BASIC RESEARCH PROJECTS

In fiscal year 1967, the Foundation awarded 3,976 grants totaling $172.6 million. In the proposals receiving favorable action, the total amount requested was $342 million so that, on the average, awards provided 50 percent of the funds requested. Some of this reduction in funds resulted from shortening the time for project support. If awards and support requested are compared over this shortened time span, the percentage of funds provided was 78 percent of that requested.

Table 4 which follows gives the distribution by fields of science of basic research project proposals received and grants awarded in fiscal year 1967.

These research grants were awarded to 406 institutions in 49 States, the District of Columbia, and Puerto Rico. More than 90 percent of the funds went to 310 academic institutions. Of these 214 received two or more research grants and 110 received at least $200,000.

In the engineering sciences, the program of Research Initiation Grants for young faculty members beginning independent investigations has been continued. The Foundation received 561 proposals requesting $9.8 million, and awarded 166 grants for a total of $2.2 million. Almost every State was represented in the proposals submitted.

Table 4.—National Science Foundation Basic Research Projects, Fiscal Year 1967

[Gross obligations, amounts in millions]

	Total requested		Awards	
	Number	Amount	Number	Amount
Social Sciences:				
Anthropology	263	$11.1	147	$3.7
Economics	118	8.6	81	3.2
Economic and social geography	24	.9	15	.4
History and philosophy of science	69	2.3	43	.8
Political science	52	1.8	32	.8
Sociology and social psychology	221	13.5	118	4.1
Special projects	26	4.7	15	2.0
Subtotal	773	42.9	451	14.9
Biological and Medical Sciences:				
Cellular biology	478	42.0	239	10.2
Environmental and systematic biology	646	34.4	390	11.4
Molecular biology	425	44.0	254	11.5
Physiological processes	682	55.5	343	11.1
Psychobiology	256	20.6	118	4.6
Special programs	38	8.3	30	4.6
Subtotal	2,525	204.8	1,374	53.4
Mathematical and Physical Sciences:				
Astronomy	144	11.7	118	5.9
Chemistry	760	63.3	420	17.4
Mathematical sciences	545	48.7	422	14.4
Physics	523	68.7	269	23.7
Subtotal	1,972	192.4	1,229	61.4
Environmental Sciences:				
Atmospheric sciences	122	16.7	90	7.2
Earth sciences	333	18.5	224	8.0
Physical oceanography	135	17.6	91	7.8
Subtotal	590	52.7	405	23.0
Engineering Sciences:				
Engineering chemistry	191	10.1	78	2.9
Engineering energetics	223	12.6	72	3.2
Engineering materials	460	23.7	161	3.1
Engineering mechanics	192	10.7	82	6.0
Engineering systems	235	11.6	87	3.5
Special engineering projects	79	3.9	30	.9
Subtotal	1,380	72.6	510	19.6
International Science Activities	3	.1	3	.1
Total	7,243	565.5	3,972	172.6

National Research Programs—Fiscal Year 1967

At times a research program may be so large or complex as to require coordinated planning and funding on a national basis, particularly if international cooperation is involved—even though the funding is largely in the form of grants to universities and colleges. In the case of each of the programs listed in table 5, the Foundation has been assigned the responsibility for cooperation or management by the President, or by the Congress, or by agreement within the executive branch.

Of the programs listed below, the U.S. Antarctic Research Program has remained relatively stable, but specific attention has been given this year to some complementary research in the Arctic. Foundation activities in the International Biological Program represent the initial stages of U.S. participation in a widespread effort to accelerate the growth in understanding of basic biological processes through international cooperative scientific research.

In fiscal year 1967, the program of the International Years of the Quiet Sun was concerned largely with data analysis and continuing review. Further work along this line will be continued under regular basic research projects in the future. The Weather Modification Program has received increased funding which has enabled it to expand its objectives to include social and economic, legal, and ecological aspects of weather modification. In addition, greater stability has been attained by increasing the time duration of grants so as to permit forward planning.

International Cooperative Scientific Activities includes projects initiated as a result of formal agreements between the United States and the governments of other nations (see International Science Activities, page 165), as well as exchange of scientists between nations and other activities designed to promote the overall strength of science.

In addition to these programs, the Foundation excepts to provide support for activities in connection with the Global Atmospheric Research Program (GARP), and the Ocean Sediment Coring Program. The Global Atmospheric Research Program is an internationally developed

Table 5.—*National Research Program Grants and Contracts*

	Number	*Amount (millions)*
U.S. Antarctic Research	143	7.58
Arctic Ocean Research	1	.13
Deep Crustal Studies of the Earth	1	.06
International Biological Program [1]	12	.50
Weather Modification	41	2.09
International Years of the Quiet Sun	18	.25
International Cooperative Scientific Activities	25	1.05
Ocean Sediment Coring Program [2]		

[1] Funded from basic research in FY 1967.

[2] Continuing program begun in FY 1966, no funds added in 1967.

program to study the general circulation of the earth's atmosphere. The Line Islands Experiment, which is discussed in connection with the atmospheric sciences, was an early part of GARP and was conducted in 1967. An early U.S. activity will embrace research efforts in connection with the Barbados Oceanographic and Meteorological Experiment (BOMEX) scheduled for 1968. The Ocean Sediment Coring Program will provide a means for scientists to make detailed analysis of ocean sediments taken from holes drilled at many different locations on the ocean floor. Drilling operations will be conducted from a research vessel suitably modified to meet the unique requirements of the project.

Cooperative Agreement With the Ford Foundation

Significant progress was made in cooperation between government and private foundations in the support of research when, for the first time, a joint funding arrangement was agreed upon in fiscal year 1967 by the National Science Foundation and the Ford Foundation for a 150-inch telescope at the Cerro Tololo Inter-American Observatory in Chile. The stimulus to these special types of cooperative effort stems from the unique site characteristics present at Cerro Tololo, and the needs for filling gaps in our astronomical knowledge of the skies of the Southern Hemisphere. Details of this project, scheduled for completion in 1973, are discussed on page 55.

Special Commission on the Social Sciences

Federal support for basic research in the social sciences has increased markedly in recent years and is expected to increase even more in the future. As a result, activities of the Foundation, as well as other governmental agencies, in these fields have reached the point where it seems wise to have a fuller understanding of how social sciences can be used more effectively; how collaboration between scientists and engineers can be enhanced and what measures and recommendations on the broad direction of research programs in the social sciences are needed. To meet these needs, the National Science Board has authorized appointment of a Special Commission on the Social Sciences.

National Sea Grant Program

The National Sea Grant College and Program Act (Public Law 89–688) was signed in October 1966. This new legislation assigned to the National Science Foundation responsibility for a new program of development of marine resources. This program represents a new departure for the Foundation since the act gives authority not hitherto possessed by the Foundation for the conduct of applied research in scientific and technical areas related to the development of marine resources.

In this new program, the Foundation, through its newly established Office of Sea Grant Programs, will help academic and research institutions to develop their capabilities in marine resources by supporting applied research on techniques and practices in ocean engineering, fisheries, aquaculture, marine chemistry and related fields. This program additionally will support training and communications programs to increase the supply of skilled manpower and provide useful information to the marine industries and interested bodies of individuals.

Foundation support of Sea Grant Programs will be developed in close coordination with those Federal agencies now charged with responsibilities in this area, notably the Bureau of Commercial Fisheries of the U.S. Department of the Interior. The role of the National Science Foundation will be to contribute to the national effort, primarily by building within academic institutions the research and training capabilities essential for rapid advance toward full utilization of marine resource potential.

Specialized Academic Research Equipment and Facilities

Modern science is characterized by its use of continually developing and increasingly complex and expensive equipment and facilities, which because of their cost cannot be funded out of normal operating expenses of academic institutions. The Foundation provides, therefore, a limited amount of support to these institutions for the acquisition of facilities considered most essential to the advancement of basic research. Table 6 summarizes the support given during fiscal year 1967.

Table 6.—*Specialized Academic Research Equipment and Facilities, Fiscal Year 1967*

	Number	*Amount (millions)*
Astronomy	12	1.860
Atmospheric Sciences	19	.954
Biological and Medical Sciences	25	1.668
Chemistry [1]	88	3.137
Engineering	44	.954
Oceanography	11	2.022
Physics	19	5.800
Social Sciences	10	.311

[1] Equipment only.

National Research Centers

National Research Centers funded by the Foundation are government-owned facilities established in response to an extraordinary research need that cannot be met by merely expanding programs at existing institutions. The facility in each case is actually operated by a corporation formed by a group of universities but the Center is funded by and under the general supervision of the Foundation. As a scientific institution, it maintains

Table 7.—National Research Center Funds, Fiscal Year 1967

Name	Amount
National Center for Atmospheric Research	$12, 300, 656
Kitt Peak National Observatory	5, 505, 000
National Radio Astronomy Observatory	4, 985, 000
Cerro Tololo Inter-American Observatory	1, 713, 000
Total	24, 503, 656

close collaboration with the scientific community. Table 7 gives the expenditures for the four National Research Centers that have been established by the Foundation.

At the observatories only a limited staff of outstanding astronomers and support personnel are resident. Most of the available telescope time is used by visiting astronomers and graduate students from the scientific community at large. In the case of the National Center for Atmospheric Research (NCAR), a sizable resident staff of highly qualified scientists from many disciplines does basic research in the atmospheric sciences. In this way, broad, interdisciplinary efforts can be undertaken to solve complex problems. The Line Islands Experiment is an example of how NCAR exercises leadership in the conduct of broad, cooperative projects. In addition to the work of the resident staff at NCAR, there is noteworthy participation by visiting scientists who use the specialized equipment available at NCAR and join in projects which are wider in scope than could be mounted by their own institutions.

BIOLOGICAL AND MEDICAL SCIENCES

Research in the life sciences was impressive during fiscal year 1967. Most of the significant investigations were in the areas of the major advances of the recent past, but several exciting probes have been made in new directions, and new patterns of inquiry into biological problems seem to be emerging as a result of the rapid disintegration of boundaries that earlier separated biological disciplines.

Within all disciplines of the life sciences, the study of biological problems has been extended to the molecular level. Barriers that formerly existed have been replaced to a great extent by a sense of interdependence and mutuality of interest. On the one hand investigators whose interests are at the molecular level are aware that their findings become more meaningful when related to higher levels of biological organization; and on the other hand, biologists concerned with problems of systematics, population dynamics, and evolution are now using techniques and concepts of molecular biology to extend their knowledge. Systematic and evolutionary studies have been invigorated, for example, by the use of molecular techniques for measuring the degree of similarity of proteins or DNA molecules of different biological groups.

Counterparts of these examples are seen in the new studies in molecular biology that deal with evolution and the origin of life.

These investigations can be conducted now because the genetic code has been deciphered. They are concerned with the evolution of the codons, the smallest unit of DNA that imparts genetic information. Until now, studies of organic evolution have dealt with species, individuals, or organ systems. Now as a result of "cracking" the genetic code, the study of evolution can be directed toward basic questions relating to the origin of life itself. Still another example of the reciprocal benefits accruing from the sharing of concepts and tools between heretofore separate fields of inquiry can be seen in population studies. A number of population problems—population of cells within a developing individual as well as populations of individuals within a species—are being approached at a very refined level.

While all of this cross-fertilization is going on at the molecular level, equally significant advances are being made at the opposite end of the size spectrum—at the level of whole ecosystems. At this huge scale, where the research subject may be the plant and animal community of an entire drainage basin plus, literally, the sky above and rocks below, biologists are drawn out of the limits of their field and cooperate with meteorologists, geochemists, and other physical scientists.

The breakdown of disciplinary boundaries within the life sciences is a consequence of the fact that to a great extent biology is evolving from a discipline-oriented to a problem-oriented science. This trend has been accelerated by the development of highly sophisticated instrumentation and by the team approach to research.

These factors, plus the widespread application of the concepts of molecular biology, have brought about a great burst of interest in four particular interdisciplinary areas of biology: immunization, differentiation, membrane biology, and neurobiology. The multidimensional mysteries in these areas represent new frontiers in biology, and important advances are anticipated in them during the coming years.

The breakdown of boundaries within the life sciences is matched by an increasing awareness of the continuum between the life sciences and the physical and social sciences. Much of the basic research supported by the National Science Foundation has relevance to population problems, food productivity, nutritional deficiency, disease control, and control of environmental quality. Increased attention has been given to the biological aspects of these areas during the past year as the International Biological Programs (I.B.P.) advanced from the late planning to the early operational stage.

The I.B.P. is an international cooperative program in the biological sciences to determine on an international cooperative basis the present and future capacities of the world's biological communities and man's adaptabilities to meet changes in these communities. The Office of Sci-

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ence and Technology has designated the Foundation as the coordinating agency for Federal participation in the I.B.P. The role of the United States in the I.B.P. will be to work with other nations and support urgent biological studies requiring international collaboration in the hope that worldwide cooperative effort will help less-developed nations, lead to significant developments in the science of biology, and promote a much-needed interchange of personnel between developed and less-developed countries.

Much interest in biological research during the past fiscal year was focused on regulation as a biological phenomenon. In the sample of projects described below, different levels of such control are illustrated.

Isolation and Mode of Action of Gene Repressors

A paradox puzzled biologists for many decades. They had observed that genetic material is replicated with great fidelity during cell division. Genes in each cell of an individual arising from a single fertilized egg must therefore be identical, and yet cells in different parts of the individual differ in appearance and function. To resolve this paradox an assumption was made. It was assumed that all genes, although present uniformly in all cells, are not active at all times and that different genes are active in different cells. If this assumption were true, the mystery to be solved was how this differential gene activity is regulated. The mystery was greatly clarified by the Nobel Prize-winning experiments of Francois Jacob and Jacques Monod of the Pasteur Institute in Paris, who, working with bacterial cells, hypothesized that there is a class of genes whose only function is to turn off the activity of other genes. They called them regulatory or repressor genes, and each one regulates the activity of a specific set of genes. They hypothesized that the product of a regulatory gene, the repressor, in some way prevents the gene it regulates from making its product. Since 1961 when the Jacob and Monod hypothesis was formulated, there has been an intensive search for a repressor in a number of laboratories. Indirect evidence indicated the hypothetical molecule was probably a protein, but there was no way to determine if it acted on the genic material directly or on the cellular machinery where gene-controlled products are synthesized.

Early during the fiscal year, S. Walter Gilbert and Bruno Müller-Hill of Harvard University working with Foundation support reported the isolation of the repressor that regulates the synthesis of the enzyme that breaks down the sugar lactose in the bacterium *Escherichia coli*. This repressor was identified as a protein. Repressor molecules exist in both an active and inactive form depending on whether or not they are combined with very specific small molecules, or inducers. When the inducer is present, the repressor is inactive. Repressor molecules are difficult to isolate because they are present in cells in very low concentrations. Drs. Gilbert and Müller-Hill approached the task of isolation by concentrating the repressor-inducer complex by a dialysis equilibrium method. This method separates different substances in solution by means of their differential diffusion through semipermeable membranes. In this study, a concentrated protein fraction from a bacterium that produced a repressor that binds tightly to the inducer was placed on one side of a membrane and a radioactive-labeled inducer on the other. After diffusing the inducer through the membrane, it was found that the protein concentrate contained a substance which caused the inducer to be concentrated in the protein fraction. This substance was the sought-after repressor.

Independently of this study, and with support of a Foundation grant, Mark Ptashne, also of Harvard University, used a different approach and a different system to isolate repressor molecules in purified form. The repressor that Dr. Ptashne isolated regulates the genes of a virus that infects bacteria. The genetic material of this virus can be incorporated into the chromosome of the bacterium it infects. However, it can do this without lethal effects only when the repressor produced by a gene of the infecting virus prevents the viral genes from functioning. If the repressor is inactivated, however, the infected bacterium produces more viruses and eventually bursts. The same repressor also gives immunity to the bacterial host cell from superinfection by similar viruses. The virus repressor isolated by Dr. Ptashne is much smaller than the "lactose" repressor isolated by Drs. Gilbert and Müller-Hill, having a molecular weight which is at most a fifth of the "lactose" repressor.

Having isolated the repressor in pure form, it was possible for Dr. Ptashne to determine where and how these molecules prevent gene action from being expressed. He mixed the isolated repressor protein DNA from the virus strains he used and demonstrated that the repressor molecules attach to DNA molecules and that this binding is specific. It is concluded from this that repressors work at the level of the genic material itself and in the simplest possible way—by physically binding with the genes they repress, thus blocking the synthesis activity of the genes.

The confirmation of the Jacob and Monod hypothesis has been demonstrated only in bacterial and viral systems, but it probably will have application in higher organisms. The experiments described above suggest the possibility that gene regulation can be controlled experimentally, and this could lead to the control of diseases and the prevention of expression of inherited defects.

Cancer Induction by Viruses

Boris Ephrussi of Western Reserve University, Ohio, has been investigating regulation at the cellular level by comparing such fundamental cellular processes as cell division in different strains of cells and in their hybrids grown in cell culture. A simple experiment was performed this year with collaborators (V. Defendi, H. Koprowski, and M. Yoshida) from the Wistar Institute, Philadelphia, that provides strong evidence that viruses that induce cancer do so by adding genetic information to the host cell.

Cancer cells are distinguished from normal cells by the fact that they are unable to regulate cell division. Since this regulation is an inherited trait, it is likely that the induction of cancer involves a genetic change. Before it was known that viruses could transform normal cells into cancer cells, many geneticists and cell biologists believed that cancer was caused by mutations in body cells resulting in the loss or malfunction of an essential regulatory gene. When it was demonstrated that viruses could induce cancer, it became plausible that cancer could be the result of the addition to the cell of genetic information carried by the virus. It was still possible, however, that the cancer-inducing viruses accomplished their deadly work by causing mutations and deletions. Dr. Ephrussi and his colleagues resolved these alternative hypotheses. They grew normal mouse cells and mouse cells that had been transformed to cancer cells by polyoma virus in the same culture and examined the hybrid cells produced by fusion of the two types to see if they had the properties of normal or cancer cells. The results were clear. The hybrid cells had the properties of the parental cancer cells.

These results indicate that neoplasia, which is viral induced, cannot be the result of the loss of genetic information because the hybrid cells contain the genetic information of the parental normal cells as well as the genetic information of the parental cancer cells. It is concluded, therefore, that the induced tumorous condition is caused by the addition of genetic information; namely, the genetic information of the cancer-inducing virus that persists in the transformed cells, perhaps incorporated into the cells' chromosome.

Influence of Environment on Brain

Mark Rosenzweig and his associates, Edward L. Bennett and Marian C. Diamond, all of the University of California at Berkeley, have been investigating the hypothesis that the environment in which the individual lives contributes to his brain chemistry and anatomy. There are many hints that support this hypothesis, but convincing proof has been difficult to find. In brief, the general procedure of these scientists has been to raise rats from birth in "enriched" as well as "impoverished" environments and examine the influence of these environments on the animals' brains. The enriched environment is one in which animals are housed in groups of 10 to 12 in a large cage that is provided with "toys" such as ladders, wheels, boxes, etc. Each enriched-experienced animal has a littermate which has been assigned to an impoverished condition. Animals in this latter group live in individual cages that have solid sidewalls so that an animal cannot see or touch another. These cages are placed in a separate, quiet, dimly lighted room. Following 80 days of experience in either the environmentally enriched or environmentally impoverished environment, the animals are sacrificed and an examination of the brain is made.

The enriched-environment rats consistently develop greater weight of their cerebral cortex than do their littermates, not having an enriched environment and this greater weight is reflected in greater thickness of this part of the brain. Biochemical effects have been also examined, with attention being directed toward the enzyme acetylcholinesterase. This enzyme is important at those central nerve junctions where acetylcholine is the chemical transmitter that conveys messages from one neuron to another. Total activity of acetylcholinesterase was found to increase slightly but consistently in the enriched-experience animals, both in the cortex as well as in the rest of the brain.

There are other enzymes in the brain that can also act on acteylcholine, although perhaps less specifically than does acetylcholinesterase. These other enzymes are known collectively as cholinesterases. The investigators found that cholinesterase activity is increased eight percent in the cortex of the environmentally enriched rats.

These studies are but a beginning in this new and exciting brain and behavior area. Research is being continued in an attempt to answer many of the questions which these early findings have raised. Does an enriched environment have an effect on adult animals, or is this effect limited to young animals? Are the differences caused chiefly by the enrichment experience of the one group or by the restriction or experience of the other? Is the magnitude of cerebral changes a function of the duration of the experience?

Whole Ecosystem Studies

Environmental biologists, or ecologists, have been working on larger and larger systems. The progression, not smooth, continuous, or complete has been from the ecology of individual organisms, to the ecology of populations, to the study of natural communities, and now to the study of ecosystems—those intricate combinations of biotic communities and their physical environments considered as unitary interacting systems.

Because of the enormous complexity of ecosystems, study of them has several distinctive characteristics: multidisciplinary, team efforts; a need for automatic data collection and recording; a strong reliance on mathematics and computer assisted simulation. A comprehensive ecosystem analysis would include the physiological ecology of plants and animals, the structure and fluctuation of populations, analysis of production and diversity of organisms, study of the cycling of mineral nutrients, and analysis of the flow of energy and water through the system. To conduct a study as complex as this requires the collaboration of ecologists of several kinds as well as mathematicians, geochemists, and meteorologists. This level of investigation is new, and methods of putting all of the pieces together have not yet been fully worked out. As a result, not all current ecosystem studies have all of the attributes of a comprehensive study.

One ecosystem investigation has been underway for several years at the Hubbard Brook Experimental Forest, West Thornton, N.H., under the direction of G. E. Likens of Dartmouth College and F. H. Bormann of Yale University. The objective of the study has been to follow the cycle of water from rain to stream runoff and with it the materials in solution in the water. The rate of weathering of dissolved materials from rock is being calculated, and the rate of loss of water and dissolved materials downstream is monitored continuously. Drs. Bormann and Likens found that natural, undisturbed forests are able to hold and recirculate essential nutrient elements with an annual loss downstream of only 1 percent. The retention of nutrients is intimately tied up with the uptake of water by trees, the water ultimately being lost through the leaves by transpiration. The importance of plants in conserving mineral nutrients was clearly shown, for when a watershed was clear-cut and treated with herbicide, water flow downstream increased, and loss of nutrients was increased 3–15 times.

A very different approach to the study of ecosystems is being taken independently by F. E. Smith, University of Michigan, and E. W. Fager, Scripps Institution of Oceanography. Both of these biologists are concerned with developing mathematical models of the interactions among populations that form a food chain within a natural community. Starting at the simplest levels, these models predict by means of computer simulation the events expected in populations of a plant, an herbivore, and a predator as each species changes rates of reproduction, age at maturity, and food intake (for the animals). At more complex stages, these models are expected to predict the effects of increasing the number of species of plants, herbivores, and predators and variations in their characteristics on numbers of individuals of each species. Much more important, models of this sort may enable the biologist to predict the response of whole ecosystems to disturbances such as invasions and exploitation.

Ecosystem studies involving theoretical simulation and empirical field work are needed to answer serious practical question such as: What kinds of biological systems are appropriate for man to harvest? How intensively may these systems be cropped without destroying them? Happily, some of the most exciting basic ecological studies are precisely those likely to lead us to the answers to these crucial problems.

MATHEMATICAL AND PHYSICAL SCIENCES

The mathematical and physical sciences comprise the most central and fundamental areas of scientific interest, and their continuing health and vigor are basic to the progress of all science. Recognizing the importance of this, the Foundation devoted about one-third of its basic research project support in fiscal year 1967 to the mathematical sciences and the physical sciences: chemistry, physics, and astronomy.

Such traditional divisions are now recognized more as practical working divisions than independent fields of specialization. The underlying picture of matter is the same for all, as these sciences continue to reinforce and systematize their interactions with each other and with other areas of science and technology. For example, considerable insight into molecular reactions of current interest in chemistry has resulted from the use of sophisticated techniques and instrumentation which are based on principles from disciplines other than chemistry.

Over the past two decades, research in astronomy has proceeded along two separate but generally converging lines, the classical approach using optical telescopes and the more recent technique of radio astronomy. During the past 2 years in particular, substantial progress has been made in optical identification of celestial sources of radio emissions. This has been made possible by the steadily improving accuracy with which radio astronomers can measure the positions of radio sources in the sky.

The science of chemistry is concerned with materials, their properties, and the transformations which they undergo. These chemical reactions, or transformations, generally occur during molecular collisions, the understanding of which is basic to all of chemistry. Thus, much current research in chemistry is concerned with those mechanisms by which electrons and energy are transferred between atoms and molecules. Considerable insight into these processes has resulted from the use of molecular beam, spectroscopic, photochemical and electrochemical methods made possible by continuing advances in electronic, optical and vacuum instrumentation. The increased understanding of these fundamental processes leads to greater insight into the chemistry of living organisms, the synthesis of new materials, and improvements in existing industrial products.

The revolution in physics over the past half century has introduced new realms of knowledge, and its practitioners have not only contributed substantially and directly to human betterment but have additionally spurred advances in other branches of science. In addition to its great contribution to engineering, to industrial technology in general, and to space exploration, physics has provided a unified conceptual structure for the natural sciences as well as expanding its own boundaries. As a result, many interdisciplinary sciences, such as biophysics, geophysics, and astrophysics have emerged. In these interdisciplinary areas, it becomes increasingly difficult to distinguish where the one discipline ends and the other begins.

Mathematics has always been indispensable to the physical and engineering sciences. Increasingly, it is becoming so for the biological and social sciences. As such, it is studied for its intrinsic intellectual interest as well as for its utility in many of man's commercial, industrial, social, and scientific endeavors.

Some of the examples of Foundation-sponsored activities discussed in the following paragraphs illustrate the advances in and the interdependence of the physical and mathematical sciences.

Chemistry

Space Age Polymers

In 1949, Peter Kovacic was working in an industrial laboratory on methods of chlorinating aromatic compounds, a process of considerable commercial importance. He found that ferric chloride reacted cleanly with some aromatics, but with the simplest one, benzene, he could only recover a black tar. He later found that the same result had been published in a French journal in 1898. This process did not seem to have commercial possibilities and the project was dropped. When he joined the faculty of Case Institute of Technology in 1955, however, he decided to look more carefully into the fundamental chemistry of these reactions. During the next nine years, with support mainly from the National Science Foundation, he transformed a reaction which appeared to have no commercial possibilities into a practical way of making a useful material. The product, polyphenyl, is a plastic consisting of a string of benzene rings. It is not broken down by high temperatures, radiation or most chemical reagents. It is easy to make from cheap starting materials, and can be molded into many forms. This combination of advantages has aroused considerable interest in both industry and government agencies. After some further improvements on Dr. Kovacic's method, polyphenyl is now being produced commercially in limited quantities for use as a heat shield for reentry of space vehicles, and as an insulator in electronic equipment which must operate at high temperatures.

Nitrogen Reaction Under Mild Conditions

For the last 2 years, George Helmkamp of the University of California at Riverside, supported by a Foundation grant, has been trying to make thiirenium salts, a new type of organic compound containing a three-membered ring of two carbon atoms and one of sulfur. The properties of such compounds would be important to chemical theory. One of the compounds he wanted to start with was known to be sensitive to air, so he used it under a blanket of pure nitrogen gas, which does not ordinarily react with anything under mild conditions. To his surprise, the product was a reactive new compound containing more nitrogen than the one with which he started. Further experiments clearly showed that the nitrogen was coming from the blanket of nitrogen gas he used, that chemically related compounds also reacted with nitrogen, and the product reacted easily with a variety of other compounds to form stable chemicals in which the nitrogen was firmly bound.

Last year's annual report pointed out the importance of more economical methods of making ammonia in solving the world food problem. Dr. Helmkamp's reaction could take nitrogen out of the air, and it does not require high temperatures and pressures, which increase the cost of present production methods. Like the method described last year, it does require some expensive chemicals in its present form, and the product is not directly convertible to ammonia. Much more work will be needed to see if these problems can be overcome, but the principle of getting nitrogen to react under mild conditions has been established.

Inorganic Enzymes

A chemist at Ohio State University, D. L. Leussing, with Foundation support, has shown that certain simple metal ions may perform in a way similar to nature's powerful catalysts, enzymes. Enzymes are large complicated protein molecules which, in biological systems, cause reactions to go many times faster that when the reactants are brought together in test tubes without the enzyme. Enzymes perform two distinct roles. First, they bring two reactant molecules together by forming a complex species in which each reactant molecule is bound to the enzyme. Second, under the influence of the enzyme, the two reactant molecules undergo a fast reaction.

For a long time, chemists have studied the combination of certain nitrogen-containing compounds with certain oxygen compounds to form products named Schiff bases after their discoverer. Schiff bases play an important role in many biological reactions. Since many metal ions interact with the uncombined reactants forming complexes, it has been thought for several years that metal ions might mimic enzymes in Schiff base formation. Although these metal ion systems are considerably simpler than biological systems, the reactions had proven to be too complicated to yield to a mathematical analysis.

Dr. Leussing was able to achieve a solution using a modern high-speed digital computer. First, a large quantity of equilibrium data was obtained on systems containing two molecules in the presence of various metal ions. The results were then subjected to analysis which determined that zinc ions form complexes containing two molecules bound to a single metal ion. Analogous to enzymatic action the two molecules react within these mixed complexes to form Schiff bases.

It was found that zinc ions are as good as, if not better than, enzymes in the first stage of the reaction where the reactants are gathered in the complex. However, the rate of combination in the second stage is considerably slower with zinc.

Studies on this and similar systems should enable many of the factors involved in enzyme reactions to be examined under simpler and better defined conditions than can usually be obtained in biological media. The results will increase our understanding of the role these factors play in both the simple systems and enzyme systems. Perhaps some day it may be possible to tailor simple enzyme-like systems to perform highly specific functions very rapidly at low temperature. Such synthetic enzymes could find a wide range of applications from the treatment of certain diseases to the manufacture of various chemical products.

Superconducting Molecular Alloys

Current research by Harden McConnell at Stanford University, supported by two Foundation grants, is directed toward the preparation of novel, high-temperature superconductors. An attempt is being made to prepare a basically new composition of matter, a "molecular alloy." These molecular alloys are prepared by codepositing metal atoms and molecules, especially organic molecules, on a quartz target in an ultra-vacuum system, at controlled relative rates. The mixture of metal atoms and molecules obtained thereby may be termed a "molecular alloy" when the electrons from both the metal atoms and the molecules participate in the process of electrical conduction. Unsaturated organic molecules are particularly good candidates to form such molecular alloys since these molecules have been known for a long time to contain electrons which behave much like electrons do in metals even though as a rule organic solids are not metallic conductors. Metallic elements such as vanadium or niobium are particularly good candidates for combining with such organic molecules since these elements alone are good superconductors at low temperatures and are known to form strong bonds with unsaturated organic molecules.

There are at least two reasons for suspecting that some of the molecular alloys of the type described here may prove to be high-temperature superconductors. On the purely theoretical side, enough is now known about the electronic structure of the superconducting state, and the electronic interactions responsible for superconductivity, to permit one to hope to "design" a high-temperature superconductor by optimizing insofar as possible those electronic interactions thought to be crucial for superconductivity (e.g., electron screening, electron-phonon and possibly electron-exciton interactions). Indeed, unpublished calculations made under a number of simplifying assumptions by Dr. McConnell in 1964 predicted very high transition temperatures for a pyrazine-vanadium alloy.

The second reason for suspecting that molecular alloys of the type described here may prove to be high temperature superconductors stems from experiments carried out over the past 2 years in which it was observed that organic molecules, when deposited on the surface of thin metal films, can modify the superconducting temperatures of these films. In this work it was clearly demonstrated that this was a "chemical shift" of the superconductivity, and that the direction of the shift could generally be predicted from the chemical composition of the unsaturated organic molecule deposited on the film surface. Although the observed changes of transition temperature were small they are considered to be quite encouraging since one anticipates a very strong dependence of transition temperature on composition in molecular alloys. In the thin film experiments with sequential depositions the effective concentration of the organic molecules can only be of the order of one percent, whereas in the codeposition experiments now underway this molecular concentration can be 10 times higher or even more.

With support from the Foundation, Dr. McConnell has completed construction of a high vacuum and cryogenic system capable of preparing molecular alloys and studying their superconducting qualities. He has recently carried out experiments on the enhancement of the superconducting critical temperatures of aluminum films containing various concentrations of organic molecules. He intends to continue both experimental and theoretical work in this area.

Ion Cyclotron Resonance Spectroscopy

Since the very beginning of the science of chemistry, chemists have been trying to understand, in increasingly greater detail, the nature of chemical reactions. During the past several years, a powerful new technique has been developed which promises to be of considerable importance in the study of ion-molecule reactions. This technique is ion cyclotron resonance spectroscopy, and its development into a practical tool was assisted in no small measure by John D. Baldeschwieler, at Stanford University, with the support of the National Science Foundation.

Working in close collaboration with Peter Llewellyn of Varian Assocates, Dr. Baldeschweiler and his coworkers have significantly advanced the usefulness of cyclotron resonance through the introduction of double resonance techniques. In this technique one type of ion is heated with a strong alternating electric field of a frequency characteristic for that ion. When these hot ions collide with other ions or molecules new chemical species are formed which also exhibit characteristic resonance absorption cyclotron frequencies. The temperatures and concentrations of these new ions can be investigated by irradiating the mixture with a second weak alternating electric field of the proper frequency. More importantly, if the second ion is formed from the first, the amount of energy absorbed from the two alternating electric fields will be related. Thus, ion cyclotron resonance spectroscopy enables cause and effect relationships to be established in complex chemical reactions.

An important variation of the double resonance experiment has also been developed. In this technique a strong field of frequency ω_1 is periodically pulsed and the signal at ω_2 is detected with a phase detector referenced to the pulsing frequency, then the difference between the single and the double resonance is directly displayed. Only those products that are coupled to the irradiated species by chemical reaction will appear in the double resonance spectrum. The Stanford group has obtained a series of field sweep spectra of a methane-nitrogen mixture for various values of ω_2/ω_1.

Dr. Baldeschwieler and his coworkers plan to use the ion cyclotron double resonance technique to study detailed mechanisms of reaction between ionic fragments and molecules with a variety of structures and functional groups. With these techniques it is also possible to study the effect of translational energy on ion-molecule reaction rates.

The impact of this newly developed technique on the chemistry community is already evident. For example, Dr. Baldeschwieler has been selected as the winner of the 1967 American Chemical Society's Award in Pure Chemistry for his pioneering research in nuclear magnetic double resonance, conformation of biological macromolecules in solution, and ion cyclotron resonance spectroscopy. Moreover, a commercial ion cyclotron, double resonance spectrometer is already on the market. Clearly this new technique represents a very powerful tool which chemists can use to unravel the finer details of chemical reactions.

Electrode Processes

Since all chemical reactions involve changes in either the number or the positions of electrons within molecules, electrochemistry has been for many years an important area of chemistry. Recent theories of the manner in which electrons are transferred in chemical systems have stimulated the design of new experiments to test these theories. Research directed at correlating rates of electron transfer with the structure of a solution adjacent to an electrode placed in the solution has been of recent interest. This part of the solution becomes very ordered when a potential is applied and is known as the electrical double layer. The degree of ordering is complicated by the fact that many substances are adsorbed on electrodes. Organic molecules or ions may alter the structure of the solution next the electrode if they are adsorbed. In order for a molecule or ion in solution to gain or lose electrons at an electrode surface, it must first move to the electrode surface through the double layer. It is in a preelectrode state at that time. This is followed by the gain or loss of electrons at the electrode. It is difficult to measure the properties of the double layer when electrons are being transferred across it.

A knowledge of the factors influencing the double layer is important for an understanding of corrosion, the nature of colloidal dispersions, electron transfer in living systems and, in fact, for an understanding of electrical phenomena at any interface.

The preelectrode state is important because a substance at an electrode surface may have to undergo a prior chemical reaction before it can accept or give up an electron. Thus, an ion or molecule in solution may have to wait at the electrode surface before it reacts. Paul Delahay of New York University has been very active in research directed toward the solution of these puzzling factors. He has developed a large number of experimental methods to study extremely fast electrode reactions. These include the potential and current step function techniques. Dr. Delahay has shown that any reaction at an electrode will change the properties of the double layer and this cannot be ignored when an interpretation of rates of electron transfer is to be made. Dr. Delahay was selected for the 1967 Palladium Medal Award of the Electrochemical Society for his contributions to electrochemistry. Much of his research has been supported by the Foundation.

Chemistry Instrumentation

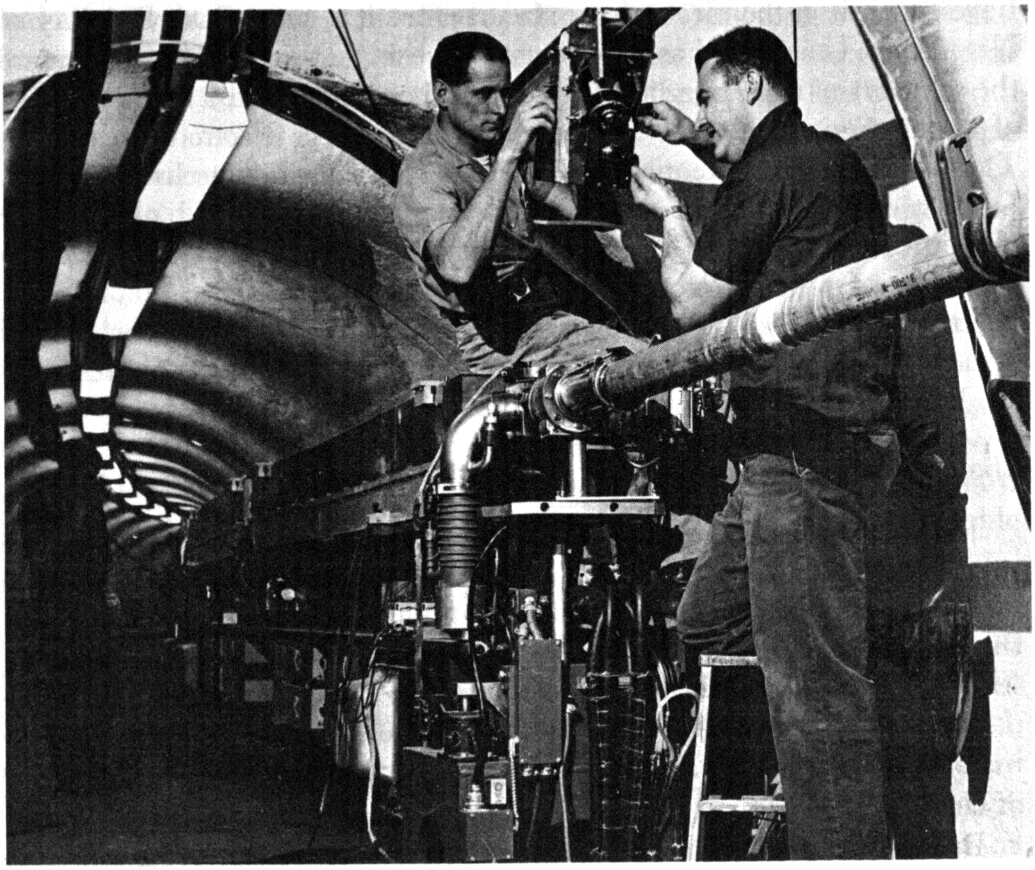
The rapid development of electronic instruments has enabled chemists to ask more searching questions than ever before, and instrumentation has been a substantial factor in contributing to impressive advances. At the same time, the necessity for up-to-date equipment at academic institutions has placed a heavy strain on departmental budgets. The Foundation views the availability of modern instrumentation for both teaching and reserch to be a central problem for most university departments of chemistry.

During the fiscal year 1967 the research instrument program contributed to the purchase of some $4.6 million worth of general purpose research instruments at 88 institutions. Foundation grants for this purpose totaled $3.1 million, the balance of more than $1.5 million being provided by the institutions. A detailed study of the present status with a new projection of future requirements is underway. (Support for facilities and equipment is also available through Foundation programs for institutional development which are described in the section beginning on page 145.)

Physics

Major Physics Research Facilities

In its support of major university physics research facilities, the Foundation seeks to insure that genuine innovations in concept and design are recognized and exploited. As one example, a project has been undertaken at the University of Indiana to develop a quite new type of cyclotron whose magnetic field is arranged in separated sectors or quadrants. Similarly, and also with Foundation support, investigators at the University of Utah placed in operation this year a muon-neutrino facility of unique design. This detector for extremely energetic particles was built at relatively low cost and records events up to a maximum path length of 45 linear feet in an array which has a trapping mass for



Cornell University Photo

Figure 1.—***This television camera at the Cornell synchrotron can be moved by remote control to any point in the half-mile-long tunnel, thus facilitating observation of operations.***

desired particles of a thousand tons—and a rock shield against unwanted ones of 1,000 feet.

Construction of the Cornell 10 BeV electron synchroton, initially funded by the Foundation in 1965 and discussed in the 16th Annual Report, is nearing completion. This is the world's most powerful circular electron accelerator and was designed at the Laboratory of Nuclear Studies at Cornell University. The last of the bending magnets for the accelerator ring was installed in February 1967, and the injection system was installed in March. Using temporary magnet power supplies and a temporary radio-frequency accelerating system, acceleration of an electron beam to 2 BeV was achieved without difficulty in May 1967. The primary electrical distribution system was completed in June. With one-half of the final acceleration system in operation, an energy of 7 BeV was achieved in October.

The accelerator will be ready to begin operation late in the fall of 1967, several months ahead of schedule and within the programed budget of $11.2 million. Initial experiments are now being prepared at

Cornell. Moreover, groups of scientists at the University of Rochester and Northeastern University are preparing experiments which will be performed at the Cornell accelerator. Several groups at other institutions have begun planning for additional experiments.

Basic Research Projects

Elementary Particle Research

The magnetic moment, or intrinsic magnetic character, of an elementary particle is an important physical property which can be determined by measuring the change in orientation of particles as they move through a very strong magnetic field. Because of the short lifetimes of many types of particles, such measurements are very difficult. During the past year, with Foundation support, a group of scientists from the University of Washington completed a measurement of the magnetic moment of the positively charged sigma particle. This experiment was carried out at the Bevatron accelerator in Berkeley, Calif., and required the use of specially designed spark chambers inside a pulsed, high-field magnet. The techniques of pulsed, high-field magnets were adapted from those developed originally for research in solid state physics. The experimental results are in rough agreement with current theoretical predictions. This experiment will be repeated with improved equipment in order to obtain a more accurate result and thus provide a more crucial test for theories. The technique will be extended to other particles.

Another area of elementary particle research is the investigation of the laws of physics at high energies and in very small regions. Physicists at Northeastern University, supported in part by the Foundation and using the Cambridge Electron Accelerator, have explored the validity of the laws of electromagnetism at small distances by measuring the photoproduction of pairs of muons with a large angle between the two outgoing particles. The results show that present theories are correct down to distances of 4×10^{-13}cm. (comparable to the size of atomic nuclei). This experiment will be extended to higher energies and smaller distances using the Cornell 10 BeV electron accelerator.

The Shape of the Atomic Nucleus

One of the most intriguing problems facing investigators of atomic nuclei is that of determining the shape of the nucleus. The shapes of nuclei provide important clues about the nature of nuclear forces. Since the nucleus is far too small to "see" with any kind of optical instrument, indirect methods must be used in such a shape measurement.

A large class of nuclei, namely all those which are made up of an even number of protons and an even number of neutrons, are known to have spherical shapes in the ground state, which is the ordinary state in which they are found in nature. The ground state is the nuclear state of lowest energy. A nucleus can be excited; that is it can be brought from the ground state into a state of higher energy. Usually a nucleus will remain in an excited state for only a very short time. In typically less than a billionth of a second it returns to its ground state. Despite the short life of the excited state, it has become possible to determine the shape of the nucleus in that state.

A recently developed technique has been used by J. de Boer and his collaborators at Rutgers University to provide information on nuclear shapes.

Positively charged projectiles are accelerated in a Tandem Van de Graaff accelerator to velocities about one-tenth of the speed of light. When these projectiles come into the vicinity of the nuclei to be studied, they are deflected into a hyperbolic orbit due to the mutual repulsion between the projectile and target nucleus. On its orbit, the projectile stays in the vicinity of the nucleus for a very short time, only about 10^{-21} sec. During this time, however, the nucleus experiences a strong electric field which is produced by the passing projectile and which can set the nuclear particles in motion. The nucleus may then be transferred into one of its excited states. If the nucleus finds itself in an excited state while the projectile is still close to it, the electric field produced by the projectile will, for the remainder of the short interaction time, interact with the nucleus in its excited state. Careful measurements of the probabilities for excitation for various projectiles will therefore yield information about the nature of the excited state. A detailed theoretical analysis of the whole excitation process requires a large modern computer. These calculations show that one can, in this type of experiment, determine whether the excited state is spherically symmetric (baseball-shaped), has prolate deformation (football-shaped), or has oblate deformation (lens-shaped).

Studies of this type have so far been performed for a score of different nuclei, all of which exhibit prolate deformation in the excited state (that is the excited nuclear state may be thought of as a tiny football). A recent experiment performed at Rutgers has indicated that an excited state of a particular tin nucleus, Sn^{116}, has an oblate deformation. This nucleus is, so far, the only known nucleus which is lens-shaped. We do not yet know why nuclei have one shape rather than another and further investigations in this field are therefore of great interest.

Nuclear Cooling Technique

The temperature of a system is a measure of the random component of its internal motions. At very low temperatures, these random motions subside to the point that even quite weak forces between the particles can begin to produce large effects. This can lead to very striking changes in the bulk properties of the material as in the well-known cases of superfluid helium and superconducting metals. The question as to whether nature has more such surprises has been one motivation behind efforts to produce lower and lower temperatures.

This quest for very low temperatures began in the last century with the development of techniques to liquify materials which are normally gases and led ultimately to the liquefaction of helium and its subsequent use to cool materials to approximately 1° on the absolute scale. (On the absolute scale, 0° K. is the equivalent of —273.16° C.) In the 1930's a technique was developed which made use of the magnetism associated with electrons in matter to produce temperatures as low as 0.003° K. At that time it was recognized that by using the magnetism of atomic nuclei, a temperaure as low as 0.000001° K. might be obtained. A technique based on this effect known as nuclear cooling has been developed and has produced a temperature within 0.0008° of the absolute zero over a large enough volume to permit experiments to be performed. The difficulties in achieving this low temperature stem primarily from the following sources: (1) It takes very little energy to warm things up a great deal at such low temperatures; (2) it is very difficult to transfer even minute amounts of heat at these low temperatures; (3) in order for the nuclear cooling technique to work, the system must first be cooled to temperatures around 0.01° K. in the presence of a very large magnetic field; (4) the measurement of such temperatures is not simple and must involve very small amounts of energy.

The second requirement means that in order to be able to transfer heat from any material to be investigated to the cooling substance, the coolant must remain at its lowest temperature for a long period of time. In view of the first requirement then, the entire system must be extremely well isolated so as to avoid stray heat inputs. In the system developed with Foundation support by John M. Goodkind of the University of California at San Diego, this stray input has been reduced to one billionth of a watt. This allows the specimen to remain below 0.001° for at least 8 hours. All of the other problems have also been solved to the extent that Dr. Goodkind measures a temperature of 0.0008° in one part of the apparatus and estimates it to be 0.00035° in the coldest region. For measurements at somewhat higher temperatures even longer working times are feasible. For example, it takes 36 hours to warm from 0.003° to 0.007°. The technique was developed primarily to investigate the possibility that at sufficiently low temperatures the isotope helium-3 will become a superfluid as does ordinary helium. The measurements in liquid and solid helium-3 have been carried to 0.004°. To date superfluidity has not been observed in helium-3—a significant result. Further modifications should allow measurements in helium-3 to as low as 0.0001°.

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A major virtue of the atomistic approach, and very characteristic of all of physics, is that it permits interpretation of a great diversity of natural phenomena in terms of an extremely small number of basic entities and concepts. Consequently a few physical constants appear repeatedly in physical theories for diverse phenomena. A careful study of the numerical values of these constants as obtained from experiments in different parts of physics can give information about the overall consistency and correctness of basic physical theories.

A particularly interesting recent example is the research Donald N. Langenberg and his group carried out at the University of Pennsylvania with NSF support. These were solid-state experiments performed on "Josephson junctions" (superconducting "sandwiches" consisting of two superconductors separated by thin insulating oxide layers). When a Josephson junction is irradiated with microwaves extra currents can flow in the junction whenever the voltage across it has certain discrete values. The discrete voltages at which the extra current appears and the frequency of the applied microwave radiation are proportional to one another, and are related by a constant of proportionality, 2e/h.

Through the research undertaken at the University of Pennsylvania, this ratio has been determined more precisely than ever before. This new, more accurate measurement of 2e/h has far-reaching consequences in what has been termed one of the major unsolved problems of quantum electrodynamics (the interaction of radiation with atomic and nuclear systems). There had been an apparent discrepancy between the theoretically calculated and experimentally-measured values for an energy level difference in the hydrogen atom. When the theoretical expression is evaluated using the new constants, the discrepancy is mostly dispelled. And it may be concluded that the theoretical quantum electrodynamic calculation is indeed correct. Thus, a solid-state experiment performed in a low temperature laboratory has cleared up a problem in particle interactions!

Astronomy

The Foundation is the principal Federal agency providing support for research in astronomy at colleges and universities, and has been designated by the Federal Council for Science and Technology as the lead agency for Federal programs in support of ground-based astronomy. In addition, the Foundation maintains three major national observatories. A prime function of these observatories is to provide access to major observational facilities in good viewing locations to qualified visiting scientists and students from universities throughout the nation. To insure efficient operation these centers also have outstanding resident research staffs. They also serve as foci for the design and development of improved instrumentation.

Kitt Peak National Observatory

Facilities and Utilization

Kitt Peak National Observatory (KPNO), near Tucson, Ariz., was established in 1958 for the purpose of strengthening basic research and education in astronomy in the United States. As a national scientific facility, KPNO is operated for the National Science Foundation by the nonprofit corporation, Association of Universities for Research in Astronomy, Inc. (AURA).

The research activities of the observatory are organized into three principal fields—stellar, solar, and space astronomy. In addition to the scientific programs of visiting astronomers (including graduate students) and resident staff, major efforts are also conducted in engineering design and construction of auxiliary instrumentation for use on its telescopes and in space experiments. One of the Observatory's most important current contributions to progress in astronomy is the distribution of engineering design drawings and specifications to various universities and other organizations, including some abroad. Since July 1965, more than 1,200 such drawings, representing about 96,000 man-hours of design time, were distributed throughout the national and international astronomical communities.

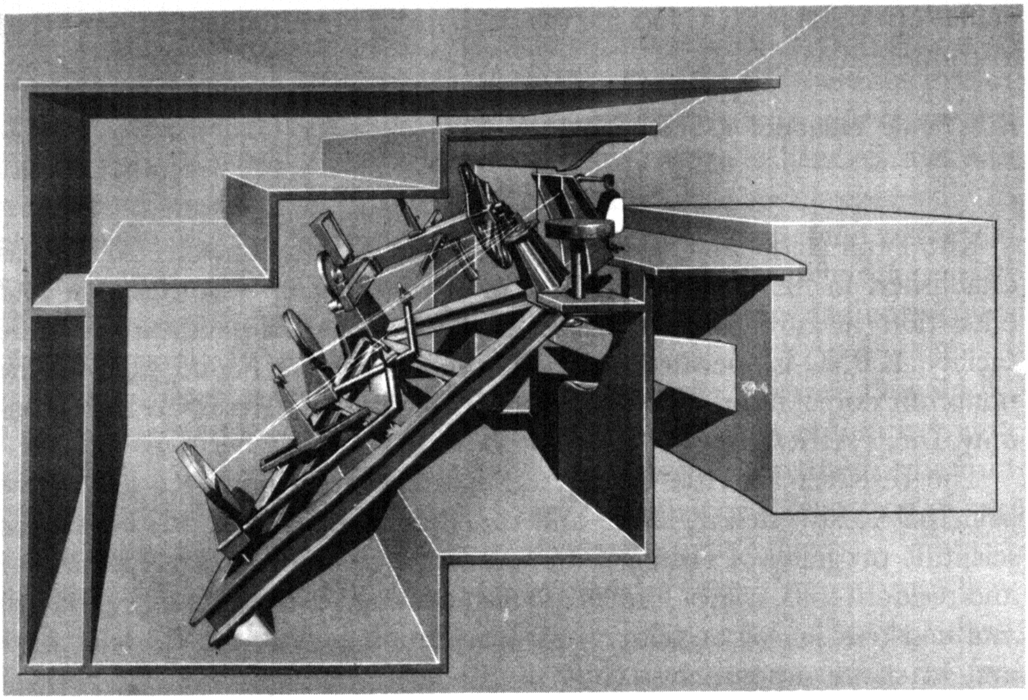
Stellar Astronomy

KPNO now operates five stellar telescopes: one 84-inch, two 36-inch, and two 16-inch reflectors, the second of the two 36-inch instruments being placed in operation in February 1967.

Significant steps in the construction of the new 150-inch telescope—to be second largest in the world—have been accomplished under the direction of D. L. Crawford and W. W. Baustian. A 158-inch diameter fused quartz primary mirror blank has been produced by the General Electric Company, and site preparation on Kitt Peak is nearly complete.

Visiting observers make use of the telescopes 60 percent of the time. During fiscal year 1967, 88 investigators from 48 U.S. and foreign institutions visited Kitt Peak to use its facilities. The largest telescope, the 84-inch reflector, is in greatest demand. Requests for more than twice as many nights as could be made available were received during the past year. This instrument's large coudé spectrograph (see Figure 2) now is equipped with three cameras, two large gratings, and an exposure meter.

Increasing use of electronic image intensification equipment at the 84-inch telescope by both visitors and staff has made possible a variety of work on very faint sources, including quasi-stellar objects, galaxies, and galactic objects.



KPNO Photo

Figure 2.—*Artist's rendering of the coudé spectrograph. This spectrograph is a powerful light-analysis instrument, so large and heavy that it is mounted in a fixed position below the telescope in an insulated, constant-temperature room. Light collected by a 5-mirror system in the telescope is brought down the polar axis, is imaged on a slit at the observer's station, and passes into the spectrograph. There it is collimated, dispersed by diffraction gratings, and re-imaged for spectrograms by a number of large Schmidt cameras. The spectrograph is invaluable for studies of element abundances, chemical and physical compositions, temperatures, masses, magnetic fields, ages, and motions of celestial objects.*

This work includes spectrographic studies of the kinematics of stars and stellar systems, and abundance analyses of a variety of stellar types. Photometric observations of stars and stellar systems for studies of galactic structure also have been continued.

Solar Astronomy

Work has progressed on refinements and additions to the McMath Solar Telescope, the world's largest. The new 82-inch diameter heliostat mirror, 10 inches thick, and made of fused quartz because of its low coefficient of expansion, has been figured to a flatness of a few millionths of an inch.

A large 15-foot focal length spectroheliograph, which has been under design and construction for three years, arrived in September 1966, and was installed in the pit alongside the 70-foot vacuum spectrograph tank. It is being used to photograph the disc of the sun in the light of two different elements simultaneously—for example in iron and calcium; or in two magnetic polarities—north or south; or in the two velocity modes—directions into or out from the sun's surface.

Three areas of solar research are being investigated with the McMath telescope—chemical composition, magnetic fields, and velocity fields. With the coming of solar sunspot maximum, the magnetic fields of the sun have become very intertwined and complex, so that the simple geometry of sunspot minimum no longer exists. Detailed studies of magnetic fields are being made with the photoelectric magnetograph, which is very sensitive to small fields, and has revealed that the surface of the sun is covered by a constantly changing network of north and south polarities of about 10 gauss strength.

Around-the-clock operation by staff and many visiting scientists has provided observing time for work on the carbon dioxide abundances in Mars and Venus, photoelectric high-dispersion spectra of a number of bright stars, discovery of hitherto undetected absorption bands in the earth's atmosphere, lithium in sunspots, and infrared studies of the outermost layers of the sun's atmosphere and the detection of components of the rare earth group of chemical elements, not previously seen in the solar spectrum.

Space Astronomy

Sounding Rocket Program

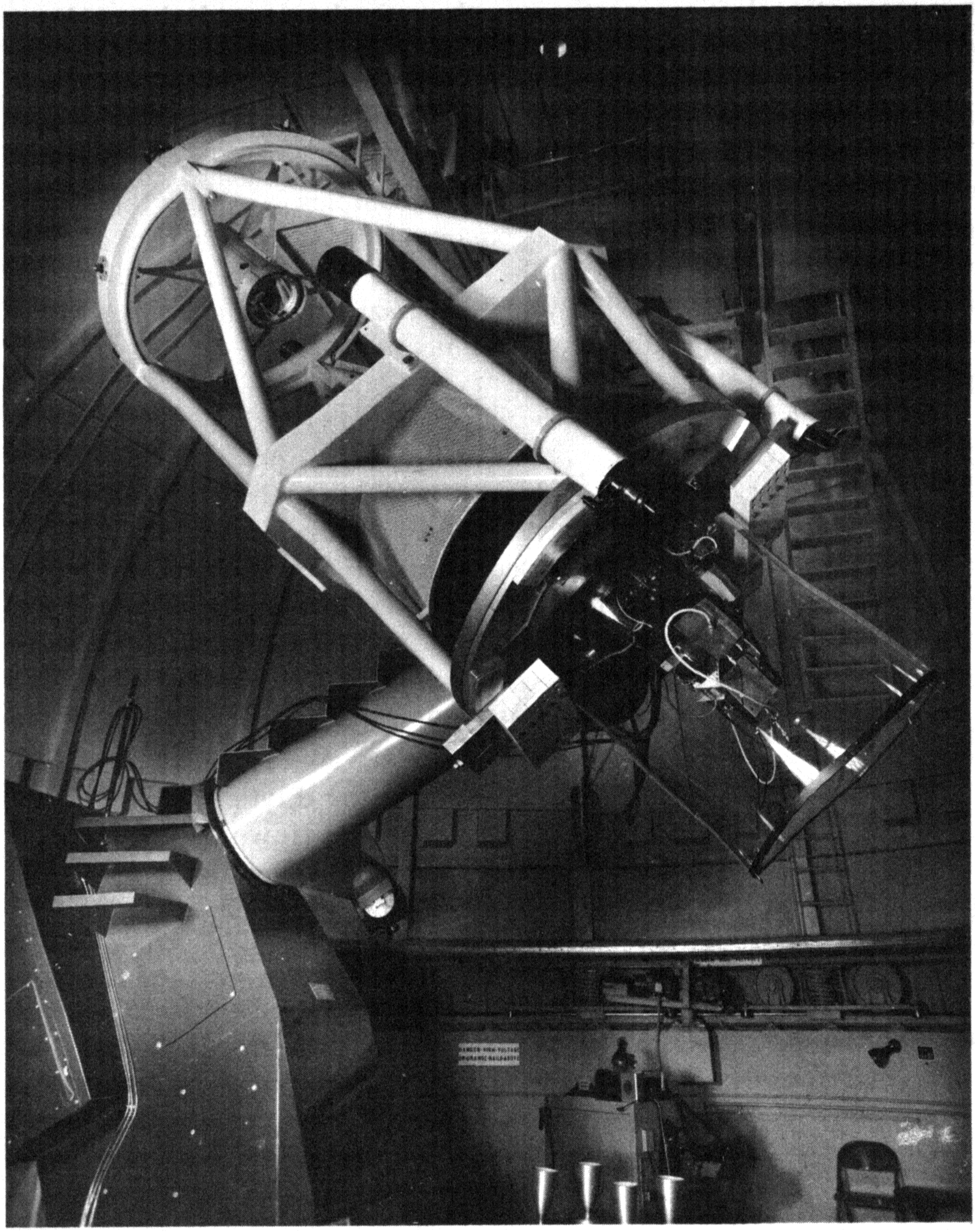
An Aerobee rocket, carrying instruments for daytime measurement of upper atmospheric emissions, was successfully flown on October 11, 1966, for A. Vallance Jones, University of Saskatchewan, in collaboration with D. M. Hunten and L. V. Wallace of the Observatory staff. Analysis of the data shows that the emission is due primarily to resonance scattering of the incident sunlight.

Remotely Controlled Telescope

The 50-inch remotely controlled telescope went into test and staff research operation. Initial research of S. P. Maran and associates included photoelectric measurements of suspected low-amplitude variable stars, and of a magnetic star. The telescope functions automatically on Kitt Peak under control of a computer in Tucson and no observer is required in the telescope building on the mountain.

Cooperation With NASA Mariner V Program

This planetary probe, launched toward Venus on June 13, 1967, by the National Aeronautics and Space Administration, carried a set of simple ultraviolet photometers provided by KPNO to measure the hydrogen and atomic-oxygen emission of Venus. The photometers, designed by C. A. Barth, University of Colorado, and by Lloyd Wallace of the Observatory's staff, were turned on shortly after orbital injection, and will remain activated through the Venus encounter. The combination of signals received allows separate measurement of the hydrogen



KPNO Photo

Figure 3.—*This 50-inch telescope on Kitt Peak, Ariz., is the first large optical telescope to be fully automated, and the first ground-based instrument to be operated by remote control from a distant command center. The telescope is operated by a digital computer at KPNO headquarters in Tucson, about 50 miles away from Kitt Peak.*

emission of the far ultraviolet spectrum and the resonance line of atomic oxygen.

During the initial stages of the flight, extensive and excellent quality data on hydrogen emission of the far ultraviolet spectrum have been obtained in the near-earth region, but no significant atomic oxygen data have been noted. This information shows that the hydrogen cloud surrounding the earth extends to at least 10 earth radii, and that it falls off in density in accord with theoretical predictions. Consequently, these data should yield an excellent determination of the earth's exospheric temperature. The prime purpose of the experiment is, of course, the same measurements for Venus, and the good agreement between theory and experiment in the case of the earth is encouraging that significant new results may be found for Venus.

Cerro Tololo Inter-American Observatory

Cerro Tololo Inter-American Observatory is situated in the Andes Mountains of Chile, about 7,200 feet above sea level and at latitude 30° south of the Equator. It is operated by AURA under a Foundation contract.

This observatory will permit the extension to the southern hemisphere of many research programs now limited to northern skies because of the lack of adequate modern telescopes in the south. Studies of the southern portion of our Milky Way Galaxy and in particular the area of the Galactic Center are of prime importance. The nearest galaxies outside of our own Milky Way Galaxy lie far to the south and are of special interest as stepping stones to the more distant galaxies. Similarly, the nearest of the globular clusters are seen best from south of the Equator. Optical identification of radio sources, on which exciting progress has been made in the north, is lagging in southern skies. The Cerro Tololo telescopes will enable United States, Chilean, and other Latin American astronomers to obtain the required observations from a location offering excellent viewing opportunities.

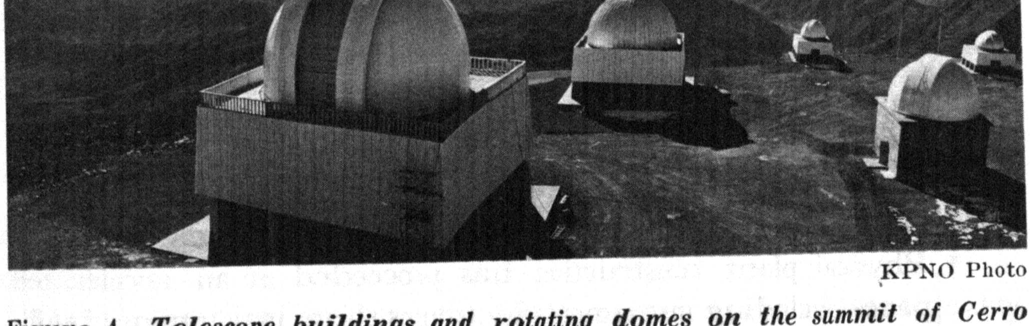
Fiscal year 1967 proved to be of major importance in the development of Cerro Tololo.

- On April 13, 1967, at the Punta del Este Conference, the Presidents of the United States and of Chile announced jointly that a 150-inch telescope would be built at Cerro Tololo. It will be jointly funded by the Ford Foundation and the National Science Foundation.
- Altogether, four of the five planned telescopes become operational during the year.
- On June 16, 1967, Dr. Victor M. Blanco of the U.S. Naval Observatory, Washington, D.C., was appointed Director of the Observatory with resident headquarters at La Serena, Chile.
- Physical plant construction has proceeded at an accelerated pace—including instrument-electronics shop, maintenance facilities, office space, and living quarters—in preparation for dedication of the Observatory which took place in November 1967.

The 150-inch telescope will be built as nearly concurrently as possible and with the same design as the one for Kitt Peak National Observatory. The construction schedule aims for its completion in 1973.

Besides the two 16-inch telescopes that have been in regular operation for the past several years, the 24/36-inch Schmidt telescope, on loan from the University of Michigan (a member of AURA), and the new 36-inch telescope are now in operation for visitors and staff. The 60-inch telescope is installed and was put in operation with most of its auxiliary instrumentation, except for the large coudé spectrograph, in November 1967. All are now in their permanent buildings with rotating domes.

The 16- and 36-inch telescopes were used during fiscal 1967 by a total of 26 visitors for a wide variety of programs involving photoelectric photometry of variable stars, globular star clusters, and southern Milky Way field stars, along with spectroscopy by slit, objective prism and scanner techniques. The first polarization measurements of the brightest X-ray source in Scorpius were made and published by W. A. Hiltner, University of Chicago, who was one of the first visitors to use the 36-inch telescope. Of the visitors, four were students, five were staff members from the University of Chile's National Observatory at Cerro Calan, Santiago, and five were staff members from the Stellar Division of the Kitt Peak National Observatory. The Schmidt telescope was moved to Cerro Tololo in October 1966 from Peach Mountain near Ann Arbor where it had been in operation for a number of years. Under project director William P. Bidelman, professor of astronomy at the University of Michigan, a comprehensive investigation of the stars visible from the Southern Hemisphere was initiated in May 1967 with the support of the National Science Foundation.



KPNO Photo

Figure 4.—***Telescope buildings and rotating domes on the summit of Cerro Tololo in the Andes Mountains of Chile. Four of the five telescopes are in operation, and the 60-inch instrument (in building at left) became operational toward the end of 1967.***

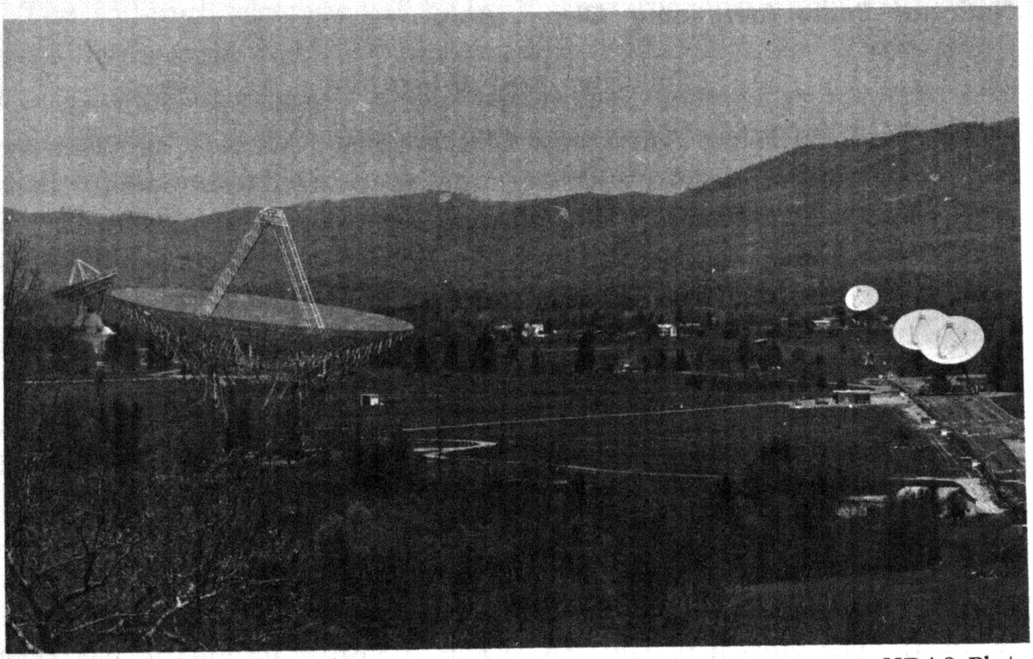
Facilities and Utilization

The National Radio Astronomy Observatory (NRAO) provides the Nation's radio astronomers with large and specialized telescopes for basic research in radio astronomy. The majority of its telescopes are located at its radio-quiet observing site in Green Bank, W. Va. A 36-foot millimeter-wave radio telescope is in the advanced stages of construction on Kitt Peak, Ariz. NRAO is managed by Associated Universities, Inc. (AUI), under contract with the National Science Foundation.

Radio astronomy continues to be one of the relatively fastest growing sciences; the total number of American radio astronomers is doubling about every 5 years. Of the current group of radio astronomers, about two-thirds have been involved in observing and other activities at NRAO. Approximately the same ratio of all the present Ph. D. candidates in the field have had contact with the NRAO in connection with their graduate research. The growth of the NRAO as a visitor institution has been more rapid than the general growth of the field. For example, from 1963 to 1966 the number of NRAO telescope systems available to visitors has tripled and the number of people engaged in research at the NRAO has also tripled, the largest increases being in numbers of visiting scientists. The number of different institutions whose staff and students utilize NRAO facilities has increased more than fourfold and the number of Ph. D. students observing at Green Bank has increased fivefold.

In addition to encouraging the use of its telescopes for thesis as well as post-doctoral research, the Observatory has each year conducted a summer research assistant program. Now averaging over 30 students each summer, the program has included a total of more than 140 students from 30 States and five foreign countries since its inception in 1959.

Among the major facilities available to astronomers in fiscal year 1967 was the 300-foot diameter transit telescope, which can be used for measurement of the quantity and distribution of hydrogen gas in near and distant galaxies, and for measuring the spectra of distant extragalactic radio sources. The 140-foot telescope, completed in 1965, is a very precise instrument and uses receiver systems operating at wavelengths of less than 21 centimeters. Three 85-foot telescopes are operated together under computer control as a variable-baseline interferometer. Of the three telescopes comprising the interferometer system, one is fixed in position while the other two may be moved along a baseline to observing stations where they are anchored in place during operation. This system offers high resolution and enables the radio astronomer to map certain radio sources with detail not possible with a single telescope. The new 36-foot telescope at a site 5,300 feet high near Kitt Peak, Ariz., to operate at millimeter wavelengths, became available to visiting astronomers in late 1967. The use of shorter wavelengths aims at achieving satisfactory resolu-



NRAO Photo

Figure 5.—*This view of the National Radio Astronomy Observatory shows (left to right) the 140-foot telescope, the 300-foot telescope, the fixed 85-foot telescope, and two movable 85-foot telescopes. The latter three instruments are used as an interferometer.*

tion from smaller antennas, but the antenna surface must be constructed to better tolerances, since the surface must approach perfection to a tolerance much smaller than the shortest wavelength used.

New supercooled amplifiers, now under construction, are expected to facilitate identification of radio signals from space. These parametric amplifiers are being developed for use with the 300-foot transit telescope, the 140-foot steerable, and the three-element interferometer, all at Green Bank. Four computers have been acquired to operate online at each of the major telescope systems, including the 36-foot telescope at Kitt Peak. These computers will handle data acquisition and recording, receiver and telescope monitoring, antenna pointing, and data processing.

Very Large Antenna Array (VLA) Design Project

The preliminary design has been completed and the detailed design has been started for an array of radio telescopes that promises to provide a significant advance in observational radio astronomy. This design project envisions development of a major national instrument capable of observing discrete radio sources more than one hundred times fainter than presently possible, using an array of 36 telescopes each of 85-foot aperture, mounted on railroad tracks and arranged along the arms of a Y-shaped configuration, each leg of which is 13 miles long. This instrument, expandable for spectral line observations, polarization and instrumentation at several frequencies will revolutionize the field and promises to yield data that could have a bearing on the question of the origin of the universe. The VLA would give to radio astronomy research the same high resolution of 1 second of arc that has been available to optical astronomers for centuries.

Other Telescope Design Projects

Reasonable cost and weight estimates are now available for various unconventional designs for the Largest Feasible Steerable Telescope (LFST) including the floating sphere and three types of azimuth-steerable but limited elevation motion telescopes. A small engineering group is reviewing the 600-foot NRL telescope design. S. von Hoerner has developed computer programs that will yield optimum design parameters for a telescope that would perform in a homologous manner (i.e., whose surface remains a perfect parabolic mirror regardless of antenna position) when moved.

Very High Resolution Studies

In May 1967 NRAO successfully initiated a series of very long baseline (VLB) interferometer experiments in which any given radio source can be observed simultaneously at a given frequency by two telescopes separated at large distances without the need for a physical connecting link between them. The resolution obtainable is directly governed by the distance of separation (baseline) and we can now achieve baselines equivalent to the diameter of the earth—though with limited coverage. Data at each telescope are recorded on magnetic tape while accurate timing pulses are placed on the tapes by mutually synchronized "atomic" clocks. The tapes are later analyzed by computer where fringes are seen unless the source is fully resolved. The independent local oscillator interferometer receiver was constructed in conjunction with astronomers at Cornell University-Arecibo Ionospheric Observatory and the University of California, La Jolla. The first successful run was made between the 140-foot telescope and the Naval Research Laboratory antenna at the Maryland Point Observatory at a frequency of 610 Megahertz over a baseline of 250 miles or 4.62×10^5 wavelengths. The same group in June 1967 operated a VLB experiment between the 140-foot antenna and the 120-foot Haystack facility of MIT-Lincoln Laboratory at 18 cm. wavelength over a baseline of 500 miles or 4.70×10^6 wavelengths. A group from MIT-Lincoln Laboratory shared facilities at the latter baseline at the frequency of the OH (hydroxyl) line and showed the linear size of the OH emission region in the source of W3, which is 6,000 light years away, to be less than the diameter of Jupiter's orbit. This corresponds to a resolution of 0.006 seconds of arc. Experiments in these two series are continuing between the NRAO 140-foot telescope and the Mark II antenna at Jodrell Bank in England, and between the NRAO 140-foot and the Hat Creek antenna of the University of California, Berkeley.

Work on ionized hydrogen (HII) regions has accelerated since the NRAO confirmation in 1965 by P. G. Mezger and B. Hoglund of the existence of radio recombination lines from ionized hydrogen regions. These recombination lines are the result of changes in the relative orbital position of electrons. By the middle of 1967 a number of hydrogen recombination lines had been observed ranging between 4 and 59 cm. wavelength, and lines from the elements helium and carbon had been discovered with the 140-foot telescope. Workers from Harvard, MIT and the NRAO were active in the field. These recombination lines originate from HII regions and offer astronomers valuable physical parameters such as electron temperatures, internal motions and line-of-sight velocities that characterize the physics and kinematics of these young ionized regions where star formation is often in process. An extensive observational program has developed that involves continuum mapping of these radio sources with the 140-foot antenna at 2, 6, and 11 cm. wavelength in order to: (1) Obtain high-resolution maps; (2) determine accurate positions so that recombination line observations can be made and optical identifications may be attempted; and (3) compare the radio brightness of the regions with their optical brightness in order to measure the amounts of absorbing dust lying between the source and the sun. Optical work is being undertaken by a group at the University of Wisconsin who are using data from the 140-foot telescope taken by both the Wisconsin workers and NRAO staff. Four radio emission lines were either discovered or confirmed on the 140-foot antenna during fiscal year 1967 by P. Palmer, B. Zuckerman, and co-workers from Harvard. B. Burke, T. Reifenstein and T. Wilson (MIT) with P. Mezger are continuing a survey of a hydrogen recombination line at 6 cm. to study a large number of faint distant HII regions. With the aid of a model that predicts the distances to these sources based upon their line-of-sight velocities, these astronomers hope to compare the positions of these regions with the spiral arms in the Milky Way observed with the 21 cm. line of neutral atomic hydrogen in an attempt to derive a consistent picture of the gas distribution in the galaxy.

University Astronomy Research Facilities and Equipment

A further stimulus to the already gratifying progress in optical astronomy can be expected in more widespread utilization of image intensifiers. (See 16th Annual Report, p. 24.) Several groups are proceeding with the development of various approaches to the problem of efficiently utilizing the sensitivity of photoemissive surfaces, including the use of tubes with electrical readout, such as the image orthicon. The cascaded tubes developed for the Carnegie Committee with Foundation sponsorship have been distributed to 19 observatories as of June 30, 1967, and their routine use by investigators is beginning.

In fiscal year 1967, the Foundation supported the construction of the following instruments for research in astronomy, with significant contributions from the universities involved in almost every case:

- Four optical telescopes having apertures of 24 (2), 42, and 48 inches respectively.
- Two radio telescopes, one a dish of 120-foot aperture and one decametric array.
- Two additional panels were provided for the Ohio State University tilting plane reflector which, together with a standing paraboloid of 360x70-foot size, make up a transit-type radio telescope.

Basic Research Projects

Supernovae: Explosive Stars

We are accustomed to thinking of the sun as a very dependable star. Its vast nuclear energy production deep within apparently proceeds at a very steady rate; and the end product of this process, the radiation of this energy from the surface of the sun out into space, seems not to vary noticeably. The sun is a typical star and nearly all of the stars show very little if any change in brightness when measured on photographs of the night sky. However a small percentage of the stars are unusual in this respect and are seen to undergo changes in brightness which range from the barely detectable to those which are catastrophic in character. These stars of changing brightness are referred to as the variable stars and a number of types of variability have been found and studied. In the explosive variable class are groups of stars that undergo very large brightness changes in a relatively short time. Within this class the most spectacular type of star is the nova. The name nova, implying literally a new star, arose quite naturally. When a stellar object suddenly appeared among the well known stars of a constellation in a position where no star had been known, it was natural to suppose that this was a new star, although of temporary character compared with the so-called "fixed" stars, since such an object always slowly faded back to naked-eye invisibility in a few months. It is now known that these nova outbursts represent a period of violent behavior in those stars which, it is believed, have used up their nuclear fuel and are having severe troubles in settling down into their final evolutionary state as so-called white dwarfs of low luminosity. Ordinary novae, on the average, increase in brightness by nearly a million times during such an outburst. The extreme objects of this class, called supernovae, undergo more violent explosions and may increase in brightness as much as a billion times. It is estimated that one supernova outburst per galaxy occurs every three or four hundred years.

Such supernovae have attracted the interest of astronomers for many years. Recent dramatic advances in astronomy, and imaginative studies now under way, point to the possibility that understanding of these galactic phenomena may now be relatively near at hand. Several astrophysicists have advanced theories about the supernovae phenomenon, and to test these theories it is essential that the supernovae be detected as early as possible in the explosive process.

It is believed that the explosive action of supernovae is important to the development of second-generation stars within a galaxy—new stars which are thought to form from the condensation of interstellar gas and dust combined with the debris from such stellar explosions.

In addition, since supernovae are so tremendously bright at maximum, they can be seen at great distances, far beyond that at which other types of stars can be distinguished in the same galaxy. Although two types of supernovae have been identified, it is found that the various types, on the average, attain roughly the same intrinsic brightness when they are at a maximum. They can be used therefore as indicators of the distance from earth of the galaxy within which the stellar explosion occurred. Since less than 100 supernovae have been found, it is clear that further improvement in the statistics of supernovae can contribute to refinements in the measurement of cosmic distances. In the astronomy research program, several groups are tackling this problem.

For a number of years F. Zwicky at the California Institute of Technology has carried on a supernova search through a program of photographic coverage of nearby galaxies, and in 1967 this program produced what has been widely recognized as a remarkable scientific coincidence. Toward the end of June, two supernovae from distant galaxies were photographed on the same night. Thus light from two distant objects in space—one 30 million light-years away and the other about 600 million light-years away—arrived on earth at the same time. No brightening of these objects could be found on similar photographs made 25 days earlier.

Two new supernovae search plans were initiated in 1967, with Foundation support, providing for broader and more sophisticated coverage of supernova events in galaxies, and these searches should bear fruit over the coming years. Allen Hynek of Northwestern University will use a semiautomatic telescope which presents the galaxy image, to the observer, enhanced in brightness by means of an image orthicon. At a dark sky site in New Mexico this 24-inch reflecting telescope, furnished by NASA to a Northwestern University team for monitoring changes on the surface of the moon, will be used during the period when the moon is below the horizon for a supernova search. The observer compares the galaxy image with a prior photographic record to detect the supernova when it first becomes visible.

Another investigator, Stirling Colgate of New Mexico Institute of Mining and Technology, with Foundation assistance, is working toward still further automation of the supernova search by comparing the galaxy image with an earlier image of the same galaxy stored in the memory bank of a computer. Foundation grants support development of the telescope and the electronic discriminator for comparing the galaxy images and detecting the supernovae. Considerable development work is ahead before all refinements in this equipment can be completed.

A common feature of these two approaches is that the supernova event is identified as soon as the galaxy is examined, making immediate telephonic communication possible with other observers having larger telescopes with appropriate photometric and spectrographic equipment. The goal is to reach a better understanding of the universe in which the earth is a microscopic component.

Probing Cosmic Radio Background

Physicists are increasingly giving attention to the problems of extremely large-scale systems such as those posed by astronomy or cosmology. In the area of cosmology a highlight of the past year has been verification of the high degree of isotropy, or equal intensity in all directions, of the cosmic radio background. As discussed in last year's annual report, this radiation, originally discovered by Penzias and Wilson at the Bell Telephone Laboratories in 1965, was interpreted by Dicke and coworkers at Princeton University as being the greatly cooled remnant of an intense radiation field believed present during an early stage of expansion of the universe some 10 billion years ago. Measurements of the spectral distribution of the radiation at a variety of wavelengths in the microwave region from 2.6 mm. to 21 cm. by various groups of investigators confirm that the radiation has indeed the properties expected of a photon gas at a temperature of about 3° K., or 3° C. above absolute zero. Studies at these and other wavelengths are now in progress in an attempt to reveal spectral structure that may shed light on the conditions present when the radiation decoupled from matter billions of years ago, enabling galaxies and stars to form.

The recent measurements of NSF grantees, Partridge and Wilkinson, collaborators of Dicke at Princeton University, showing that the radiation is highly isotropic, to within 0.1 percent over an equatorial band circling the sky, confirms the cosmic origin of the radiation. If it were of solar (or galactic) origin, then one would expect the intensity to show some correlation with the position of the sun (or Milky Way)—no such correlation is observed.

The isotropy of the radiation also suggests that the universe itself was highly isotropic when the radiation last interacted strongly with matter in the far distant past. Furthermore, no large scale inhomogeneities in the present density distribution of galaxies are likely, for such fluctuations in density would, by causing scattering, disturb the original isotropy. The credibility of the assumptions of large-scale homogeneity and isotropy of the universe, much used by cosmologists in forming evolutionary models of the universe, has thus been much enhanced.

If the earth is in motion relative to the sources of the cosmic background radiation in the universe in the distant past, then one would expect the intensity of the radiation to be somewhat greater in the forward than the backward direction. Thus, for the first time, one has the possibility of determining the absolute velocity of the earth with respect to the universe as a whole. The precise measurements of Partridge and Wilkinson show that the component of the earth's velocity in the equatorial plane of the sky, cannot exceed 300 km. per second with respect to the background radiation. Since it is known that the sun is participating in the general rotation of our galaxy, with a velocity of some 250 km. per second, and it can be expected that the galaxy, and the cluster of galaxies of which the Milky Way is a member, will also have random velocities of the same order, it is seen that with a small increase in sensitivity, the absolute motion of the earth in space should be detectable. Efforts to refine the measurements are now in progress.

Mathematical Sciences

Strictly speaking, there is no division of mathematics into pure and applied, though there are, of course, mathematicians whose motivation is primarily in basic research as there are others who are particularly challenged by problems arising in science or having immediate application. But the usefulness of a mathematical result in a nonmathematical field does not at all depend upon the motivation and the mood of the mathematician who created it. Although much significant mathematical work has been directly inspired by the needs of other sciences (the invention of calculus belongs to this category), it is still true that some of the most important applications of mathematics resulted from applying tools created for pure mathematics.

The most classical example is, of course, the theory of conic sections. The Greek mathematicians who investigated parabolas, ellipses and hyperbolas had no way of knowing that a millenium and a half later these curves would become working tools for astronomers and physicists. The time lags in science are becoming much shorter and when Einstein needed tensor calculus it was already available as a result of the work of Italian differential geometers. The usefulness of the representation theory of finite groups in quantum mechanics was not at all impaired by the fact that its creators, Frobenius and Shur, were not interested in applications and one of them is said to have had a positive distaste for them. A more recent example is symbolic logic, a discipline which borders on philosophy and which even most working mathematicians consider esoteric. It seems generally recognized that many years of developmental work and millions of dollars were saved by the fact that among the godfathers of electronic computers were two men steeped in mathematical logic (von Neumann and Turing).

Other instances of the interplay, unexpected and impossible to plan, between pure and applied mathematics, are given by the recent advances in the theory of stability of motion which are of relevance both to computation of satellite orbits and to the design of accelerators. The work of Jurgen Moser (New York University) uses an idea which originated with John Nash (Northeastern) while the latter was solving a problem in differential geometry in the large (embedding of Riemann manifolds) which at that time seemed not to have anything to do with applications. The same is true of the theory of functions of several complex variables and of the representation theory of Lie groups which belong to the most vigorous branches of contemporary mathematics, and are at the same time of use in theoretical physics.

Thus the history of science, including the most recent history, seems to justify the claim that irrespective of the purposes of mathematicians, good, original mathematics has an excellent chance to prove useful for other sciences. Mathematics is much bigger than the small group of professional mathematicians. For every man proving or trying to prove theorems, there exist hundreds of users of mathematics, from theoretical physicists whose mastery of mathematics equals that of the professionals, to programmers, high school teachers, etc. Our whole science and technology-based society is permeated by mathematics and will probably become more so as time goes on. Society has, therefore, a vital interest in mathematical culture as a whole. Mathematicians are almost unanimous in feeling that we are living in a golden age of mathematics. The best of new mathematics done today is as profound and as significant as some celebrated achievements of past centuries. The number of mathematical investigators has increased by a large factor, and many talented young people are entering mathematical work. This is, of course, particularly significant for a discipline in which important achievements have so often been the work of young people.

A visible sign of the good state of today's mathematics is the large number of famous old problems which seemed inaccessible a few years ago, and which are now being solved. In each individual case the solution may be attributed to the genius of an individual, and to his courage in embarking on months or years of hard work in the uncertain hope of solving a problem which has baffled generations of mathematicians.

To take an example of a very active field of mathematical research which has already had and promises to have more significant applications, a very large part of modern work on partial differential equations consists in finding existence and uniqueness proofs. In doing this, tools from various fields of mathematics are used. The work is certainly nearing completion as far as linear problems are concerned. But nature is not always linear. Compressible fluid flow, viscous flow, flow in elastic pipelines (e.g. blood flow), magnetohydrodynamics and plasma physics, general relativity, and other disciplines challenge the mathematicians to solve nonlinear problems. In this field very much has been achieved during the past 10 years, but much more remains to be done. From the point of view of physical sciences, the task is not just to learn and to use existing mathematics, but to create new mathematics adequate for the problems in question.

Much of the work in the theory of partial differential equations sounds very esoteric. The theorems are usually based on highly refined inequalities, called in this connection "estimates" and on very general principles, often borrowed from topology, and used to assert the existence and uniqueness of a solution to a problem. Only a few years ago such work would have been held purely theoretical and of no interest for applications where one wants a solution expressed in a workable form, say by a sufficiently simple formula. The advent of the modern computing machine has changed this. If a problem, e.g., a boundary value problem for a differential equation, is sufficiently understood theoretically, then, in principle at least, a numerical solution can be obtained on a machine. If the mathematical theory of the problem is not understood, if we do not know the proper conditions to prescribe, the general quantitative and qualitative properties of the solution to expect, then the biggest machine and an unlimited number of machine hours will not yield a solution. Of course, even if the theory of the problem is well understood, the actual computation of the solution may still require refined and original work in the newly developed discipline of numerical analysis.

The theory of partial differential equations borrows tools from other mathematical disciplines. This is only one instance of the general confluence of fields and unification of thought which are so characteristic of modern mathematics. About 20 years ago, mathematics was in a period of specialization. The various special disciplines seemed to become more and more removed from each other and fears were expressed that, in days to come, mathematicians working in different fields would be unable to talk to each other. Fortunately, today's development goes in the opposite direction. The boundaries between the fields almost disappear. Applied mathematics has kept pace with this advance of mathematics generally. While mathematics is difficult to describe technically, the following examples of applications seem worthy of mention.

Economic Design of Structural Columns

A problem which has always been of importance to the construction engineer and architect is that of constructing structurally sound tall columns. Today, when construction materials of almost all kinds are much more expensive than in earlier times, the question of economy looms large in the designer's mind, and it becomes worthwhile to consider the question of the shape of the structurally most efficient columns which can be made from a given amount of material.

Clearly a very thin column could be made, but experience shows that a sufficiently thin column will buckle under its own weight (to say nothing of the effect of a load on the upper end). A squat, thick column is free of this defect, to be sure, and may in some cases be useful. On the other hand, it is known from experience that one can construct reasonably thin columns which do not buckle. A little more thought and observation convinces one that a nonbuckling column which tapers in some way toward the top can be made taller than one of constant cross section of the same volume. But just *how* should it taper?

The answer to this question has been given by research done by J. B. Keller with the help of a grant from the Foundation. More specifically, Dr. Keller sought the tallest column of given cross section which will not buckle that can be made with a given volume of material. He considered both a column loaded on its top as well as one free of such load.

The problem can be formulated mathematically by writing down an equation which expresses the balance which must exist just as the column begins to bend between its resistance to bending and the tendency of the column weight (or weight and load) to bend it. This leads eventually to what is known in mathematics as a nonlinear integro-differential equation. Equations of this sort are notoriously difficult to solve. In Keller's problem a solution may be obtained numerically, but the shape near the top and bottom can be found by simpler means.

The following interesting results were found: the tallest tapered unloaded column is 2.034 times as high as an untapered column made of the same volume of material and cross section. If the columns are assumed to carry a load at the top, the ratio of the height of the tapered to untapered column decreases from 2.034 at zero load to 1.075 when the load becomes infinitely large. Further, the taper is straight near the bottom for both the loaded and unloaded column, but in the former case the column comes to a point at the top while in the latter it is rounded.

Spiral Structure of Disk Galaxies

Problems on the astronomical scale also attract the attention of applied mathematicians. During the past year, NSF supported work in the area of applied mathematics has made an outstanding contribution to the solution of a mathematical problem posed by accumulated astronomical observations.

Galaxies or concentrations of stars, like the Milky Way we live in, have been familiar to astronomers for a long time. Most galaxies are disk-shaped, and most of these have conspicuous spiral structures. But why do they have such a regular spiral structure? How and why do they maintain their interesting pattern when the inner part of the galaxy rotates faster than the outer part?

These questions have been investigated intensively in recent years, and C. C. Lin and his students at the Massachusetts Institute of Technology have provided a striking example of the application of mathematics to the theoretical explanation of these galactic formations.

To construct a mathematical model for spiral structures in disk galaxies, one must take into account the individual stars with their gravitational forces and velocities; the interstellar gases and associated gravitational field and pressure; and the magnetic field existing in the highly conducting interstellar gas. A complete theory must attempt to take all these components and forces into account and establishes their interrelationships in terms of mathematical equations. Two main approaches are possible. One theory is to explain each spiral arm as essentially a tube of gas constrained by the interstellar magnetic field. Alternatively, the matter in the galaxy (stars and gases) is viewed by Dr. Lin as maintaining a density wave where each star moves under the joint gravitational field of the other stars and gases. This produces, in the presence of rotation of the disk galaxy, a spiral gravitational field which underlies the observable concentration of young stars and the gas. Although magnetic forces are also present in the galaxy, they are small compared to gravitational forces, except possibly in the spiral arms of the galaxy.

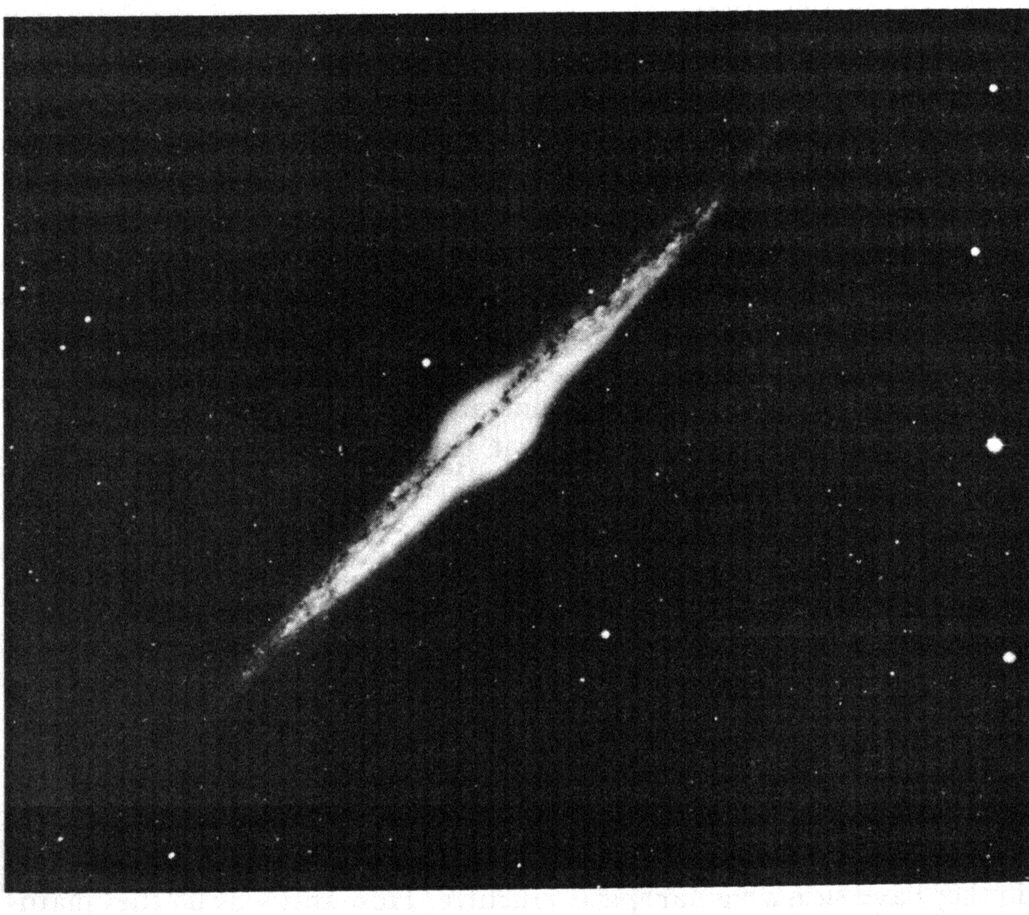


Figure 6.—*Spiral galaxy (NGC 4565) seen edge on. Mount Wilson and Palomar Observatories photograph with the 200-inch telescope.*

To the governing equations of his system Lin applies what is called a perturbation technique, i.e., assumes a small deviation from a permanent pattern, and examines the consequences. His theory predicts the trailing spiral arms of a rotating galaxy, and forbids leading arms—in satisfactory accord with observation. Lin also deduces an approximate relation between the arm spacing and the galaxy's position in space which are in rough accord with observations of our own galaxy obtained by radio wave observations. Further, using a two-arm model for our own galaxy, Lin deduces that a spiral pattern can exist only between certain distances and these distances are again consistent with the observations of radio astronomers.

It is interesting to note that the gravitational plasma postulated in C. C. Lin's general equations has an analog in plasma physics. Possibly experimental models of our galaxy could be built by using plasmas in a laboratory. This work was partially supported by the National Science Foundation, and is continuing.

ENVIRONMENTAL SCIENCES

The environmental sciences are concerned with man's surroundings: the characteristics and composition of the planet earth from which he receives substances, and the sun from which he receives heat and light. Although many activities in the study of the environment are closely related to physics, chemistry, or biology, interdisciplinary efforts are becoming increasingly common both in the field and in the laboratory.

The importance of environmental science studies stems from the realization that our advanced stage of civilization has not been achieved without damage to the environment upon which life depends. A thorough understanding of the total environment is needed to assess this damage, to forecast future dangers, and to provide for future requirements of civilization.

Studies of the environment play a substantial role in the national and international scientific programs which the Foundation supports. In some cases these projects take the form of large scale field operations including scientists from many disciplines and many nations and involving the use of ships, aircraft, rockets and other facilities. Some of these programs and activities are described in the discussion which follows.

The United States Antarctic Research Program

The year 1967 marked the end of a decade of intensive U.S. scientific investigations in Antarctica begun in the International Geophysical Year, 1957–58. The Antarctic Research Program is one of a number of major research programs in which the Foundation shares responsibility, and which because of their nature and magnitude require coordinated planning and funding on a national basis. In the case of the U.S. Antarctic Research Program, the National Science Foundation has management and funding responsibility for all research activities and the Department of Defense provides the major logistic support through its U.S. Naval Support Force, Antarctica.

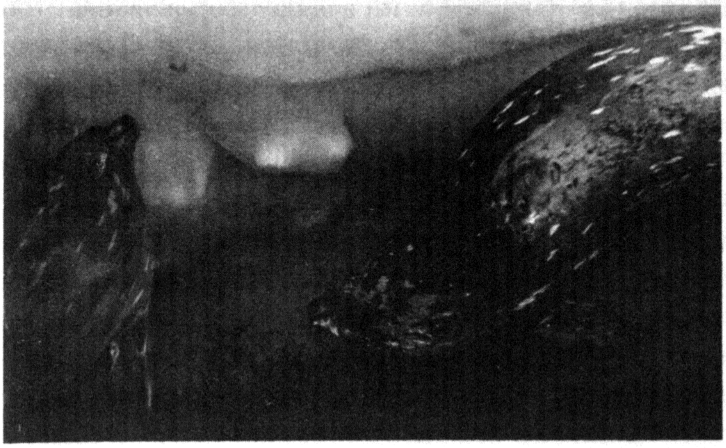
Research projects conducted on the Antarctic Continent and aboard ships in surrounding seas span a broad range of the physical and life sciences as well as those disciplines usually classified broadly as environmental sciences. In the 1966–67 austral summer season these varied activities involved 169 scientists and technicians, with 33 individuals wintering over at the five U.S. Antarctic stations in 1967. The scientific complement of the Antarctic research vessel *Eltanin* averaged 34 persons for six cruises in fiscal year 1967.

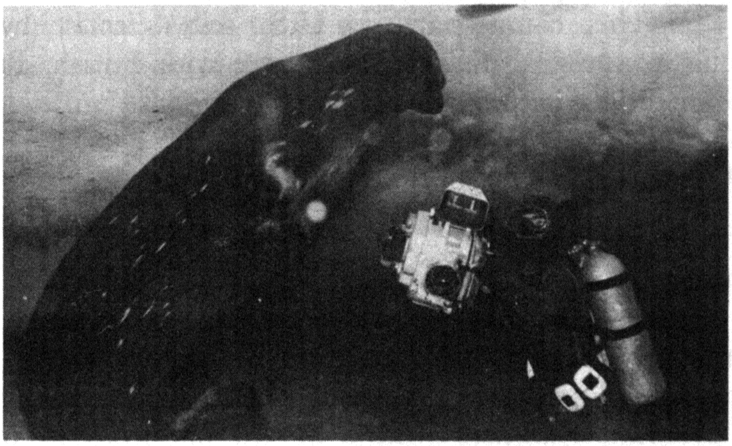
Events of the past year indicate substantial progress in the enhancement of facilities and techniques for research in the Antarctic region. One of the major accomplishments was the aerial photography by U.S. Navy aircraft of 340,000 square miles, double that of any previous summer. This effort represented the seventh summer of aerial photography; and in three or four more summers, this work will be completed. All remaining areas of Antarctica have either been photographed by other nations or are entirely covered with snow and ice.

In the southern summer of 1966–67, the installation at Byrd Station of a coring rig inaugurated the Antarctic phase in the development of equipment and drilling techniques to penetrate the icecap. Initial coring trials progressed to below 700 feet; in the following summer (1967–68), it is expected to reach bedrock at eight or nine thousand feet below the surface. Information from the subsequent deformation of the core hole, as well as from ice temperatures at this depth will contribute to an understanding of the flow of icecaps. Core analyses in laboratories will be concerned with those characteristics of the ice and the included gases and particulates by which the ice can be dated and the history of its buildup and metamorphosis can be determined.

On Anvers Island, location of Palmer Station, second stage development for the station commenced with the laying of the concrete foundation for a habitation and laboratory building, the construction of a boat dock, and the erection of fuel storage tanks. A research trawler, *Hero,* has meanwhile been under construction in Maine. The 125-foot wooden vessel will be based at Palmer Station throughout the navigation season. Together, the station and vessel will provide facilities for scientific investigation of the Antarctic Peninsula area, particularly the rich marine life.

The Antarctic research vessel *Eltanin* was midway in her sixth scientific cruise of the year at the end of June 1967. Four cruises were made in the South Pacific between Chile and New Zealand or Australia, one was confined to the Tasman Sea, and the remaining cruise represented





Photos by Carletron Ray, Johns Hopkins University

Figures 7, 8, and 9.—***From an observation chamber under the ice at Turtle Rock near McMurdo Station in the Antarctic, scientists observe family life of the Weddell seal. Underwater acoustics and social behavior are among the areas of scientific interest, and the seals seem equally intrigued by the presence of observers.***

the ship's first venture into the Ross Sea with a 1-day stop at McMurdo Station.

In all, *Eltanin* was at sea for 86 percent (313 days) of the year. The scientific complement on each cruise numbered from 32 to 37, and included women as well as men. In observance of the provisions of the Antarctic Treaty promoting the greatest feasible interchange among nations in the Antarctic, the ship accommodated, at various times, scientists from Australia, Chile, France, New Zealand, and the United Kingdom.

Hospitality and professional assistance were also freely exchanged on the Antarctic Continent, where eight foreign scientists from six nations worked within the U.S. Antarctic Research Program. One of these, a Soviet atmospheric physicist, spent the winter of 1967 at the Pole Station, while his counterpart, a U.S. soils scientist, wintered at Molodezhnaya. Other U.S. scientists were with British, French, and Japanese expeditions in the past year.

Weather Modification

The Foundation's contribution to the national effort to reach a better understanding of climate and weather—leading in time to a measure of control—includes a balanced national program of university and institutional research devoted to studying the basic scientific aspects of weather modification and to training the necessary manpower. In addition, the program embraces studies of the interrelationships between weather modification and sociology, economics, law, and ecology.

Evidence continues to grow that man can indeed change the course of weather, though as yet only in special cases and on a very modest scale. Under certain atmospheric conditions, fog can be dissipated, precipitation can be increased, and some modification of thunderstorms is possible to the extent that incidence of hail and lightning can be lessened.

A national plan for an increased research effort to dissipate warm fog has been developed in 1967 by the U.S. Air Force, with support from the Foundation, and the results of this study are now being evaluated. A similar plan for an increased national research effort in the suppression of hail was developed by a group of specialists working through the National Center for Atmospheric Research.

While research in cold-cloud rain augmentation continues to receive emphasis in university and institutional programs, fiscal year 1967 has brought an increase of effort in the previously underexploited areas of warm-cloud modification and hail suppression research. Such areas as the role of ice in summer rain, the role of electricity in clouds, and the dynamics and microphysics of clouds are examples of the type of university research projects underway.

Statistical analysis of cloud seeding results has indicated that under extremely cold cloud conditions, cloud temperature may influence the effectiveness of seeding. The optimum cloud temperature for positive increase in precipitation due to silver-iodide seeding from winter storms over the mountains has been shown to lie between —12° C. and —24° C. Optimum temperature limits for convective clouds over plain areas are still under investigation. Research has also shown that when silver iodide is exposed to ultraviolet from the sun, the nucleation efficiency decreases by a factor of 6 in 1 hour. A new technique for detecting as little as 10^{-9} grams of silver in rainwater exposed to silver iodide seeding has also been developed which requires neutron activation for a period of only 3 minutes, as compared to several days by the standard techniques.

The use of high-speed electronic computers to construct mathematical models of weather modification processes is growing rapidly. A mathematical model of a hurricane has been developed for use on an electronic computer which has proven to be quite realistic in simulating the deepening and mature stages of a typical hurricane. This model has demonstrated convincingly the importance of sea surface temperature on both the development and maintenance of such storms, and provides a valuable clue for possible modification techniques other than cloud seeding. It is visualized that, within the next 5 to 10 years, the models now being constructed with Foundation support will also provide the increased understanding of the atmospheric processes needed to discover ways for modifying fog, hail, tornadoes, and drought conditions.

Although the larger part of Foundation support for weather modification activities has been for university research, the National Center for Atmospheric Research makes an important contribution and investigators associated with industrial corporations and nonprofit institutions have also received support for particularly promising projects. In addition, the Foundation has sponsored research by other Federal agencies in their own laboratories to insure that ideas of significant scientific merit would be pursued. This diversity of support has resulted in a broad research and development effort extending across the entire spectrum of weather modification problems.

In accordance with its reporting responsibilities established by law, the Foundation, in fiscal year 1966, published a regulation stipulating that all persons planning attempts to modify the atmosphere must file notification of intent with the Foundation at least 30 days prior to the initiation of field operations. The regulation further provided for submission of quarterly activity reports and the maintenance of logs of activities which would be subject to examination by the Foundation upon request. In fiscal year 1967, 61 new notifications of intent were filed with the Foundation in addition to 18 other projects continuing from the previous year.

The United States–Japan Cooperative Science Program

The United States-Japan Cooperative Science Program was established in 1961 to foster closer collaboration in science between the participating nations. The National Science Foundation is the principal coordinating, administering, and funding agency for American participation. A similar role in Japan is undertaken by the Japan Society for the Promotion of Science (JSPS) under the auspices of the Ministry of Education. Both participating nations contribute equitably to the total program in the form of funds, equipment, materials, or other means.

While the cooperative program provides for exchange of visiting scholars, exchange of scientific information, and projects for improvement of science education among its activities, five of the eight specifically stipulated areas of cooperation cover broad fields of scientific research which emphasize the environment of the Pacific area. The Foundation and JSPS work closely together in fostering communication between scientists with similar interests and in the development of meritorious scientific projects that fit the criteria of the program.

A number of studies now underway are devoted to reaching a better understanding of the nature and behavior of hurricanes, typhoons, and cyclones. Other Japanese-American partnerships are investigating narcotics and drug abuse, biological studies of Pacific fauna, and phytogeographical relationships between Japan and North America.

International Years of the Quiet Sun

Fiscal 1967 was the last year for funding projects under the International Years of the Quiet Sun (IQSY), although the analytical and interpretive phases will continue into the future. The observational phase of the IQSY extended from January 1964 through December 1965. It provided a mechanism for international and multidisciplinary studies of the sun and the effects of the sun upon the earth during a minimum in the 11-year cycle of solar activity.

The overall coordination of the program, encompassing efforts by more than 60 nations, was vested in the IQSY Committee of the International Council of Scientific Unions. Coordination of the United States participation was accomplished through the U.S. Committee for IQSY of the Geophysics Research Board of the National Academy of Sciences. The National Science Foundation coordinated participation by agencies of the Federal Government and provided special funding. From fiscal year 1963 through 1967, the Foundation supported 164 IQSY projects at a total cost of approximately $11 million.

Since the observational period of the IQSY that ended in December 1965, efforts have been directed at analyzing and interpreting the data accumulated. From this phase of study, a new insight is expected into solar-terrestrial process. A better understanding of the sun and its interactions with the earth has already emerged. As a consequence, interest has been further stimulated in solar-terrestrial research in such areas as the composition and interaction dynamics of solar emissions and studies of the atmospheres within the space between the sun and the surface of all planets.

Work by Syun Akasofu at the Geophysical Institute in Alaska has shown that the aurora in the polar region has the shape of an oval that is blown off center by the solar wind. Kinsey Anderson and the group at the Berkeley Space Sciences Laboratory have demonstrated that the particles are not just funneled into the auroral oval from the solar wind but are often accelerated by processes that occur locally in the terrestrial magnetic field or magnetosphere. The new determination by Kenneth McCracken and coworkers, at Southwest Center for Advanced Studies, of the cosmic rays that come into the terrestrial atmosphere permit a mapping of the interplanetary plasma to distances from the earth not possible with satellite probes for many years in the future.

Atmospheric Sciences

Atmospheric science is a field based primarily on the principles of chemistry, physics, and mathematics. The term embraces many areas and has had the effect of merging the interests and activities of meteorologists, atmospheric physicists and chemists, engineers, mathematicians, biologists, agriculturists and medical doctors into a group of scientists interested in all aspects of the atmosphere.

Foundation support for atmospheric science includes research on phenomena in the lower atmosphere where most weather, climate, and pollution effects are confined (meteorology); in the middle atmosphere where incoming solar energy is directly absorbed and complex physical interactions occur (aeronomy); and in the high atmosphere (solar-terrestrial programs).

Of particular interest in the atmospheric sciences is the International Meteorological Program, which is an international cooperative effort in atmospheric studies and weather forecasting. As part of this effort, a World Weather Program to have the entire world under meteorological surveillance by 1972 is planned. The research portion of the World Weather Program is known as the Global Atmospheric Research Project (GARP). Part of GARP includes a series of experiments to study tropical meteorology which affects weather throughout the world. As a preliminary to GARP, the Line Islands Experiment was undertaken in fiscal year 1967 and is described on page 81.

National Center for Atmospheric Research

An important factor in the forward thrust of atmospheric research during the 1960's has been the creation in 1960 of the National Center for Atmospheric Research (NCAR), a Foundation-sponsored laboratory in Boulder, Colo. The Center is operated by the University Corporation for Atmospheric Research, of which 24 American universities are members.

NCAR's mission is to provide the nucleus for a concerted attack, primarily through basic research and education-related activities, on difficult and challenging areas in the atmospheric sciences, especially where they relate to problems of major social concern, such as in long-range weather prediction, weather control, and air pollution.

During the past year, progress was demonstrated both in the evolution of interdisciplinary research projects (e.g., NCAR's work on a mathematical model of the global atmosphere), and in NCAR's management of joint-use facilities and joint NCAR-university-government research expeditions. (See Line Islands Experiment on p. 81.) As the quality and scope of the national atmospheric sciences effort grow to meet the challenge of dealing with global-scale atmospheric problems, NCAR's position as a focus of university-based activities will prove of increasing value to the Nation.

In the summer of 1966, NCAR participated in Project Hailswath, a cooperative 1-month pilot field study of practical and scientific problems encountered in hail suppression research. The experiment, carried out near Rapid City, S. Dak., brought together leaders in hail suppression and cloud physics research in a multidisciplinary pilot project in hailstorm

NCAR Photo

Figure 10.—*New NCAR laboratory building near Boulder, Colo., was dedicated on May 10, 1967. The structure houses the Laboratory of Atmospheric Sciences, including a 35-foot-high cloud and raindrop shaft in which the processes of raindrop growth and electrification are simulated.*

field studies. The experience obtained under Project Hailswath aided members of a Foundation-supported study group in formulating recommendations for a national hail suppression program. Several NCAR staff members served in the study group, which was formed by U.S. and Canadian scientists at the request of the Interdepartmental Committee on Atmospheric Sciences of the Federal Council for Science and Technology. The group is scheduled to submit its recommendations to the Foundation early in 1968.

NCAR's major research is carried out by two divisions: the High Altitude Observatory (HAO), located in laboratories in Boulder, Colo., and in an observatory at Climax, Colo.; and the Laboratory of Atmospheric Sciences (LAS), with quarters in the new NCAR Laboratory which was dedicated on May 10, 1967.

High Altitude Observatory

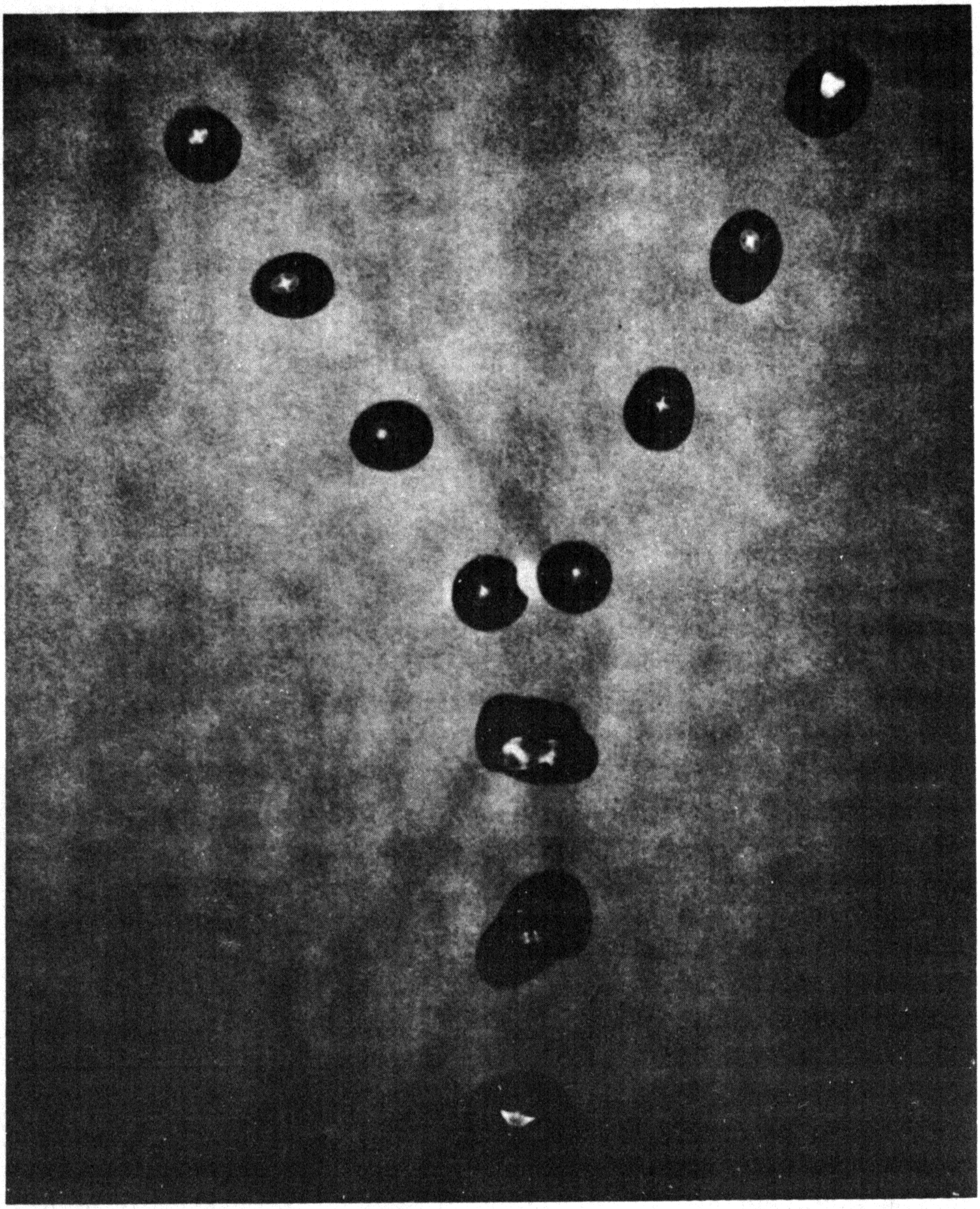
Major events in the HAO program in fiscal year 1967 included participation in three expeditions to South America to record the solar eclipse of November 12, 1966 (see p. 87). It was during this eclipse that a nine-man team, based on the high plateau of Bolivia, secured an exceptionally fine white light photograph of the solar corona.

While eclipses afford the best opportunity to study the solar corona, they do not permit sustained observational programs. To improve the observational capability, NCAR has concluded an agreement with NASA to carry a solar coronagraph on future satellite flights. An HAO-developed coronagraph mounted on NASA's orbiting Apollo Telescope Mount, planned for 1969, will continue the new phase of coronal investigation opened by the HAO in 1964 and 1965.

Laboratory of Atmospheric Sciences

Recent important research advances in the Laboratory of Atmospheric Sciences included significant refinement of numerical models of the general global atmospheric circulation. A two-layer model began yielding computer printouts of large-scale atmospheric patterns; some are printed onto 35-mm. film, to be viewed as motion pictures of worldwide motions. A six-layer model has also been formulated and will be brought into operation within several months. These increasingly realistic models comprise an important part of NCAR's research on global scale atmospheric processes. They will be essential for understanding the many processes that must be heeded in long-range forecasting, for testing the full potential of various large-scale weather modification techniques and will have an important role in the Global Atmospheric Research Program, a part of the World Weather Program.

Investigations of rain droplet growth and effects of electrification on droplet coalescence were carried out in the new 35-foot-high NCAR



NCAR Photo

Figure 11.—***Stroboscopic picture shows the electric discharge and coalescence of a pair of oppositely charged water drops in rain shaft experiments. Electric charges in thunderclouds aid the coalescence of embryo raindrops to rainstorm drop size. Uncharged drops of sizes similar to those shown here tend not to coalesce in the absence of a strong electric field.***

Laboratory cloud and rain shaft. Photographic analysis of charged and uncharged droplets falling in an electric field has yielded information on the relative contribution of various processes of droplet growth and rain formation. Charged droplets discharge upon coalescing, giving off electromagnetic radiation, which appears identical with thermal emissions in the UHF and microwave region. The results should ultimately have application to terrestrial weather modification programs.

The Advanced Study Program

The Advanced Study Program at NCAR promotes breadth in the definition and solution of problems in the atmospheric sciences. Its chief aim is to bring postdoctoral fellows to NCAR to do basic research for one-year periods. Eight postdoctoral fellowships were awarded for the academic year 1966–67, and nine for 1967–68.

In addition to the postdoctoral fellows and graduate students participating in the NCAR graduate fellowship program, a total of 78 visiting scientists pursued research programs at NCAR for varying periods during the year. Numerous scientists from colleges, universities, private or government laboratories in the United States or abroad visited NCAR during the year to discuss scientific problems.

The Facilities Laboratory

The NCAR Facilities Laboratory (FAL) operates facilities in scientific ballooning, aviation, field observing, and computing, to serve both NCAR and the university community of atmospheric scientists. Each facility supplies equipment and staff for the technical aspects of atmospheric research projects when requested; each conducts an equipment and method development program to keep technical capabilities abreast of scientists' needs.

FAL activities in fiscal year 1967 included advances in the Global Horizontal Sounding Technique (GHOST) balloon development. In a flight-test program covering the 12 months ending in March 1967, 43 constant-level balloons were released from Christchurch, New Zealand, and 6 from the Antarctic, to trace horizontal wind fields of the Southern Hemisphere. Three balloons stayed aloft at the 200-millibar level (approximately 40,000 feet above the surface) for over 200 days, one of them circling the globe 19 times. One flight at the 300-millibar level (approximately 30,000 feet above the surface) lasted 51 days; the majority of flights at this level were forced down by severe icing conditions and methods are now being developed to overcome such difficulties.

GHOST development comprises a part of the Global Atmospheric Measurement Program (GAMP), and NCAR continued to cooperate with the Environmental Science Services Administration and the New Zealand government in the GHOST test program.

Meteorology

Meteorology involves basic research on phenomena occurring in the lower portion of the earth's atmosphere from the surface to about 60 km., although there is no sharp upper boundary. It is in this lower portion of the atmosphere that most of the earth's weather, climate and pollution is observed. A few examples of the type of research and some results will serve to illustrate the breadth and nature of the program.

Water Vapor

Water vapor is an important factor in the atmosphere. Lack of it or lack of a mechanism to trigger its release results in drought. Too much rain in a short period of time results in floods. One of the basic problems regarding water vapor is how does it get from the seas to the atmosphere and back again.

In order to have rain, it is necessary to have condensation nuclei. One of the sources for the nuclei is the bursting of air bubbles from the surface of the ocean. The bursting air bubbles provide the principal mechanism by which chloride particles are introduced into the atmosphere to act eventually as condensation nuclei. An electrical charge also is created as the bubbles burst. This causes an electrical gradient to be formed between the sea surface and the air.

A group led by John Day at Linfield College in Oregon is investigating the bursting of the bubbles through use of a diffusion cloud chamber in which the humidity environment can be controlled. Time-exposure photographic techniques are used to observe the trajectories of jet drops and bubble film droplets. It is possible to compute the velocities of the droplets, and from these data information regarding particle size and energy distribution can be inferred.

Electrical charge generation mechanisms are being studied in laboratories at the Woods Hole Oceanographic Institution and at the University of Minnesota, as well as in a region of intensive bubbling of the surf along the shore in Hawaii. Laboratory observations indicate that the bursting bubble charge mechanism is modified by surface active organic films. It has been noted that fresh water and sea water differ greatly in the production of nuclei and electrical charges.

Once the nuclei enter the atmosphere they are transported to areas that are cooler and contain enough water vapor so that condensation can take place. The atmosphere contains many kinds of particles that can and do act as nucleating agents. A group at the University of Missouri is studying nucleation phenomena from both the experimental and theoretical viewpoint. During the course of the investigation it has become apparent that droplets in the atmosphere do not act as efficiently as theory would predict because of the many types of nuclei competing for the available water vapor.

The movement of water vapor is difficult to trace in the atmosphere. Dr. Gote Ostlund at the Marine Institute of the University of Miami is using tritium, a radioactive form of hydrogen to trace water vapor in hurricanes. Tritium that is found normally in the stratosphere becomes a part of a water vapor molecule through normal processes and can be traced through the atmosphere. Investigations in hurricanes using tritium as a tracer have reinforced the opinion that the latent heat of water evaporated from the sea surface is one of the major sources of the hurricane's energy.

Water vapor is transferred into the atmosphere rapidly in the tropical areas of the world. Our lack of understanding of atmospheric processes in the tropics coupled with a sparseness of data have resulted in incomplete knowledge of how the tropics affect the general circulation and the distribution of heat and water vapor. The Line Islands Experiment (LIE) was undertaken in March and April 1967 in the equatorial Pacific (Christmas, Fanning, and Palmyra Islands) to aid in understanding better the atmospheric processes in a tropical ocean area.

The LIE had as its specific objectives the investigation of:

(1) The nature of convective processes in a typical equatorial maritime environment, and the interactions between the convective activity and larger scales of motion in and near the Intertropical Convergence Zone;

(2) The extent to which standard instrumentation is sufficient to define both convective and broad-scale atmospheric features in the tropics;

(3) The degree to which the satellite photographs can be calibrated against ground, ship, and airplane-based observations, and the reliability of satellite-derived cloud motions in depicting the true atmospheric motions; and

(4) The mechanism of heat, momentum and moisture transport from the boundary layer to the upper layers of the atmosphere.

The experiment, coordinated by the National Center for Atmospheric Research with support from the Foundation, involved nine university groups and various Federal agencies including the Army, Navy, Air Force, Air National Guard, ESSA, NASA, AEC, and the Department of State.

The experiment was successful in that many detailed and useful observations and measurements were made. Preliminary results indicate that clouds never extend above 20,000 feet in this area, few thunderstorms are found, and the region is not a source of heat to help drive the general circulation of the atmosphere. In addition, the LIE has shown that new instrumentation must be designed for tropical use because instrumentation designed for wind-latitudes does not have the needed resolution.

The LIE was the first of several tropical meteorological experiments planned within the next five years in recognition of the lack of knowledge regarding fundamental physical processes taking place in the tropics. The next experiment is scheduled for the summer of 1969 near the island of Barbadoes. All of these experiments are a part of the Global Atmospheric Research Program (GARP) which is the research effort of the World Weather Watch.

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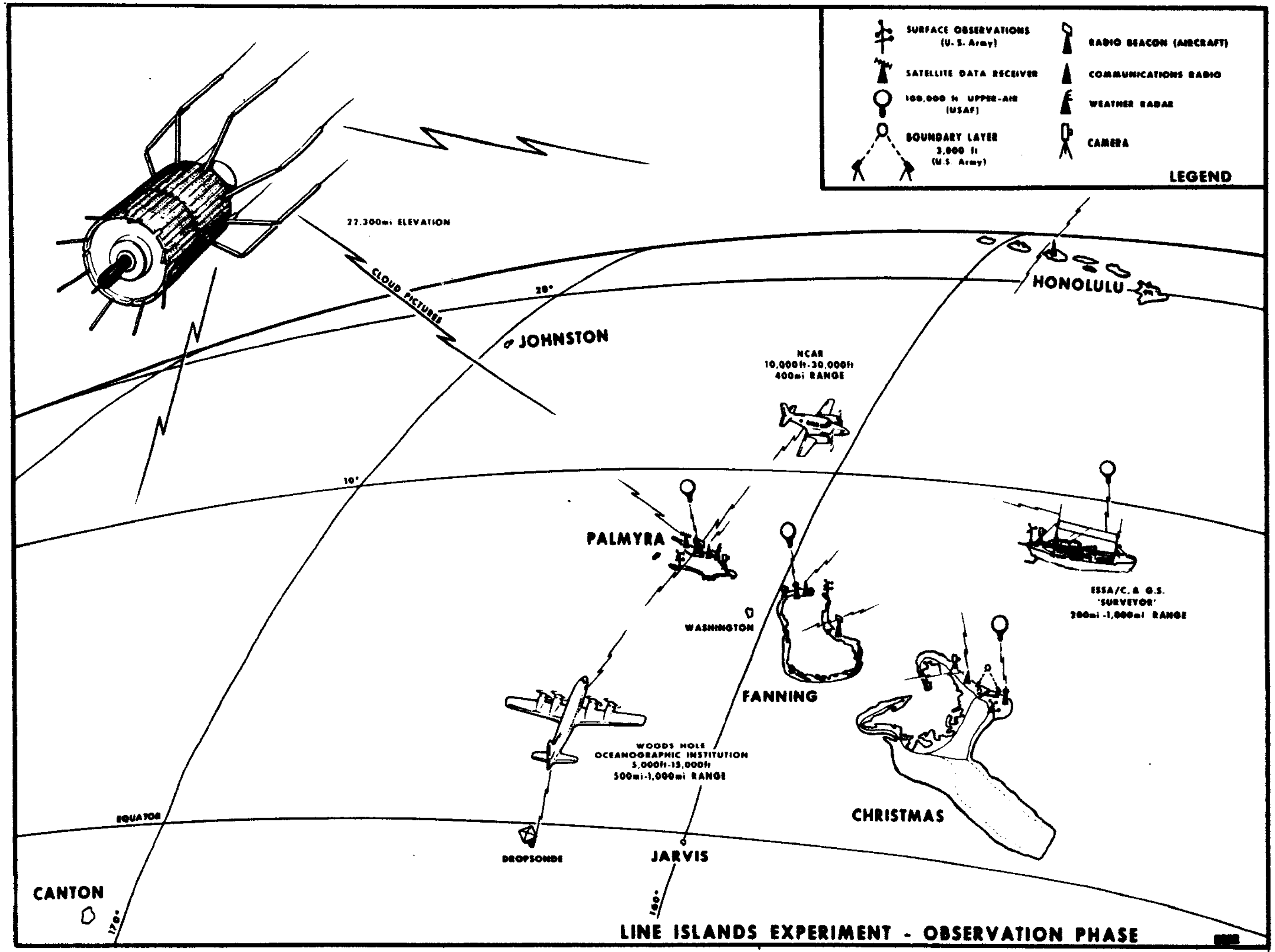


NCAR Photo

Figure 12.—

NCAR Photo

Figure 13.—*NCAR technician checks wind speed instrumentation at an observing site on Palmyra atoll during the Line Islands Experiment in the spring of 1967.*

Aeronomy is the study of the physics and chemistry of the upper atmosphere extending from about 50 km. above the earth's surface to the boundaries of the magnetosphere. It is in this region that incoming solar radiation and particulate matter from space react with the earth's atmosphere to form the ionosphere, that high energy particles become trapped in radiation belts surrounding the earth, where photochemical processes manifest themselves in visual displays such as aurora, and that important energy transport processes to and from the lower atmosphere occur.

Recently, new studies in aeronomy have come into prominence. These are concerned with the dynamics of the upper atmosphere and, for example, involve the interrelationships between ionization densities, magnetic storms, planetary and gravity wave influences and magnetic conjugate point excitation mechanisms.

Impact of Solar and Cosmic Particles

Airglow, its most spectacular form the visual aurora, continues to be an important subject of study for atmospheric scientists. Displays of light in the form of green glow, red arcs, and sheets or curtains of many colors not only beautify the polar night sky, but contribute quantitatively to our knowledge of atmospheric composition, the input of solar and cosmic particles bombarding the earth, and the photochemical reactions between particles and atmospheric constituents.

The earth is continuously bombarded with numerous types of high-energy particles and electromagnetic radiation that, without the cover of the earth's atmosphere, would end all life on earth as we know it. While providing this protective cover, the atmosphere emits light at certain wavelengths as evidence of the nature of the impinging particles and radiation. Auroral displays are observed mainly in the polar latitudes because of the guiding effect of the earth's magnetic field on the incoming charged particles, but airglow reactions occur at all latitudes during both day and night. Sensors have been developed to detect electromagnetic radiations associated with these reactions and are providing data which are being used to increase our knowledge of the physics of the upper atmosphere.

Investigators at the University of Pittsburgh have made important contributions to the understanding of atmospheric radiations by combining theoretical calculations with ingenious airglow measurements. It is now possible to measure airglow even in the presence of sunlight. New information has been acquired concerning the distribution of the atmospheric constituents and the important chemical reactions taking place under varying geophysical conditions. Thus far, measurements indicate that solar radiation produces electrons in greater amounts in the region of 50 to 120 km. than at other altitudes. The airglow observations have also proved useful in detecting the chemical composition of meteoric dust as it strikes the atmosphere.

After years of observing the aurora visually and then photographically, a method of television observation of the very faint aurora has been perfected at the Geophysical Institute of the University of Alaska using an image orthicon tube of high efficiency. The instrument output is displayed on a television screen and photographed with a movie camera. Both a direct image view and a spectrally resolved image of a region of the aurora are available for comparison.

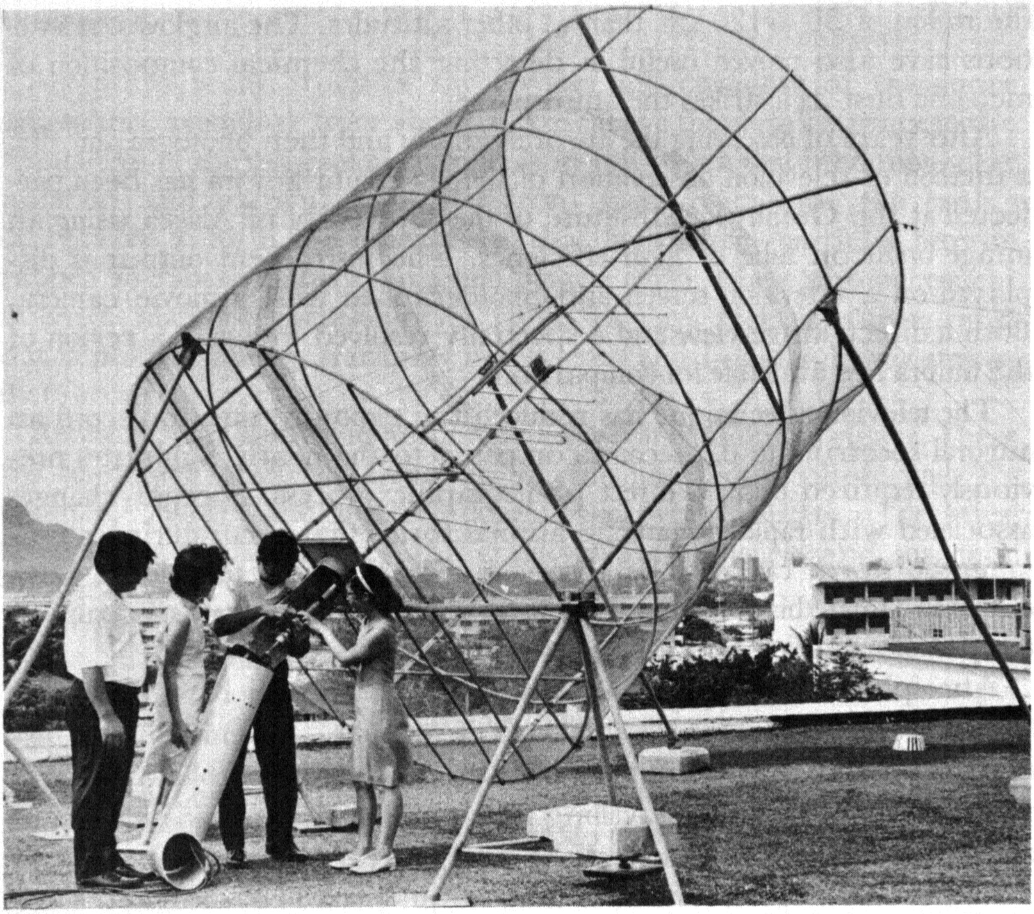
The television technique has reduced the exposure time to record an auroral spectrum to 0.5 second compared to the nearly 3 minutes previously required using a direct photographic process. Spectral changes associated with rapidly changing auroral forms that occur during a geomagnetic storm can now be observed with this new technique. Data obtained from this system will be used to study the energy spectrum of the particles causing auroras.

Atmospheric scientists at the University of Hawaii have utilized a technique of radio-wave observations of satellite transmissions to disclose large-scale characteristics of the ionosphere. They exploit the Faraday effect on radio-waves travelling through a magneto-ionic medium to determine the electron content of the ionosphere. From the observed data the integrated electron content of the ionosphere can be calculated along precisely defined electromagnetic ray paths between the satellite and receiver.

Results from this experiment have indicated the presence of rapid variations in electron content over single fixed ray paths, and suggest the presence of drifting clouds of electrons in the upper atmosphere. These large scale motions are being studied to test their dependence on solar disturbances and particle bombardments of the atmosphere. Other results obtained by the University of Hawaii investigators include an anomaly which showed that the electron content was higher in spring and autumn than in summer or winter and the observation that electrons appear to drift upward during the nighttime.

Solar-Terrestrial Research

Solar-terrestrial research includes the study of the relationship of our nearest star, the sun, to the planet earth. The large storms that rage across the solar surface are not only of intrinsic interest but are representative of the stars, whose surfaces man cannot yet resolve. These storms enhance the ionization of the earth's upper atmosphere and hence affect worldwide communications by X-ray and ultraviolet bursts and control the aurorae emitted by particles. An understanding of the physical processes within a plasma such as surrounds and blows toward the earth is



University of Hawaii Photo.

Figure 14.—*Student assistants make adjustments on antenna rotator unit at the University of Hawaii. This device is part of the system used to measure the electron content of the ionosphere, a subject of particular scientific interest in the latitude of the Hawaiian Islands.*

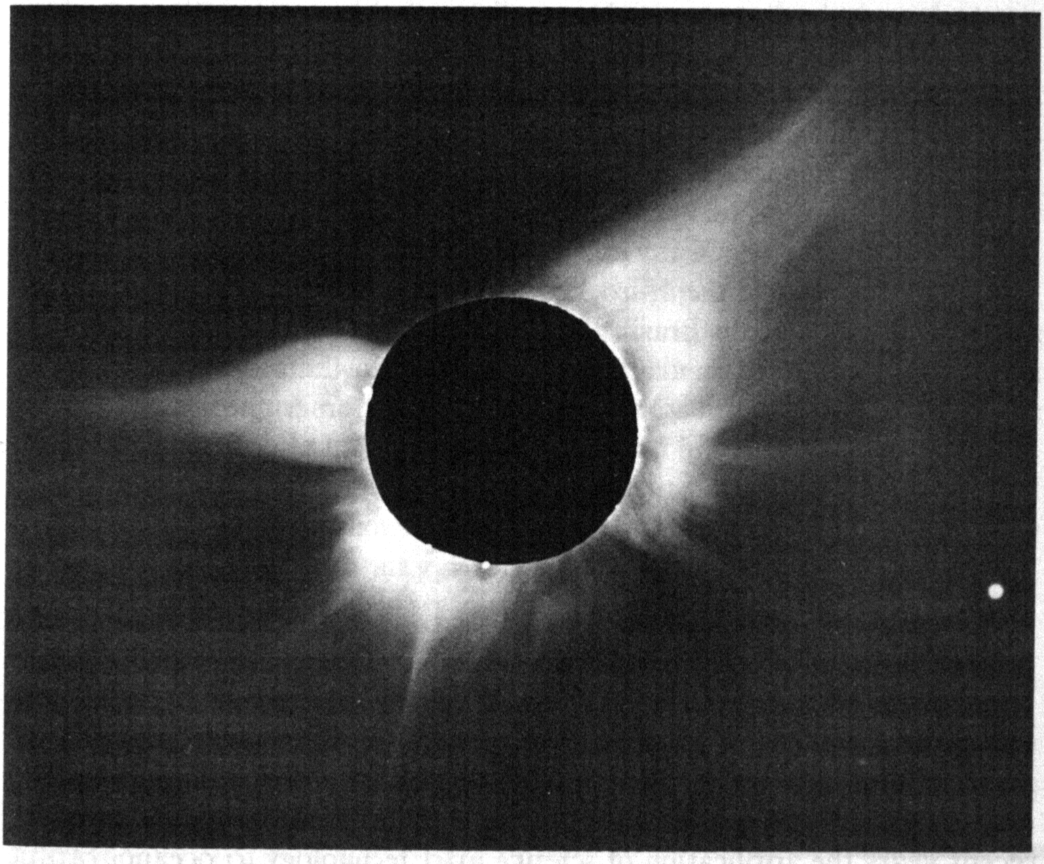
fundamental to the search for the control mechanisms that produce large scale lower atmospheric patterns.

During the past year an experiment designed to test whether hydromagnetic waves can supply enough energy to heat the upper atmosphere has been completed. At least during the minimum solar activity the results indicate that while the waves may trigger changes some other source of upper atmosphere heating must be found. These results have brought forth renewed interest and successful detection of gravity waves in the upper atmosphere.

Many solar-terrestrial processes become easily visible or are stimulated when a total solar eclipse occurs on the earth. The corona or solar wind emanating from the sun and large prominence storms at the solar limb become visible to even the casual investigator stationed inside the eclipse path and can be studied with increased resolution. To the ionospheric scientist changes in the earth's upper atmosphere can be followed and compared with predictions during this natural event.

A total eclipse of the sun occurred on November 12, 1966, across South America from Peru to Argentina, Bolivia, and Brazil, an event of interest not only for astronomers but for many atmospheric scientists as well. Observations coordinated by the National Science Foundation involved approximately 800 individuals from the United States. This was the most intensively observed eclipse in the 4,000 years of recorded history. Some 87 U.S. research projects were conducted from ground stations, aircraft, and rockets.

Among the outstanding results obtained during the eclipse was a "white light" photograph of the solar corona made from a ground-based installation. This photograph records light scattered from the very hot electrons and from the much cooler interplanetary dust. It was taken through a special filter so that the coronal light of the sun could be recorded on a single film even though the variation in brightness over a few solar radii outward from the sun is as large as a factor of 10,000.



NCAR Photo

Figure 15.—*Total eclipse of the sun, photographed from a site near Pulacayo, Bolivia, on November 12, 1966. This is the first eclipse photograph to show on one exposure the radial streams and structures of the corona out to great distances. The difference in brightness between the inner and outer regions of the corona required development of a special filter, without asymetries or imperfections, which decreased in intensity toward the outer edges. White object to the right of the sun is the planet Venus.*

The detailed structure of the coronal forms results almost entirely from the differences in the concentration of electrons. The regularity of the streamers is caused by electrons that are constrained by the magnetic field of the sun. At the base of the streamer can be seen arches and gaps that appear to be regions where electrons are trapped in the local magnetic field of the active solar region. The active regions are likely to flare, producing strong X–ray radiation and streams of high-energy protons and electrons that may interact with and be trapped in the earth's atmosphere.

During the eclipse, five aircraft from the United States Atomic Energy Commission, the Air Force Cambridge Research Laboratory, and the National Aeronautics and Space Administration were flown along the path of totality for a series of spectroscopic experiments spanning the ultraviolet and infrared portions of the spectrum. The spectroscopic observation requires careful filtering of the light in order to determine the distribution of ions. The ions emit at a wavelength characteristic of their species, their temperature, and the method of excitation. A detailed spectral study leads to an understanding of the processes that produce the million-degree temperatures in the solar corona. Other observations made during the eclipse have yielded information about the abundance of different elements in the corona. Together with the "white light" photographs, the spectral observations permit a study of the active regions of the sun that often lie beneath the white light streamers.

Observations of the X-ray emission from the solar corona were carried out aboard several of the 15 rockets launched from a specially prepared site near Rio Grande, Brazil. The rockets also carried instruments to study the response of the earth's atmosphere to the sudden decrease of sunlight. The successful measurements of electron temperature and the abundance of ions in the upper atmosphere are useful in describing the transfer of energy within the ionosphere.

Oceanography

Few sciences offer as much promise toward the solution of future human needs as the science of the seas, oceanography. By far the larger portion of all living organisms dwell within the oceans. The ocean waters and the ocean floor contain virtually inexhaustible mineral resources. The eventual prediction and control of world climate depends to a large extent on the prediction and control of ocean currents. In recent years the application of science and technology to oceanographic problems has opened the door to new understandings and new applications. Efforts by the National Science Foundation to lay the basic framework for inquiry and knowledge while educating and training the oceanographers of the future are represented by the following examples of the many research studies supported by the National Science Foundation.

Water Masses of the Pacific Ocean

Oceanographers have long recognized that the oceans consist of a number of large water masses which usually have internally consistent temperatures and salinities. These water masses, moving with the oceanic circulation, have a strong influence on the weather and often serve as barriers to fish migration. The difficult problem of identifying oceanic water masses and of determining their influence on world climates was advanced in the past year on many broad fronts. The work in the Pacific is illustrative and covers the area from the Arctic to the Antarctic and from the Americas to Japan.

It has generally been believed that both surface and subsurface water masses derive their characteristics from direct contact with the atmosphere, and that subsurface water masses would form when a high-density water mass encountered one of lower density and sank beneath it. Recent work of J. L. Reid of Scripps Institution of Oceanography has helped to trace the origin and movement of these water masses.

The low-salinity, intermediate water masses encountered in the mid-latitudes in the Pacific Ocean, known as the Subarctic Water Mass, supposedly originated at the sea surface in the northern Pacific Ocean during the winter seasons. Dr. Reid was not convinced of this and with the Scripps Institution of Oceanography research vessel, *Argo,* cruised from Kodiak, Alaska, to Hakodate, Japan, between January and April 1966 in the expedition known as "Boreas." Despite the winter conditions encountered, nearly 200 oceanographic stations were occupied, and the data collected definitely demonstrated that the Subarctic Water Mass originates, not at the surface, but by vertical mixing well below the surface. Thus a new insight into the process of water mass formation was gained.

Recent studies have shown that changes in water mass characteristics in one part of the ocean may have a pronounced influence on oceanic and atmospheric conditions in distant areas of the earth.

J. Bjerknes of the University of California at Los Angeles, recently completed an extended investigation under a grant from the Foundation of one of the greatest and most extensive oceanic anomalies, the El Niño conditions in the eastern Pacific Ocean equatorial regions. He showed that periodic anomalies in the equatorial easterly winds have a major influence on the atmospheric circulation in the Gulf of Alaska and in the North Atlantic and may be the cause of severe winters experienced in Europe.

El Niño conditions start with decreases of the prevailing equatorial easterlies in December. Easterly winds along the equatorial regions, due to earth rotation effects, move the waters north in the Northern Hemisphere and south in the Southern Hemisphere. This results in spreading of the surface waters and subsequent upwelling of subsurface cold waters. During El Niño conditions, this effect is subdued, and surface temperatures are 2° to 3° C. above normal over vast areas from the Americas to the mid-Pacific.

Dr. Bjerknes showed how the Northern Hemisphere weather reacted to this increased sea temperature: stronger westerlies over the Northeast Pacific, deeper low pressures in the Gulf of Alaska, consequent weaker westerlies north of Iceland, and weaker lows in the Icelandic areas. A determination of the requirements for long-term climatic changes will necessitate monitoring oceanic as well as atmospheric conditions for an extended period of time.

Hot Brines and Heavy Metals

The floor of the Red Sea is an area which is believed to be spreading apart at the rate of about 1 cm. per year. In the center of the Red Sea is a median rift, which like many of the rifts associated with the ocean ridges, shows an abnormally high geothermal heat flow. Within isolated deeps in the rift, 2,000 meters or more below sea level, hot brines were first examined during the International Indian Ocean Expedition by American, British, and German oceanographers.

Additional information on these hot brines was obtained from a special investigation on board the Woods Hole Oceanographic Institution research vessel *Chain* during a 6-week cruise in October and November 1966. The two principal deeps, located in a narrow 100-mile-long strip in the median rift valley were known as the Discovery Deep and Atlantis II Deep after the ships that were used in the investigation. A smaller deep discovered on this cruise is now called the Chain Deep. The largest is the Atlantis Deep, covering an area of about 30 square miles. Here, hot brines are found 200 meters above the ocean floor, with the temperatures changing abruptly from about 22° C. (72° F.) to 56° C. (133° F.), and salinities increasing almost tenfold. This brine, being much heavier than normal sea water, settles to the bottom of the deep. Heavy metals found in this water, include copper, gold, iron, lead, manganese, silver, and zinc. Some concentrations are many thousand times the amount normally observed in ocean waters and may have economic value.

Sediment cores obtained from the deeps showed brilliant colors due to the various oxides of iron, zinc, copper, and other metals. Seismic profiling records taken from the *Chain,* indicate the sediments are more than 100 meters thick.

The possible explanation of the hot brines and associated core material is that rifting has allowed magmatic solutions to ascend from the mantle where they react with the Red Sea waters. Similar situations may be found in other rifts in the oceanic ridges, indicating that the center of the sea floor is spreading.

Temperature Sensitivity of Marine Plankton

Most physical oceanographers are concerned with the character of the water masses of today's oceans. At the Lamont Geological Observatory of Columbia University, biological oceanographers Allan Bé and Andrew McIntyre are more concerned with the planktonic flora and fauna of the oceans and with their relationship to distinct water masses.

Drs. Bé and McIntyre are studying present day and fossil planktonic coccolithophores and foraminifers, small plants and animals which float in the surface waters of the ocean and produce hard parts of calcium carbonate. They find that a number of these present day organisms are sensitive to temperature and can be used as reliable indicators of warm or cold waters of specific temperatures. Sediment cores containing similar organisms taken from the floor of the North Atlantic provide a sedimentary record of the Atlantic Ocean over the past several million years, a period during which glaciers advanced and retreated over the North American continent. The climate accompanying glaciation cooled the oceans; during the periods between glaciation, the oceans warmed. Drs. Bé and McIntyre have found that glacial cooling of the surface waters is reflected in the distribution of the temperature-restricted planktonic organisms. The cold water forms in sediments of glacial age are found farther south than their presently living counterparts. They have established that the approximate position of the northern boundary of the Gulf Stream during the last period of glaciation was at about 30° north latitude, some 15° farther south than its present position. Thus biological data are permitting a better insight into the nature of the ocean circulation both today and in the past.

Biological Adaptation to Polar Environment

In a project undertaken in connection with the U.S. Antarctic Research Program, Edvard A. Hemmingsen of Scripps Institution of Oceanography and an assistant carried out physiological experiments at McMurdo Station on the cornea of polar animals. Ultraviolet light, which can cause severe snow blinding in man by damaging the unprotected cornea, has no effect on polar animals, such as penguins and seals, although they spend long periods of time on bright snow fields. Dr. Hemmingsen used an artificial ultraviolet source to determine the radiation doses necessary to produce corneal tissue damage in Antarctic animals. Surprisingly, although there were differences between the types of animals tested, the threshold level for damage was approximately the same or even lower than for animals which live in regions where much less radiation is received. Since the tolerance level is probably a balance between damage of corneal tissue and the rate of repair, the polar animals must have a relatively rapid repair mechanism.

During the visit at McMurdo, Dr. Hemmingsen also was able to inspect a specimen of fish of the family Chaenichthyidae, which was unexpectedly caught in a trap near the station. Unlike any other vertebrates, fish of this family are anemic—they lack hemoglobin and have a completely colorless blood.

This group of fishes, one of many in the order of perch-like fishes, is found only in the Antarctic or the waters adjacent to it which provide low, stable water temperatures. It is sometimes called an ice fish because of its transparency, which is due to the fact that it is almost lacking in scales.

This family of fishes is of interest because, as vertebrates, they ought to have some means of storing oxygen in their blood, and yet they lack any blood pigment to store it. On what kind of mechanism do they rely to pay the oxygen debt built up in muscles and other tissues by their metabolism? In an attempt to add to our knowledge on this subject, preliminary physiological studies were made of the consumption of oxygen by this fish under varying conditions of oxygen concentration of aquarium water.

The oxygen consumption was determined in an aquarium over a period of about three weeks and was found to be about one-third of that of most cold-adapted fish with hemoglobin. Most striking, however, was the fact that the oxygen consumption was not markedly affected by the oxygen concentration of the water. Oxygen consumption remained constant even when the oxygen pressure was reduced from 150 to 33 mm. of mercury, indicating a very efficient system for oxygen uptake. Most likely, the lack of hemoglobin is partly compensated for by increased blood volume and cardiac output. Further physiological studies of these fishes are being planned.

Organic Aggregates

One of the most significant recent developments in biological oceanography is the discovery that dissolved organic materials are transformed into particles in the open sea. The particles, which have been called organic aggregates by their discoverers, are from 25 to 100 microns in size. When aggregated further, they are the ropy or flaky "marine snow" that has puzzled observers in deep sea submersibles since Beebe's first dives in the bathysphere. They are present at all depths in all parts of the world oceans that have been sampled. Similar aggregates can be produced in the laboratory by bubbling air through natural sea water. They also appear in laboratory cultures of some marine micro-organisms and in sea water that has been stored in the laboratory.

When first seen in stored samples in the 19th century, they were thought by some to be the primordial ooze from which all life arose. This idea is being revived in modern form, as organic aggregates are suspected to play a key role in food transformation in the sea.

There are vast resources of dissolved organic matter in the ocean, but until organic aggregates were discovered it was difficult to see how such materials were used for food by marine animals. The dissolved organic materials are so diluted by sea water that even bacteria cannot utilize them very effectively. The aggregates are sites on which additional organic matter can adhere and on which bacteria can grow. Probably both the aggregates themselves and the bacteria growing on them are important food sources for small marine animals. This means that the food chain of the ocean is more complex than it has been thought to be, and some of the steps in it may not be biological processes.

The ultimate source of the dissolved organic matter in sea water is still debated and is another subject of active research. It is known that both plant and animal plankton lose significant quantities of soluble materials. The plants lose small carbohydrate molecules that seem to be early products of photosynthesis. The animals lose nitrogenous compounds and other organic materials that come in one way or another from their food. The methods of modern analytical chemistry make it possible to identify and quantify most of the organic materials present in the sea, even at very high dilution, and this is being done. Soon it will be possible to develop a realistic model of the pathways of energy and materials through biological systems of the sea. When this has been done, it will be possible not only to understand living processes in the sea but also to use them more effectively.

Specialized Oceanographic Research Facilities

In its programs for providing assistance for acquisition or development of specialized facilities for research in the environmental sciences, the Foundation has placed considerable emphasis on the construction of new laboratories for marine field biological stations. In the last three years, over $3 million has been spent in support of the construction of two specialized ships and five land-based marine facilities in the biological sciences.

In November 1966, the specialized research vessel *Alpha Helix,* built with Foundation assistance and operated by the Scripps Institution of Oceanography, completed its first scientific expedition—to the biologically rich area of the Great Barrier Reef off the northeastern coast of Australia. A series of diverse scientific investigations were carried out by a total of 44 scientists, representing 11 U.S. and eight foreign institutions.

Early in 1967, the ship set out on a research expedition to the Amazon River where research was done on the physiology of local fauna; the transition between marine, freshwater and air habitats; insects; and plant physiology.

Considerable interest has developed in the possible development of a large facility devoted to tropical marine sciences. Although the main

Photo: Scripps Institution

Figure 16.—*Following completion of its first scientific expedition to the Great Barrier Reef off the coast of Australia,* **Alpha Helix** *departed on a voyage that would take its complement of research scientists to the upper reaches of the Amazon River.*

thrust would be toward marine biology, physical sciences and terrestrial biology would not be excluded. In 1967, an award was made to Associated Universities, Inc., to study the need for such a facility. If a national facility emerges from these considerations, this would provide opportunities for American scientists to cooperate in comparative studies of terrestrial and marine tropical organisms, under controlled laboratory conditions and with modern instrumentation.

In the physical marine sciences, the main facilities funds during the past year were allocated for the construction of oceanographic research facilities in Technological Building II at the University Heights campus at New York University, and an addition to the Oregon State University oceanographic research laboratory.

Under the Arctic Ocean Research Program, three contracts were let for conceptual designs of a research facility to be frozen in the

Arctic icepack and to drift across the Arctic Ocean with the ice. Because of the expense of supplying fuel to the remote Arctic Ocean, two of the designs included nuclear power. The facility would be used for heat budget and microclimate studies, and as a facility for the operations of helicopters in support of substations, and submersibles for under-ice studies. Extensive physical and biological oceanography could be accomplished from this facility. These designs are now being evaluated.

Earth Sciences

As used in this report the term "earth sciences" is limited to the solid earth or geological sciences. These sciences help provide man with an understanding of the solid part of his own planet as well as the processes that act upon the earth. Research in earth sciences supported by the Foundation not only includes geological investigations but physical and chemical studies of the earth and earth materials.

Continental Drift and Sea Floor Spreading

Over a century ago Alfred Wegener noted the striking similarity in the shapes of the Atlantic coastlines of South America and Africa and suggested that present-day continents once formed a single landmass. He postulated that this landmass broke up several millennia ago and that continental blocks drifted apart, thus giving rise to what is known today as the Theory of Continental Drift. Prior to the 1940's the evidence for and against the theory centered about the shapes of coastlines, paleontological patterns, and general rock similarities. During the past two decades other important lines of evidence, including paleomagnetism, heat flow data, oceanographic data, and radiometric dating, have been brought to bear on the problem of continental drift.

Recent discoveries, both on the continents and on the floor of the oceans, have provided striking new evidence to support the drift hypothesis. The oceanic evidence involves the new concept of sea floor spreading; the continental work consists of a field test in South America and Africa.

In the early 1960's oceanographers from the Scripps Institution of Oceanography first showed that the floor of the North Pacific Ocean possessed series of long linear magnetic anomalies. A local deviation from the average intensity of the earth's magnetic field is called a magnetic anomaly. Subsequently, similar patterns were found in other areas of the world oceans, with some degree of similarity on the two sides of the main oceanic ridges. Vine and Matthews of the University of Cambridge, England, in 1963 suggested that the linear magnetic anomalies might represent past reversals of the earth's magnetic field. They reasoned that, if new volcanic material was being brought up in the center of the ridge, it would retain the polarity of the earth's magnetic field at the time of its solidification. If, then, the material spread laterally on either side of the ridge, long linear anomalies would be produced, coincident with reversals of the earth's field.

Cox, Doell, and Dalrymple of the U.S. Geological Survey then applied potassium-argon dating to young volcanic rocks, and established reliable dates for several reversals of the magnetic field over the past 4 million years. At this point the stage was set and evidence began to roll in.

One of the first good indications came from the South Pacific Ocean. Pitman and Heirtzler of the Lamont Geological Observatory used data obtained from a project sponsored by the Foundation under the aegis of the U.S. Antarctic Research Program, and showed that the Pacific floor was spreading away from the top of the oceanic ridge at a rate of about 4.5 cm. per year. They were also able to extrapolate the anomalies backward 10 million years and suggested earlier reversals. Heirtzler then presented evidence of a similar nature showing that spreading near Iceland took place at a slower rate, about 1 cm. per year. Further work has now extended the evidence of spreading to all the oceans, and though the rates differ considerably, it appears that this sea floor spreading has actually taken place, providing a possible mechanism for continental drift.

Recent Foundation-supported geological investigations in South America and Africa have provided further evidence that these two continents may indeed once have been part of the same landmass. A few years ago field mapping of the states of Bahia and Alagoas in Brazil showed the existence of a long, trough-like structure called a "geosyncline," striking roughly east-west and extending from an inland point for about 400 km. to the Atlantic coast. The geologic structure of the geosyncline and associated rocks is unusual in that it trends essentially at right angles to the general trend of geologic structures along the Atlantic coast of Brazil. Using a map of the "best fit of the continents" published by Bullard in 1965, this geosyncline should project into central Gabon, West Africa.

With Foundation support, Gilles O. Allard and Vernon J. Hurst of the University of Georgia searched in West Central Africa for the possible extension of the geosyncline found in Brazil and associated rocks. In central Gabon, in the predicted geographic position, they found rocks of types similar to the Brazilian group and having a comparable structural trend. A fresh cross section of rocks, well-exposed along the path of a new road, showed metamorphism (pronounced changes in the constitution of the rocks) increasing to the northeastward, the same as it does in Brazil.

In addition to the lithologic similarity of rocks from Africa and Brazil, preliminary radiometric dating of about two dozen samples by the rubidium-strontium method has shown that the younger rocks of both areas have an age of about 6.5 million years and that the older rocks have a similar age of about 2.3 billion years.

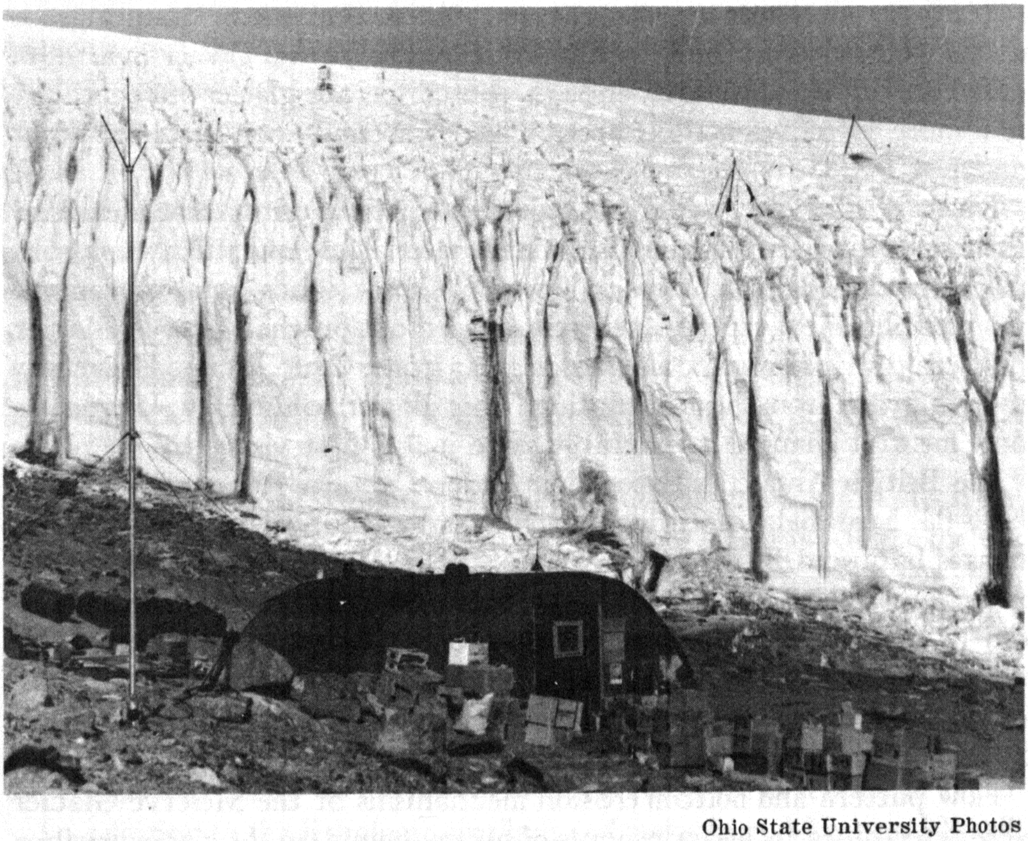
The occurrence of a geosyncline in Brazil extending to and transecting the coast roughly at right angles is in itself an unusual feature. Finding similar rocks in the same sequence and having the projected structural trend across the Atlantic Ocean in Gabon is an amazing coincidence, unless the rocks were indeed once continuous. The geographic coincidence of the two assemblages of rocks, their striking lithologic similarities, sameness of deformation style, tectonic and metamorphic characteristics, and corresponding radiometric ages constitute what is believed to be one of the strongest pieces of evidence so far presented in support of the idea that South America and Africa were once contiguous.

How Does a Glacier Work?

Over 125 years have passed since Louis Agassiz announced his then revolutionary theory that glaciers of the past had been much more extensive than today and that much of the sand, gravel, and "boulder clay," known as morainic deposits, that litter northern Europe and elsewhere were the deposits of former ice sheets. Today the glacial origin of these morainic deposits is universally accepted, but we are still not sure just how a glacier erodes and deposits the material. It has become increasingly clear that a polar glacier (that is, one whose main mass is always well below freezing) behaves differently from a glacier in a more temperate climate. Strangely enough, the temperate glacier may actually be a more effective agent of erosion and transportation than the polar glacier.

Recent studies of a typical polar glacier tend to confirm these ideas and furthermore suggest that most morainal material in Antarctica was probably formed under conditions of warmer climate when basal movement was possible. Field experiments were carried out on the Meserve Glacier by Gerald Holdsworth and associates from Ohio State University under a grant from the Foundation. This glacier, only a few kilometers long, has not changed appreciably since it was first visited by members of the British Antarctic Expedition under Captain Robert F. Scott in 1901–04. Mass balance studies show that snow accumulation in the upper areas is balanced by the loss of about 38 cm. per year from the surface of the lower third. Of this loss, only 2 cm. occur as melt water; 24 cm. and 12 cm. are lost as a result of summer and winter sublimation (the effects of seasonal vaporization and refreezing). In contrast, most of the loss in temperate glaciers is by melting although summer sublimation plays a significant role also.

Flow pattern and bottom erosion mechanisms of the Meserve Glacier were determined by measurements of survey points on the glacier surface and in a 55-m. tunnel cut laterally into the glacier along its base at a point where the total glacier thickness was about 40 m. The base of the ice, at —18° C., is frozen to weathered bedrock and till, and the lowest meter of ice contains a considerable amount of unsorted material. The



Ohio State University Photos

Figures 17 and 18.—*Aerial view of the Meserve Glacier shows a river of ice more than 150 feet thick in some areas. At the campsite the entrance to a tunnel cut in the base of the ice cliff can be seen. The tunnel and vertical holes drilled from the top surface give scientists access to samples of materials in the heart of the glacier.*

velocity is 1 cm. per day at the surface and zero at the base. At a short distance from the base, however, within the dirty ice, movements of over 5 cm. per day were measured. Continued measurements should show whether ice at this temperature can actually erode the bedrock or whether a warmer climate would be required.

Antiquity of Life on Earth

It seems fairly well-established that the earth is 4.5 to 5 billion years old. Despite this great age, highly diversified fossil assemblages begin rather abruptly at the beginning of the Cambrian period, or only about 0.5 billion years ago. Presumably the sudden appearance of such a large and diversified fauna marks the time when animal life first was able to develop hard shells and skeletal parts that are more easily preserved as fossils. This clearly implies that there was a long pre-Cambrian history of life during which the first primitive forms evolved from tiny organisms to specialized multicelled animals. But how far back into the preceding 4 billion years does this history extend? Until recently all that had been discovered were the fossils of algae some three-quarters of a billion years old and possible worm tracks only about 600 million years old.

In the past few years, however, the electron microscope has been brought to bear on the problem of ancient life, and recently Elso Barghoorn, of Harvard University, has identified ancient bacteria from three sedimentary formations about 2 billion years old and one about 3 billion years old. The 2-billion-year-old fossils occur in the Gunflint chert of southern Ontario and the Bitter Springs limestone of central Australia. The 3-billion-year-old organisms are from the Fig Tree series of South Africa and comprise the oldest known record of biological activity on the earth. The remarkably well-preserved fossils are rod-shaped organisms, about 0.56 microns (one micron is one thousandth of a millimeter) long and 0.24 microns wide. Named *Eobacterium isolatum,* they are comparable in size, shape, and complexity of structure to many species of modern bacteria. It seems probable that they are true bacteria and that life had already reached at least this stage of evolution by the time one-third of the earth's history was completed.

ENGINEERING

The Foundation supports a wide range of basic research in engineering to develop methods of application of scientific knowledge to technological problems. Engineering projects are undertaken which deal with diverse subjects such as chemical and reaction kinetics and catalysis, energy transfer (e.g. lasers and plasmas), dynamic behavior of structures (e.g. design of earthquake resistant structures), metallurgy, solid state materials, and operations research techniques as applied to the solution of social problems.

Recently, projects have trended increasingly towards more immediate engineering relevance, but a strong academic interest persists in the basic engineering sciences as well. Lately, there has been a new tendency for engineering proposals to be concerned with social problems, and grants have been awarded in the area of applying systems analysis techniques in the solution of current problems of society. Hopefully, these and related investigations will produce innovative approaches of value.

To illustrate the scope of engineering research which the Foundation supports, the following examples are selected to illustrate some important and interesting findings:

Catalytic Reactions

Man's ability to develop and use catalysts has contributed to the important technological revolutions that have taken place in this century. An area of particular note deals with mass transportation. Modern high octane gasolines produced by catalytic cracking have resulted in the high engine efficiencies everyone has come to expect. It is estimated that 90 percent of all industrial chemicals involve catalytic reactions in their manufacture. The wholesale value of products made by heterogeneous catalysis now exceeds $20 billion annually.

In heterogeneous catalysis a liquid or a gas (or both) containing the reactants is brought into contact with either a solid or a liquid which acts as a catalyst. The catalyst accelerates and directs the course of the reaction without being consumed itself. The reaction takes place upon the surface of the catalyst and involves a complex sequence of physical events. This must be followed, of course, by the reaction products leaving the surface and making the surface available for further reactions. For example, in the case of high octane gasoline, high boiling components of crude oil are vaporized and passed over a solid catalyst. Part of the products which form the reaction (when a suitable catalyst is used) are components of high octane gasoline. Gasoline may be produced by thermal methods, not involving catalysis, but the resulting product cannot be used in efficient high compression engines.

Forty years have elapsed since Sir Hugh Taylor first proposed that active centers at surfaces were responsible for the characteristic behavior patterns of solid catalysts. The identification of these centers has been a foremost problem of catalysis research. A wide array of catalytic surface defects have been proposed as active centers. The importance of each one in a particular reaction is very difficult to assess, yet the industrialist knows that his catalysts are dependable and that their activity and selectivity will not differ greatly from batch to batch.

The present research at Stanford University under M. Boudart and his students on the specific activity of platinum catalysts was directed originally at a related question. Does the catalytic activity of a solid particle depend on its particle size and surface area?

The investigator's results on platinum were made possible by the development of a reliable technique for the determination of metal surface areas. It was found that the catalytic activity per unit surface area (specific activity) for hydrogenation of cyclopropane at 0° C. on platinum catalysts was almost the same for highly dispersed samples in which nearly every platinum atom is a surface atom as for a platinum foil. The difference between the highly dispersed samples and the others is a modest twofold change in specific activity, while the platinum specific surface area is varied by more than four orders of magnitude.

The investigators also have found a remarkable lack of sensitivity of the specific activity to crystal size or details of preparation. It is emphasized that this relative constancy of specific activity is not expected invariably but only for those reactions where the majority of catalytic sites possess ample activity under the conditions of operation. It is believed possible that many industrial catalytic reactions are of this type and the identity of active centers on a given metal seems to matter little for these reactions. What matters is that there exists a broad spectrum of them, that they all participate in the reaction and that their statistical distribution of reactivities is insensitive to the mode of preparation of the catalyst.

Dr. Boudart's research clearly bridges the gap between very small particles and bulk metal and establishes the lack of effect of the dispersing medium on the catalytic activity of platinum. Acceptance of this conclusion will result in research efforts being directed toward fashioning catalytic surfaces which may be highly selective for a particular reaction and the ability to design catalysts scientifically will be greatly enhanced.

Laser Communications Receiver

A laser beam (a coherent light beam) can be used to transmit large quantities of information in a narrow beam. Laser communications use principles similar to radio and television transmission and reception but at frequencies a million times higher and with much lower loss of power.

W. H. Hartwig of the University of Texas has been studying the basic relations of low temperature absorption of high frequency light waves by materials. In the course of this study his group has demonstrated a new method of receiving television signals transmitted by means of a laser light beam. This new method depends upon the slight change in the dielectric constant of a germanium crystal when illuminated with laser light. This response to light is termed the "Photodielectric Effect." The incident light frees electrons from germanium atoms in the crystal and thus changes the dielectric properties of the crystal.

The crystal is kept at 4° above absolute zero and is incorporated into an ultrahigh frequency resonant circuit. The photodielectric effect of the crystal is used to tune the circuit. The result is that the detection of an optical signal by the crystal will shift the resonant frequency of the circuit providing a mechanism for information retrieval. The device will respond to light signals of only a few millionths of a watt and changes in signal intensity of a billionth of a second. Hence, the method is both sensitive and rapid and is capable of receiving information at an extremely high rate from very weak signals.

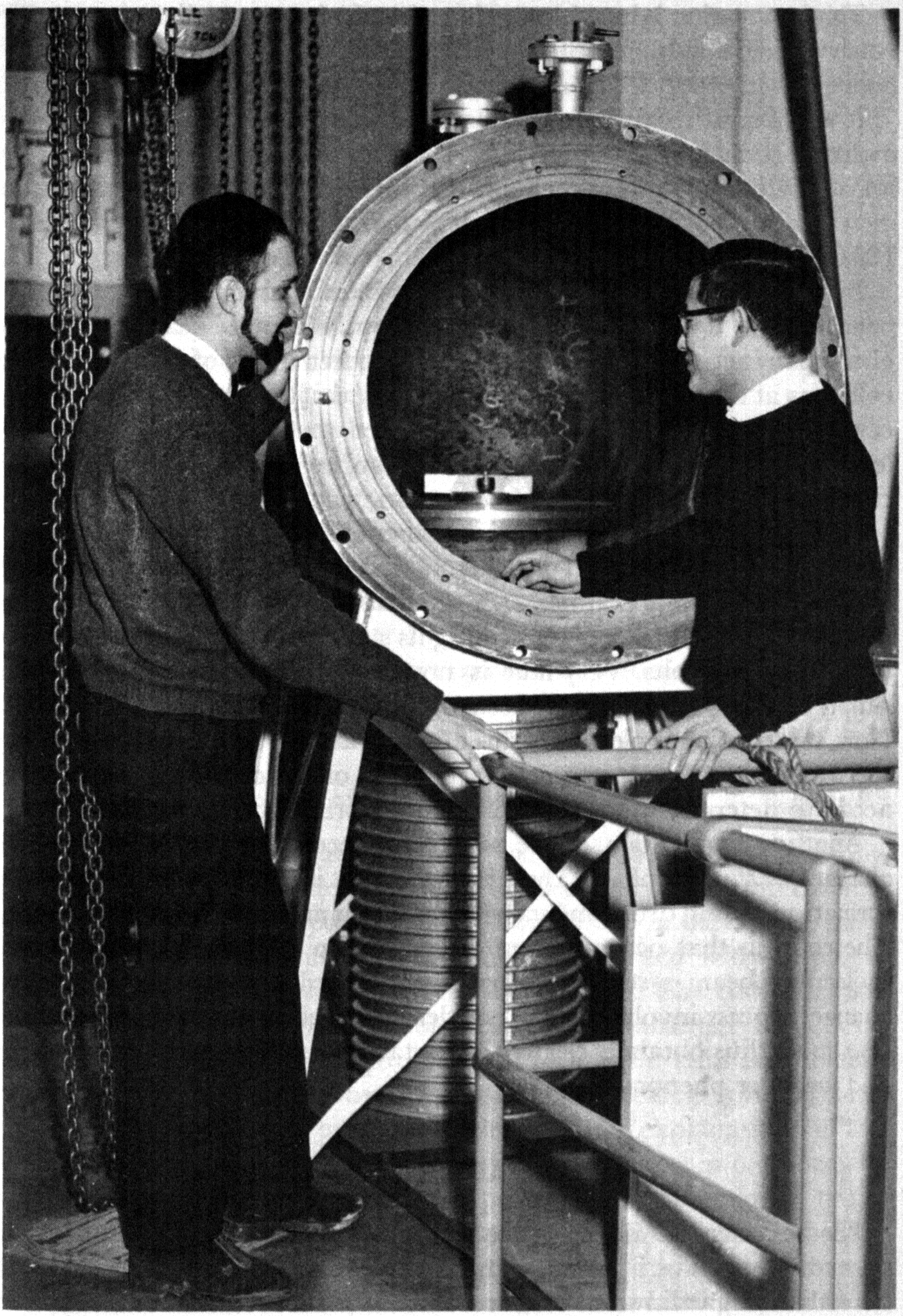
The researchers constructed a laser television transmitter which sends out a beam of invisible infrared light. The beam is made to vary in intensity in exactly the same way a television station varies its VHF or UHF signals. The beam is caught by a telescope or optical antenna and focused down into a liquid helium bath containing the circuit with its photodielectric crystal. The frequency of the circuit is shifted in accordance with changes in intensity of the laser beam. From this point the signal is amplified electronically and displayed by a television set. The television set needs no VHF or UHF circuits to reproduce the picture and sound.

The future utilization of these methods depends, in a key fashion, upon materials research. Immediate needs are to better understand the material behavior and to develop more sensitive photodielectric materials. Specifically, the development of a photodielectric material that matched the wavelength of the laser light would result in a detector that would respond to changes in wavelength rather than changes in the intensity of the beam. Such a unit would permit a single laser beam to carry more information than all the world's radio and television transmitters can now send. As yet, no way exists to simultaneously receive or transmit so much information.

The Moletron

Investigators at Princeton University under the direction of John B. Fenn have added a significant new weapon to man's store of scientific "artillery." The device uses a supersonic jet of mixed gases in a high-vacuum container to generate molecular beams with kinetic energies as high as 10 or more electron volts. Favorable results have been obtained with 16 different molecular species.

The device is important because, for the first time, controlled and detailed laboratory investigation of molecular changes at precisely the energy range in which many chemical reactions and important physical particle-surface interactions occur. This range was not previously "reachable" with molecular beams because of limitations of earlier, small, low-energy molecular accelerators and other difficulties encountered with high energy machines. Small compared to the atom- and nucleus-smashing power of cyclotrons, betatrons, and synchrotrons, which produce particle energies up to billions of electron volts, the Moletron nonetheless fills a major gap in the devices man has available to probe the unknown.



Princeton University Photo

Figure 19.—*This partial view of the "Moletron" shows location of the nozzle chamber from which a supersonic jet of mixed gases passes into a high-vacuum container to generate electrical beams with kinetic energies as high as 10 or more electron volts. Conduit through the floor is one of three leading to vacuum pumps. The device is designed to advance studies in weather phenomena and aerospace technology.*

This innovation is based on the fact that hydrogen, the lightest gas, can reach velocities as high as 30,000 feet per second—about 20,000 miles per hour—when expanded from a nozzle jet at a temperature of 5,000° F.

It was found that with a jet of mixed gases, hydrogen and a heavier molecule such as carbon dioxide, the energy of the hydrogen transfers by impact with the large molecule and the kinetic energy of larger molecules increases to 10 or more electron volts, corresponding to a temperature of 100,000° C.

In a chemical reaction, especially those in combustion systems, the components have to collide at a certain energy before they react. For many chemical reactions there has never before been a way of bringing about collisions at the proper energy in such a way that the details of the reaction can be observed. Chemists have had to infer what took place on a detailed level by working backwards from the result of mixing larger masses of chemicals together. With the Moletron one can bring about reactions in a controlled way and can study individual events in detail.

The Moletron may well prove useful in studies related to space as well as to chemistry. For example, at high altitudes a satellite is slowed down by individual molecules of gas striking its surface with energies of the order of 10 electron volts. Very little is now known about this phenomenon simply because scientists have been unable to simulate it in the laboratory. Now, by shooting molecules of this energy range at a surface and studying the results, more accurate determinations of the drag factor and more accurate determinations about orbits and orbit decay can be made.

Another application of the molecule accelerator will be to explore changes of state or phase. There is much that is not understood about the formation of rain drops and snowflakes when moisture-laden air is cooled. The cooling that occurs during expansion in the supersonic jet of the molecular beam system will permit controlled study of the energy exchange process involved in the condensation of water vapor. Meteorologists may thus obtain a clearer understanding of the earth's atmosphere and weather phenomena.

SOCIAL SCIENCES

"Social sciences" is a collective term for a number of different fields of science. They have in common the study of human society with the goal of establishing valid scientific generalizations about human behavior. But each of the social sciences has a separate history, tradition, method and focus.

Two trends are at present apparent: each discipline is becoming more technically sophisticated and more specialized, yet there is increasing convergence of interest on subject matter. Developing nations, for example, cannot be understood by considering only their economic potential, political organization, geographic limitations, or social structure.

Although it is necessary to isolate each facet for purposes of study, it is not possible to understand the functioning of a country without combining insights provided by all the disciplines. Similarly study of the problems of urban living, in the United States as well as in other parts of the world, must be drawn from many social sciences, the natural sciences, and engineering. Efforts at solutions require the technical expertise of each specialty. Often a "technically" feasible partial solution to problems affecting society has been achieved but it has not been found socially or politically acceptable or the response of people to the innovation has differed radically from expectations. It is essential that we increase our knowledge of human behavior if we hope to effect practical improvements in human organizations.

The examples of National Science Foundation-supported research which follow have been chosen to illustrate these points. Research which improves the methods or theory of a given social science discipline may seem remote from immediate pressing problems, but actually it represents the essential basis on which advances in scientific understanding rest. Other examples demonstrate some points of convergence between social sciences and the progress that is being made in providing the information necessary for corrective measures to some problems. The two efforts reinforce each other and are bringing the day closer when feasible courses of action can be devised.

Models of the Social Structure

Increasing use of mathematics and computer-based technology by social scientists points to better prospects for success in translating theoretical findings for the use of policymakers. Economists, in particular, use a large battery of such techniques and are as concerned with empirical testing of propositions as with creating new theories. The computer has made possible the development of attempts to construct large-scale models of the economy. While progress has been made in understanding factors affecting economic growth, considerable research is being done in the area of pure theory to devise more adequate explanations of the process and variables of economic growth, the relationship of money to stabilization and growth policies, and problems of international trade. Considerable effort is also being devoted to the development of more powerful and refined statistical and mathematical techniques and computer programs designed to assist in the analysis or simulation of complex economic relationships.

William J. Baumol of Princeton University has used a model of a two-sector economy to derive conclusions about the workings of the economy which may be of considerable importance for future social welfare. Dr. Baumol has used this model to explain the nature of the financial pressures besetting a variety of activities such as education, the performing arts, and those of municipal governments. The extraordinary rate of increase of costs that has beset these sectors is explained not as a matter of mismanagement or inefficiency but as a consequence of the nature of their production functions which makes it virtually inevitable for their unit costs to rise more rapidly than costs in the economy as a whole. This means that increasing proportions of society's resources will have to be channeled into these sectors if the level of supply or the quality of their services is to be kept from becoming progressively smaller. Dr. Baumol's work on the macroeconomics of unbalanced growth provides theoretical understanding of the many visible phenomena constituting the "urban crisis" and indicates the limits of various alternatives in changing the underlying economic realities.

Predictions for Empirical Social Situations

John G. Harsanyi, an economist at the University of California, Berkeley, is making progress in development of a general theory of rational behavior in situations which can be thought of as analytically similar to certain kinds of "games." His work promises to increase greatly the power of experiments in this area. Mathematical game theory—like individual decision theory which is a special case—is an active research interest of social scientists and predicts what will happen if all participants in a social situation have consistent preferences and act on these preferences in a consistent manner. By introducing necessary factual assumptions Dr. Harsanyi has found it possible to predict many observable social situations using the same general theory.

The purpose of the theory is to answer certain basic questions about real life social situations. For example, if rational individuals have a common interest in reaching an efficient solution, but have opposite interests as to the specific payoff distribution to be adopted, what factors will determine whether they can actually reach an agreement yielding an efficient outcome? Under what conditions will rational individuals be unable to reach an agreement and be driven into a wasteful conflict situation which would be in their mutual interest to avoid? What coalition structure will emerge if all participants act rationally?

William H. Riker, a political scientist at the University of Rochester, has been studying the behavior of subjects in game experiments to discover whether or not real human beings in our society behave as predicted in the mathematical theory of games. Since the theory of three-or-more-person games is a theory of the formation of coalitions and since a crucial feature of local, national and international politics is the formation of coalitions, a theory of coalition-formation in games is in fact a theory of politics.

A major finding of Dr. Riker is that the mathematical theory of games does in fact explain how people really act. Subjects acted in accordance with theoretical predictions whether or not they knew the mathematical solution of the formal scheme. Diverse experimental groups, such as students and businessmen, did not behave differently. This experimental verification of theory makes it possible to predict what kind of distribution will occur under given conditions. Since evaluations are important artifacts of politics—at least when disagreement exists—a general theory of actions will have applicability to a number of real and important situations.

Aggression as a Product of Frustration

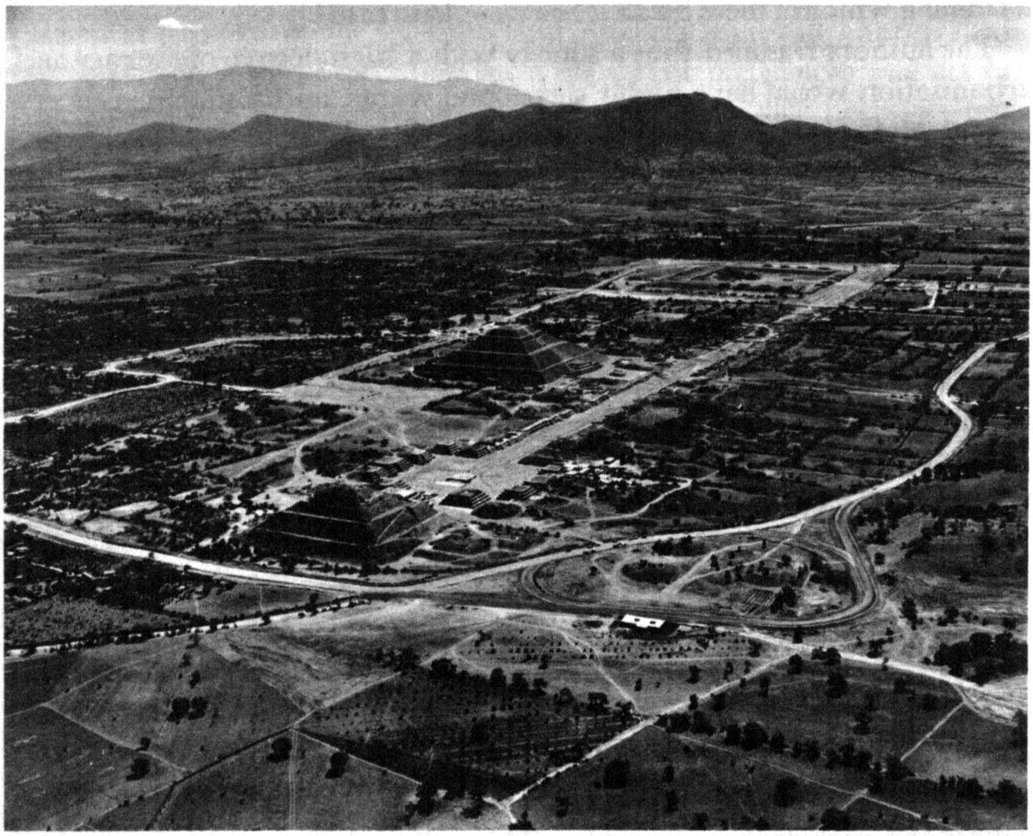
Interdisciplinary efforts frequently characterize the study of larger social units. Ivo K. Feierabend, a political scientist at San Diego State College and his wife, Rosalind, a psychologist, have developed a framework for the analysis of internal and external conflict behaviors of nations. Applying the psychological theory that aggression is the product of frustration they ranked a sample of 84 countries on an index of stability. The index ranged from stable political events like general elections through middle-range events like the assassination of a significant political figure, to *coups d'état* and civil war. Countries were rated on the basis of the most unstable event that occurred during the period between 1955 and 1961. Next, there was needed some measurable way of determining which of these 84 societies were frustrated.

The authors reasoned that a society with a high degree of literacy and urbanization would have highly developed wants, and also that a society with a high Gross National Product, high levels of caloric intake per person, and high ratios of doctors, telephones, newspapers, and radios would have a high level of material satisfaction. They then assumed that frustration occurs when wants and satisfactions are not in tune. It follows that a low level of both wants and satisfactions (traditional societies), as well as a high level of both (modern societies) could produce stability. The study bore out the hypothesis that frustrated societies are politically unstable. Of the 36 nations in the sample that show a high degree of frustration, 34 rank at the unstable end of the stability index. Of the 26 societies that show a low level of frustration, 20 are stable and only six are unstable.

When the countries in the sample were divided into groups representing modern, transitional, and traditional societies, the transitional countries had—as the authors expected—a mean instability score significantly higher than the modern group. The Feierabends, who were awarded the American Association for the Advancement of Science Socio-Psychological Prize for this work, are continuing their studies to refine their indices and include more variables. This will make it possible to develop a more detailed picture of the correlates of systemic aggression. They are also beginning work to clarify the relationship over time between fluctuations in the rate of economic development, changes in the permissiveness-coerciveness of political regimes, and variations in political stability.

Social scientists are concerned about the structure and function of social institutions in varying cultural contexts. What are the factors which tend to stabilize or change cultures? What are the dominating influences by which men conceptualize their natural and social environments? What imbues a culture with permanence, or what brings about its decay?

Urbanization, although much discussed as a contemporary phenomenon, has its roots in antiquity, and recent research by a team of social scientists is providing important new knowledge about the process as manifested in one of the world's great ancient cities. Located near present-day Mexico City and known as Teotihuacan, it flourished centuries before the Spaniards entered Mexico. Around A.D. 500, when Teotihuacan reached the peak of its strength, it was larger than Imperial Rome, and its influence was felt over much of Middle America. It was a political, economic, religious, and artistic center; like urban centers today, it was confronted with such difficulties as overcrowding, and apparently it even underwent an "urban renewal" as one response to the problem of heavy concentration of population within a relatively limited space.



Cia Mexicana Aerofoto, S.A.

Figure 20.—*An ancient city reappears from the past. Excavations by Mexican government archeologists over the past several years reveal the streets and buildings of Teotihuacan near Mexico City, and scientists are now attempting to reconstruct patterns of everyday life in bygone centuries. The central area with its pyramids and temples was the ceremonial heart of the city.*

Since there are no written records to describe life in Teotihuacan, knowledge about the city derives from archaeological research. René Millon, of the University of Rochester, and his associates have been preparing a detailed topographic map of Teotihuacan on which all of the city's several thousand structures are being located. Eight square miles in total area, the city included more than 4,000 buildings, exclusive of religious structures. At the height of the city's power its population is estimated to have been between 50,000 and 100,000, probably closer to the latter figure. Most of the population lived in one story apartment buildings that were designed to offer maximum privacy within the crowded city. The buildings consisted of a series of rooms, patios, porticos and passageways, all secluded from the street. Palaces were similarly designed. An individual apartment surrounded a central patio with its own drainage system; each patio admitted light and air to the rooms which fronted it, and residents could be out of the doors while maintaining their privacy. Dr. Millon comments that this architectural style may have contributed to Teotihuacan's permanence as an urban center for more than 500 years.

Differences in Cultural Perspective

In studying contemporary societies, scientists are developing new methods of investigation. John Adair of San Francisco State College and Sol Worth of the University of Pennsylvania have carried out an experiment in film communication that promises a significant new approach to the study of how people in different cultures perceive and interpret the world.

Seven Navahos on a reservation at Pine Springs, Ariz., were taught to make 16-mm. silent films, including editing as well as photographing. The films were about subjects of the Navahos' own choosing, and insofar as possible the researchers avoided influencing the subjects in selecting the content of the films, or in their manner of employing the equipment. It was hypothesized that if it were possible to teach members of other cultures to use film in this way, they would use it in a patterned rather than a random fashion, and that the particular patterns used in this mode of communication would be highly influenced by cultural and cognitive processes which differ from culture to culture, and which are difficult to communicate cross-culturally by other means.

Ten films were made by the Navahos, and preliminary analysis of the films indicates results that are consonant with the hypothesis. For example, the subjects in the films do a great amount of walking. To the researchers and to others who have been shown the films and are not Navaho, the walking takes up a disproportionate amount of the film and in this sense seems to be "wrong filmmaking." To the Navaho filmmakers however walking was an event in itself, not just a way of getting somewhere. The emphasis in the films on walking seems consistent with other manifestations of Navaho thought, language, and behavior that apparently reflect a perspective in which motion pervades the universe.

Processes and Products of Human Interaction

Nathan Kogan of Educational Testing Service and Michael A. Wallach of Duke University have been studying one aspect of the difference between group and individual decisionmaking, namely, the degree of risktaking or conservatism. In a number of experiments, the investigators compared the riskiness of individual decisions with the riskiness of decisions on the same issues by groups made up of the same individuals. The subjects chose from among several alternatives which clearly involved different levels of risk. Results indicate that there is a strong tendency for groups to shift toward greater risktaking in their consensus decisions. These shifts occurred with high regularity for both male and female groups, across various subject populations, and in various experimental situations. One might suppose that the effect came from mere compliance with the group, but subjects who were given an opportunity to make individual and private choices some time after the group discussion exhibited about the same magnitude of shift toward greater risktaking.

There are several other possible explanations for the shift which were considered by the principal investigators. These included the social desirability of risk taking over conservatism in our culture, the possibility that risk takers tend to be group leaders and thus influence final decisions, and the social support group members would receive if their risky decision led to failure rather than success. Previous data seem to rule out the possibility that any one of these factors accounts for the behavior. Drs. Kogan and Wallach are currently testing propositions drawn from theories of mass behavior. The small group is, of course, not a mass or "crowd," but some of the same social psychological factors which are thought to account for crowd behavior—the feeling of anonymity and of diffusion of personal responsibility, and the impression that the action being undertaken has everyone's approval—may be operating in small groups.

Effects of Teacher's Expectations on Students

As part of his long-term program of research on unintentional influence, Robert Rosenthal of Harvard University recently tested the biasing effects of teachers' expectations on students' performance. A nonverbal intelligence test was administered to all children in an elementary school. The test was described to the teachers as a measure designed to predict academic "blooming." In each of the 18 classrooms of the school (there were three classes for each of the six elementary grades), 20 percent of the children were assigned to the experimental condition, that is, the names of these children were given to each teacher who was told that their scores on the test indicated they would make unusual intellectual gains during the year. Actually, the children were assigned to the experimental condition on a purely random basis.

Eight months later, the children were retested with the same I.Q. test. The results showed a significantly greater increase in I.Q. among the children in the experimental condition than among the others. The difference was dramatic at the first two grade levels and nonsignificant at the higher grades. For the first and second grades, while 49 percent of the control subjects gained 10 I.Q. points over the 8-month period, 19 percent gained 20 points and 5 percent gained five points, the corresponding percentages for the experimental group were 79, 47, and 21.

These findings have profound implications for new educational programs and for the training of teachers, especially in the urban centers. The question of how expectations are communicated is a difficult one. Influencers are completely unaware of the effects of their expectancies and cannot identify differences in their behavior toward experimental and control subjects. Dr. Rosenthal is currently involved in an examination of filmed and taped interactions to help determine what subtle verbal, nonverbal and gestural cues may be involved in the process.

Communication in Multilingual Communities

Language is a unique ability of man, and research on spoken communication is one of the most active social science areas. Many societies, such as the United States, are monolingual in the sense that a single language serves all requirements of daily communication. A contrasting situation can be found in a number of Asian and African communities where populations of widely different cultural and linguistic background live in close geographical proximity. Among the questions which stem from the occurrence of community multilingualism is how it is possible for social interaction to take place if, as is often stated, differences in language are almost impenetrable barriers to such communication. Since multilingualism is frequent in populations with little or no formal education, why is it that individuals in our own monolingual society require years of training to gain some measure of control of a foreign language?

John Gumperz, an anthropologist of the University of California at Berkeley, has approached these problems in terms of the hypothesis that regular and frequent social interaction between speakers of distinct languages in multilingual communities generates structural borrowing between these languages and the resultant grammatical overlap facilitates intracommunity communication by making it easier for individuals to switch from one language to another as the need arises. Results obtained by Dr. Gumperz from research on Marathi and Kannada, two distinct unrelated languages spoken in a village in India support this hypothesis. The formal varieties of the two languages, learned primarily in schools, retained differences in rules that were not found in casual village speech used in everyday bilingual interaction.

In an instance of bilingualism closer to home, Stanley Lieberson, a sociologist at the University of Washington, examined trends in the ability of Montreal's population to communicate with one another between 1921 and 1961. Using census data and indexes adapted from linguistics he found that there had been no increase in linguistic communication during the period. Bilingualism in Montreal seems to be an end product of langauge contact rather than an intermediate step toward monolingualism. Both major languages have maintained their positions in intergenerational transfer.

SCIENCE EDUCATION

The ability of the Nation to achieve in science is directly related to its ability to maintain an adequate supply of well-trained scientific personnel. Hence it is vitally important that academic institutions provide science education that keeps pace with advances in science and technology and fully prepares individuals for their various professional responsibilities. A major task of the National Science Foundation is that of strengthening education in science at all academic levels, emphasizing support where the needs are most critical. Attention is given to science education for scientists, prospective scientists, and nonscientists.

Over the years the Foundation has experimented with a number of approaches to improving science education and has aimed at providing the kind of assistance to individuals and institutions that best meets contemporary needs. Educational support efforts have primarily sought to:

- Further the training of highly able graduate students and established scientists;
- Improve the subject-matter competence of teachers of science, mathematics, or engineering at the various educational levels;
- Provide modern instructional materials and courses;
- Provide special training opportunities for increasing the scientific knowledge and experience of talented high school students and undergraduate students;
- Improve science instruction at the undergraduate level by assisting institutions in acquiring modern instructional scientific equipment;
- Improve the U.S. public's understanding of science.

Foundation support for talented graduate students and advanced scholars in science, through fellowship and traineeship programs, has a high priority because these individuals are the Nation's primary source of future scientific potential and achievement. Fellowships are awarded directly by the Foundation to individual applicants who, in nationwide competition, are selected by NSF on the basis of their ability. Traineeships, however, are awarded on a selective basis to graduate students by the institutions conducting graduate trainee programs under NSF support. From 1952 to the end of fiscal year 1967, the Foundation invested more than $256 million in fellowships and traineeships for advanced-level training. This represents a total of 45,821 fellowship awards offered to the most highly qualified individuals identified from among 163,264 applicants, and 14,170 traineeships for award by the 206 institutions receiving grants. Foundation-supported research projects also provide advanced students with educational experience under the leadership of senior scientists who direct research projects.

Rapid advances in scientific knowledge have made it imperative that graduate curricula be periodically reviewed and revised so as to maintain their high quality, and that science faculty and graduate students be informed of the latest advances through high-level seminars of an interinstitutional nature. These special needs of institutions and individuals are given attention and support through various activities of graduate education programs.

The strengthening of institutions themselves is, of course, the aim of several large efforts of the Foundation—the University Science Development Program, the Departmental Science Development Program, and the College Science Improvement Program. It is expected that the National Sea Grant Program, for which grants will be awarded beginning in fiscal year 1968, will also contribute to improvement of science education.

While other institution-oriented programs have as their objective the improvement of science education and academic research at the graduate level, the College Science Improvement Program focuses mainly on the needs of four-year colleges. Established in October 1966, this program marks the culmination of efforts within the Foundation and institutions of higher education to devise a plan which would offer undergraduate institutions essential, broad-based support for improving their science programs.

Through the years only a small fraction of Foundation funds has gone to support undergraduate education and institutions. The limited assistance provided was primarily for individual projects concerned with supplementary training of college and junior college teachers, undergraduate research participation, curriculum improvement, or matching support for instructional scientific equipment. However, the Foundation recognizes that support of a broader range of activities is now necessary in order to be responsive to current needs of these institutions and to strengthen their base of science education. To meet these needs, the College Science Improvement Program supports comprehensive plans for upgrading science education in ways that are most suitable for the institution concerned. The institution's plan can feature improvement of a single department, or any number of departments, and any combination of specific projects within or among these departments. In all cases, the choice of an appropriate plan of action is made on the basis of the institution's needs and goals.

The response of undergraduate institutions to this new program has been enthusiastic. By the close of fiscal year 1967 a total of 115 requests for support of College Science Improvement plans had been received by the Foundation. In this program there are no established deadlines for receipt of proposals and approval of grants probably will be announced every 3 or 4 months. In the first 6 months of program activity, 15 grants totaling approximately $2.5 million were awarded.

Substantial progress in upgrading the initial subject-matter competence of precollege teachers of science and mathematics has been made in the last decade, but supplementary in-service training efforts are still needed at this level. The Foundation has supported teacher institutes—organized and conducted by colleges and universities—since 1953. In 1967 some 19,400 high school teachers of science and mathematics attended summer institutes devoted to their respective fields. Some 1,500 teachers were enrolled in full-time institutes conducted for the entire academic year, and 13,000 more attended in-service institutes while continuing to teach in their schools.

This year the Foundation changed its approach to providing for the needs of elementary school personnel. Instead of supporting only individual institutes for the supplementary training of teachers and supervisors of elementary schools, stress is now also placed on support for the efforts of local school systems in upgrading their instruction in science and mathematics in both elementary and secondary schools. Encouragement is given to the training of high school teachers to a level where they, in turn, are capable of instructing elementary teachers in their school systems. The Cooperative College-School Science Program provides assistance for projects which have the potential for large-scale improvement that is responsive to local needs.

Efforts leading to large-scale improvement of course-content and materials for science and mathematics instruction in the schools have received Foundation support for a number of years. Major projects concerned with physics, mathematics, chemistry, and biology courses for secondary school students were the first to receive attention. In more recent years, projects for improving materials for use in elementary schools and in undergraduate colleges have been supported.

Progress made in modernizing mathematics and science instruction for the youth of the Nation has been gratifying. The mathematicians, scientists, and educators who carry out Foundation-supported projects for course-content improvement have incorporated current mathematical and scientific ideas into textbooks and other materials used in classrooms. These materials are receiving wide use. For example, the School Mathematics Study Group, initiated in 1958, has produced materials which have been used by more than 8 million elementary and secondary school children. Some 500,000 pupils have worked with trial versions of exercises developed by the Elementary Science Study. Approximately 1.5 million secondary school students have been introduced to biology through texts, laboratory projects, and audiovisual aids developed by the Biological Sciences Curriculum Study. In chemistry, about 500,000 students have been exposed to courses developed by either the Chemical Bond Approach Project or the Chemical Education Material Study, while more than 250,000 high school juniors and seniors have studied the physics course developed by the Physical Science Study Committee.

Foundation support for fiscal year 1967 science education activities at the three major educational levels is shown in the following table:

Table 8.—*Education in Science, Fiscal Year 1967*

	Number of proposals received	Dollar amount requested	Number of awards made	Funds obligated (Net)
Graduate:				
1. Fellowships........	[1] 11,639	$71,896,793	[2] 2,971	$17,843,781
2. Traineeship and other grants........	810	95,738,163	[3] 842	31,295,405
Undergraduate [4]..........	3,873	92,298,270	1,552	25,450,349
Pre-college...............	1,750	85,693,486	1,141	51,234,731

[1] Applications.
[2] Fellowships.
[3] Includes 80 NATO and International Travel grants not included in proposal count.
[4] Includes College Science Improvement Program: Column 1—94; column 2—$17,066,449; column 3—15; column 4—$2,464,100.

Recently the National Science Foundation and the U.S. Office of Education have been working together to further curricular improvement in the schools. Under authority of the Elementary and Secondary Education Act of 1965, which is administered by the Office of Education, steps have been taken by that Office for improvement of the Nation's educational system by establishing Regional Educational Laboratories. Ultimately each laboratory will be engaged in a variety of activities ranging from basic research in education to classroom implementation of newly developed programs.

The objectives of Foundation-supported course-content improvement projects and of the Regional Educational Laboratories are to a considerable extent complementary. Foundation activities develop course materials that are made widely available to schools, but the schools are faced with the problem of making effective use of the materials. Initiation of new programs in schools is one of the major objectives of many of the Regional Educational Laboratories. Through continued cooperation and coordination of such efforts, the two agencies hope to produce fruitful results for education in general.

Another area of mutual concern to the National Science Foundation and the Office of Education is the use of computers in education. Applications of computer technology to the educational programs of institutions are now very limited, although it is in this area that a great potential exists for innovation and improvement. Pioneering institutions have shown that the use of computers adds realistic complexity to learning in engineering, economics, and statistics. The computer enables the student or the scholar to deal with realistic problems rather than oversimplified models. By decreasing the time spent in the drudgery of problem-solving and in the analysis of data, the computer frees time that can be devoted to thought and insight. Consequently, ways to use the computer for educational purposes are being explored by the National Science Foundation and the Office of Education.

The relative importance of computers in education is such that the Foundation has established an Office of Computer Activities to coordinate internal programs and an interagency committee to coordinate major Federal efforts.

GRADUATE EDUCATION IN SCIENCE

Providing financial assistance for graduate students and advanced scholars in science continues to be a very important part of the support effort at the graduate level. In fiscal year 1967, through fellowship and traineeship programs, nearly 8,945 U.S. citizens were offered opportunities for appropriate study and research at institutions in the United States and abroad. (Table 9 summarizes data on applicants, awardees, and expenditures.) Support for individuals, however, is not enough; the Foundation has a related responsibility to assure that the training offered is of the best possible quality. Thus, various attempts are being made to help institutions with problems related to the training itself.

In addition to major efforts to upgrade, at the graduate level, selected science segments of U.S. universities through its University and Departmental Science Development Programs, (see p. 145) the Foundation seeks to strengthen graduate training in other ways:

- A limited number of outstanding senior foreign scientists are supported through fellowships at U.S. universities, where they share their learning with American colleagues, enhance the local graduate academic programs, and contribute to ongoing research.
- Advanced Science Seminars enable graduate and postdoctoral students and advanced scholars to meet together under Foundation sponsorship to explore in depth the latest, advanced developments in their own or related fields of specialization. Such training opportunities, which involve personnel from many institutions, normally cannot be provided by a single institution without outside financial assistance.
- Special projects in graduate education encourage innovative efforts for improving science education at the graduate level.

Education in science at the graduate level cannot and must not be regarded as a static enterprise. Hence, the Foundation supports new approaches originated by university faculty and judged to be meritorious by other members of the academic community. Graduate students represent a critical segment of the Nation's scientific potential, and predoctoral fellowships and traineeships, awarded competitively on the basis of merit, afford them the opportunity to pursue advanced learning with a minimum of delay in earning their higher degrees.

Graduate Traineeships

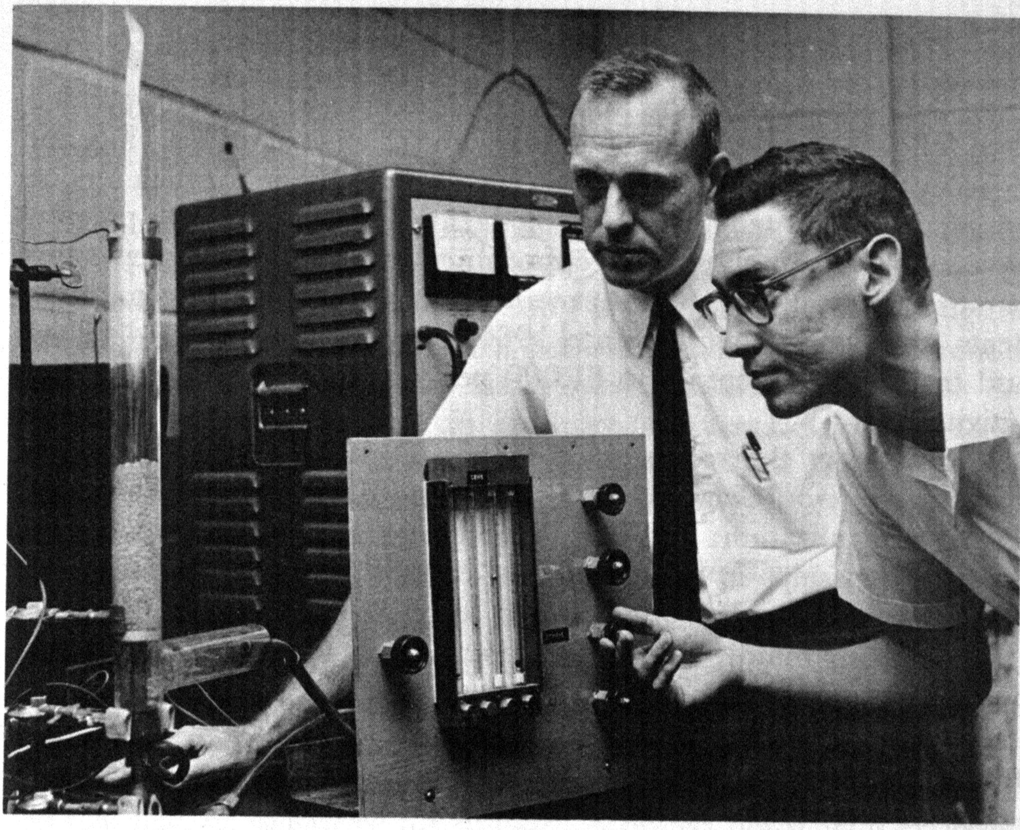
The Graduate Traineeship Program now covers all the fields of science supported by the National Science Foundation. Its aim is to increase the number of qualified individuals who pursue and complete advanced study leading to master's and doctoral degrees in these fields. Traineeship grants are awarded primarily to institutions whose existing facilities and staff can accommodate additional first-year graduate students in strong programs, or whose students can progress more rapidly toward an advanced degree with the aid of traineeships. All graduate trainees are selected by the institutions themselves. These graduate students receive their NSF support from the institutions in the form of "traineeships," as distinguished from the traditional fellowships awarded directly by NSF to individual applicants.

The Graduate Traineeship Program, inaugurated in 1964, proved to be of considerable interest to U.S. universities. In 1967, 5,077 traineeships (tenable for 9 or 12 months) were awarded to 206 universities for the academic year 1967–1968—884 more than were available in 1966–1967. Summer traineeships were requested by 194 universities and 896 summer traineeships for graduate teaching assistants were awarded (910 summer *fellowships* were awarded in 1966 by the Foundation to individual students at 166 universities).

Effective this year, the former Summer Fellowships for Graduate Teaching Assistants program is now administered as a Summer Traineeships program. Thus the institutions have the sole responsibility for selecting the graduate teaching assistants to receive such traineeships.

Graduate Fellowships

Now in its 16th year, the Graduate Fellowship Program continues to attract the most able and promising graduate students in science in the Nation. There is every reason to believe that the awardees will become leaders in their respective disciplines; indeed some already have done so. In all cases, applications are reviewed by panels of eminent scientists, appointed by the National Research Council, before the Foundation makes its selection of students to be offered awards.



Pennsylvania State University Photo

Figure 21.—*Graduate education and research go hand in hand. In this experiment at the Pennsylvania State University the student and instructor will study what effect the application of a high voltage electric field will have on the simulated flame of a gas burner or jet engine.*

Again, the largest number of the Foundation's awards for fellowships and traineeships was made to predoctoral students. A total of 8,423 graduate students were awarded support in fiscal year 1967 under the three programs (Graduate Fellowships—2,450 awardees; Graduate Traineeships—5,077 recipients, and Summer Traineeships for Graduate Teaching Assistants—896 recipients). The previous year a total of 7,878 awards was offered. Applications for the support of graduate students in the predoctoral programs increased from 28,232 in fiscal year 1966 to 31,844 in fiscal year 1967.

Fellowships for Advanced Scholars in Science

Much of the Nation's progress in science and technology can be directly attributed to the professional contributions of advanced scholars in science. In fiscal year 1967 the Foundation made 521 fellowship awards in support of high-level scientific study for established scientists: 65 Senior Postdoctoral Fellowships, 150 Postdoctoral Fellowships, 250 Science Faculty Fellowships, and 56 Senior Foreign Scientists Fellowships.

In recognition of the widely accepted view that experience in teaching can contribute substantially to the advanced training of senior fellows, the Foundation is now approving requests of fellows in the postdoctoral fellowship program to undertake limited amounts of teaching, and to accept some remuneration from the host institution for such services during fellowship tenure. Several of the awardees in this year's program have availed themselves of the opportunity to teach, and supplementary remuneration up to $2,000 is permitted. In the case of predoctoral students, the Foundation has since 1964, permitted all sponsored fellows and trainees to accept up to $1,000 per year for appropriate teaching activities.

Currently, at the request of the State Department, the Foundation administers two fellowship programs funded by the North Atlantic Treaty Organization: NATO Postdoctoral Fellowships and NATO Senior Fellowships in Science, the latter newly instituted in fiscal year 1967. These fellowships were offered to 65 U.S. scientists in fiscal year 1967 for study mainly in NATO countries other than the United States. See page 167 for further details on these programs.

Table 9.—NSF Fellowship and Traineeship Programs, Fiscal Year 1967

	Awards requested by institutions	Individuals involved in applications	Awards offered	Amount
Graduate traineeships	15,143 (206)[1]	......	5,077 (206)[1]	$26,971,053
Summer traineeships for graduate teaching assistants	7,615 (194)[1]	......	896 (192)[1]	1,059,593
Graduate fellowships		9,086	2,450	11,894,576
Postdoctoral fellowships		1,043	150	1,201,000
Senior postdoctoral fellowships		393	65	774,405
Science faculty fellowships		1,047	250	3,330,000
Senior foreign scientist fellowships		70	56	643,800
Total	22,758 (206)[1]	11,639	8,944 (206)[1]	45,874,427

[1] Number of institutions involved.

Advanced Science Education Activities

To meet special needs at the graduate or advanced level, the Foundation supports a number of advanced science education activities. Such efforts include advanced science seminars, special projects in graduate education, travel to international scientific meetings (see p. 170), and public understanding of science projects. Funds available for these activities totaled approximately $3 million in fiscal year 1967. Some projects are oriented toward the individual, offering science instruction or activity of a highly specialized nature; others are aimed at improving the quality of science training offered by institutions.

Advanced Science Seminars

Advanced Science Seminars supplement graduate school curricula by enabling participants to pursue science subjects in greater depth. In fiscal year 1967, support was awarded for 45 such projects. Among the new approaches introduced was a Seminar on Ordinary Differential Equations for graduate faculty and graduate students, which was designed to promote excellence in graduate mathematics in the Rocky Mountain area. Another seminar combined field work and lectures on Recent and Ancient Deltaic Sediments for use in graduate courses.

Special Projects in Graduate Education

Projects in this category focus on the support of innovative efforts in science education at the graduate level. With graduate education continually challenged by rapid technological and social changes, these projects are directed toward the development of new ideas for coping with current problems. Considerable flexibility is allowed in the type of activities that may be considered for support. A project normally is expected to serve as a stimulus for further improvement of graduate programs, so that institutions receiving grants are encouraged to disseminate the information gained from their particular experience for the general benefit of the academic community.

Examples of projects funded during fiscal year 1967, which reflect the wide scope of activities supported, are:

Establishment of a new center of visual science at the University of Rochester, N.Y., to provide broad, high-level education and experience in physical, physiological, and psychological vision for graduate and postdoctoral students;

Establishment of a nematode reference collection at Purdue University, Lafayette, Ind., to serve 11 universities in the Midwest as a teaching and resource tool;

Strengthening of a new graduate program in psychology at Idaho State University to provide a high-quality training program at the master's degree level;

Initiation of an experimental master of science program in physics at Wichita State University, Kans., designed for capable students with deficiencies in their undergraduate training;

Development of a new master's degree program in building technology at Washington University, St. Louis, Mo., combining the disciplines of civil engineering and architecture.

Fiscal year 1967 grants for special projects totaled 28; these were awarded to 25 institutions.

UNDERGRADUATE EDUCATION IN SCIENCE

As a source of critical basic training for the scientists and technologists of the future, the Nation's undergraduate institutions (colleges and the undergraduate components of universities) represent a very important element in the educational process. These institutions also have the broader task of providing a good general education in science for all college students in the interest of preparing their students for responsibilities as citizens. However, efforts of the colleges to maintain a high standard of science instruction are confronted by several major obstacles. Among these are lack of an adequate number of teachers who are well-trained in the sciences and a lack of modern facilities, equipment, and curricula needed for effective science teaching. The situation is further complicated by constantly rising enrollments, competition for faculty on the part of universities and industry, and ever-changing scientific knowledge.

Staffing undergraduate institutions with well-qualified science teachers is likely to become more difficult. A recent study[7] indicates that employment of science and engineering staff in the Nation's universities and colleges can be expected to double, approximately, in the next decade. Requirements for university and college staff, excluding employed graduate students, will amount to 369,000 in 1975, or 179,000 more than in 1965. In addition there will be a further staff requirement of 56,000 over the decade to restore losses from attrition. (These estimates are based on the assumption that university and college employment conditions will remain relatively unchanged over the decade.)

Current Foundation activities in undergraduate education center on urgent training needs of undergraduate students, improvement of subject-matter competence of the teachers of undergraduates, improvement of curriculum through modernization of course content and acquisition of up-to-date instructional equipment, assistance for institutions carrying out comprehensive plans for college science improvement, and experimental work in developing model projects which may benefit other institutions.

This fiscal year witnessed the establishment of the College Science Improvement Program, which is directed toward assisting predominantly undergraduate institutions to accelerate the development of their science capabilities (see p. 131).

A discussion of the various fiscal year 1967 activities in support of strengthening undergraduate education in science follows.

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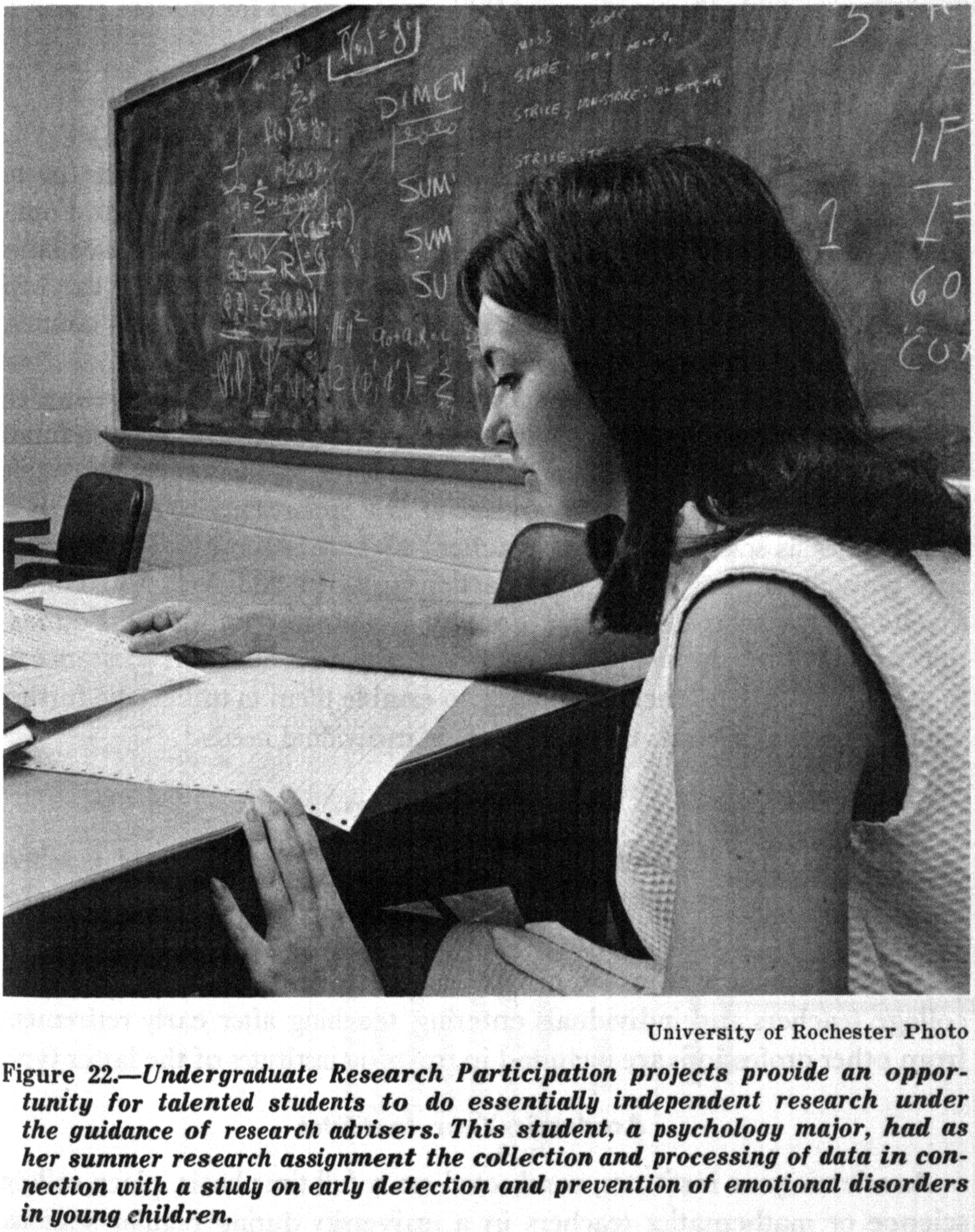
[7] *Science and Engineering Staff in Universities and Colleges,* 1965–75 (NSF 67-11).

Undergraduate Research Participation

Through Foundation sponsorship of Undergraduate Research Participation projects, talented undergraduate students in science are given the opportunity to do essentially independent research under the guidance of competent research advisers. This experience acquaints students with the intellectual challenge and reward afforded by a scientific career and prepares them for a smooth transition later to graduate work.

The Foundation has learned that Undergraduate Research Participation projects are capable of achieving different results when operating in different academic environments. Hence an attempt is made to support university-based projects for their particular effectiveness in accelerating



University of Rochester Photo

Figure 22.—***Undergraduate Research Participation projects provide an opportunity for talented students to do essentially independent research under the guidance of research advisers. This student, a psychology major, had as her summer research assignment the collection and processing of data in connection with a study on early detection and prevention of emotional disorders in young children.***

the careers of able undergraduates and for their usefulness in fostering a closer student-teacher relationship in situations where such rapport is likely to be weak. College-based projects are supported primarily to capitalize upon small outposts of scientific excellence and to bring about an increase in the number of students planning careers in science as well as an increase in the strength of departmental research programs through significant curricular changes.

During fiscal year 1967, 601 grants amounting to $5,003,850 were made to 282 institutions to provide research experience for 4,061 students. If all fiscal year 1967 requests for student participation could have been granted, about 10,860 students would have been involved. During its 9 years of operation the Undergraduate Research Participation Program has provided more than 47,000 opportunities for student research experience.

College Teacher Programs

Supplementary training for college teachers to help upgrade or to refresh their subject-matter knowledge has been supported by the Foundation since its early days. Such training, which is not ordinarily available in the regular offerings of graduate schools, is currently provided through support of teacher institutes (academic year and summer), short courses, research participation, and in-service seminars.

In fiscal year 1967, 368 grants amounting to $6,519,490 were awarded under the college teacher programs. More than 60 percent of these funds will be used for individual support in the form of allowances to enable the participants to take full advantage of the opportunity to enlarge their capabilities as scientists and as teachers of scientists-to-be. These grants will provide support for 4,874 participants. In addition, 250 college teachers were awarded Science Faculty Fellowships under the Foundation's fellowship support program, which provides financial assistance to in-service college teachers of science to enable them to undertake further scientific study or work that meets their individual needs.

Teacher Institutes

Institutes offer instruction especially designed for groups of teachers with similar subject-matter backgrounds and training needs. Some offer advanced level training; others emphasize instruction in basic subject matter for teachers who are not fully trained in science. Often junior college teachers and individuals entering teaching after early retirement from other professions are included in training institutes of the latter type.

Academic-Year Institutes

Academic year institutes, conducted on a full-time basis, place college science or mathematics teachers in a university during regular sessions.

Table 10.—*NSF Programs for College Teachers*

Program	Proposals received			Grants awarded		
	Number	Participants	Amount	Number	Participants	Amount
College teacher institutes	(221)	(7, 748)	($10, 027, 192)	(122)	(4, 141)	($4, 915, 090)
Academic year institutes	25	387	2, 264, 770	13	155	1, 026, 620
Summer institutes	139	4, 642	6, 334, 293	71	2, 323	3, 246, 870
In-service seminars	11	887	168, 231	9	762	134, 170
Short courses	46	1, 832	899, 898	29	901	507, 430
Research participation [1]	177	1, 045	2, 548, 156	246	643	1, 604, 400
Science Faculty Fellowships [2]	....	1, 047	13, 946, 000	....	250	3, 330, 000
Total	398	9, 840	26, 521, 348	368	5, 034	9, 849, 490

[1] Includes 151 Academic Year Extension grants not reflected in the 177 proposals received and Continuation Grants.
[2] Also included in statistics on fellowship programs.

Thus they may enroll in established courses, permitting them to attend regular lectures and to engage in laboratory work presided over by the university's regular staff. At the same time, these teachers can enroll in special core courses that are particularly suited to their needs. Fiscal year 1967 grants for conducting academic year institutes totaled $1,026,620. These awards will pay for the operating costs of 13 institutes and provide support for 155 participants.

A few academic year institutes, funded in fiscal year 1967 as special projects, offer training to preservice teachers. A project at Pennsylvania State University is intended to help prepare retired military personnel for positions on the teaching staffs of junior colleges and technical institutes. Another at North Carolina State University at Raleigh aims at preparation of retired military personnel for positions as junior college teachers of mathematics. A project in chemistry at Wellesley College, Mass., is designed for women who majored in chemistry prior to becoming homemakers, and offers preparatory training which will help them to assume careers in the teaching field.

Summer Institutes

Summer institutes have assisted more college teachers than any other program, and have proved to be an exceptionally effective mechanism for providing supplementary training for teachers. They are conducted at a time when college faculty members are usually free to pursue further study and when there is less demand for the use of graduate facilities by regular students. More than 18,300 training opportunities for college teachers have been provided by summer institutes since the program's inception. Fiscal year 1967 grants supported nearly 2,325 participants at 71 institutions conducting summer institutes.

In-Service Seminars

In-service seminars offer part-time training that enables teacher participants, while teaching on a full-time basis, to obtain additional knowledge of subject matter in their scientific disciplines, to become acquainted with new textbooks and laboratory equipment, or to take courses as part of a graduate degree program. Sessions are conducted on Saturdays or at other convenient times, and they are held at institutions within commuting distance for the participants.

In many instances a group of colleges and junior colleges are within ready commuting distance of a university having a strong graduate program in a given science, and here an in-service seminar can be very effective as a regional activity. Subjects of the seminars are frequently of an interdisciplinary nature, as in the case of computer simulation, space science, and optimization procedures. Or subjects may be those requiring equipment too expensive for smaller institutions to afford, such as radiotelescope systems, specially equipped vessels for use in oceanography, etc. Fiscal year 1967 grants for in-service seminars will provide training opportunities for 762 college teachers. These university-college cooperative relationships are of special interest to universities which are prepared to admit the graduates of surrounding junior colleges as transfer students.

Short Courses

Short-term intensive instruction in selected areas of scientific fields is made available to college teachers through Foundation-supported short courses, usually of 1 to 4 weeks' duration. The courses are conducted by research scientists at time periods that are convenient for the teachers. College teachers who have summer duties which prevent them from attending full-scale summer institutes often find these courses most helpful in obtaining knowledge of recent advances or developments in their particular fields of interest.

Among the new topics for short courses (formerly called conferences) supported under fiscal year 1967 grants are:

- *Recent Advances in Astronomy* (University of Nebraska),
- *Nutrition* (University of South Dakota),
- *Aerospace Engineering* (Stanford University),
- *Optimization Theory* (University of Texas), and
- *Remote Sensing of Environment* (University of Michigan).

Including the 29 short courses awarded grants this year, 264 such short course or conference projects have been supported since fiscal year 1956.

Research Participation

Opportunities for college teachers to engage in full-time research activities during the summer—and in some cases extended participation on a part-time basis during the academic year—are supported under the Research Participation for College Teachers Program. The teachers serve as associates of experienced investigators at institutions conducting major research programs. Academic-year extensions of support for research participation make it possible for some of the teachers to go on with their projects after returning to their home institutions with continued guidance from their research mentors. This represents an increasingly selective approach toward the upgrading of faculty at institutions having limited research facilities or heavy teaching loads. Such faculty experiences in research renew enthusiasm of the participating college teachers and help infuse new material and ideas into existing science courses.

Fiscal year 1967 grants for research participation for college teachers totaled $1,604,400 (including summer, academic-year extension, and continuation grants). As a result of this support, 643 college teachers will be provided research experience.

Instructional Improvement

Science curricula and instructional scientific equipment become outmoded due to the growth of scientific knowledge, rapid developments in instrumentation, and advancing technology in communications. This has produced an urgent need for colleges and universities to update their instructional programs. Rapid changes in the objectives, content, organization and methods of presentation of undergraduate education will probably continue.

Science Curriculum Improvement

Through its Science Curriculum Improvement Program the Foundation supports leaders in the various scientific disciplines in improving undergraduate course content and instructional materials. The widely divergent interests and backgrounds of different student groups and the differing special talents and interests of individual teachers make standardization undesirable. Therefore, the Foundation supports a wide variety of new approaches and materials which show promise of having a beneficial impact on the teaching of college science.

Among the significant curriculum improvement efforts currently supported are the activities of national commissions in agriculture, biology, chemistry, engineering, geography, geology, mathematics, and physics. These commissions, representing independent groups of academic scientists, are engaged in collecting and disseminating information about effective ways of improving undergraduate instruction in their respective disciplines, and in providing leadership in curriculum improvement efforts.

An important development in the improvement of undergraduate instruction has been the growth in the number of science teaching centers. These centers provide facilities for the development and testing of new instructional materials and methods by faculty members of cooperating institutions. The Foundation is providing substantial support for projects being conducted at two such centers, one located at the Massachusetts Institute of Technology and the other at Florida State University.

Examples of noteworthy curriculum improvement activities supported by fiscal year 1967 grants are:

- Production of instructional films in evolutionary and population biology by the University of California at Los Angeles and in developmental biology by the Education Development Center;
- Curriculum development in electronic technology by the Wentworth Institute, and computer animation of engineering films at the University of Pennsylvania;
- Experimentation with hybrid analog-digital computation by the University of Arizona, and development of computer programs for engineering education by the University of Arkansas;

- Development of a computer-related calculus sequence by the Center for Research in College Instruction in Science and Mathematics at Florida State University;
- Production of a major ethnological film on an African nomad tribe by Harvard University, and the development of a laboratory approach to the teaching of political science by the University of Minnesota.
- Completion of a course in physical science for nonscience majors by Rensselaer Polytechnic Institute.

Grants for college science curriculum improvement amounted to $6,797,495 in fiscal year 1967. These funds were in support of 37 projects.

Instructional Scientific Equipment

Presentation of modern concepts in science requires up-to-date instructional scientific equipment which is frequently costly. For many colleges a modest amount of Federal support for the purchase of necessary equipment can be the key to significant improvement. The Instructional Scientific Equipment Program awards 50–50 matching grants for equipment projects that are judged to offer the greatest promise of relative improvement in local undergraduate science curricula.

The beneficial results of acquiring good instructional equipment are manifold. Modern equipment opens the way to more meaningful experiments for students and tends to challenge both departments and individual faculty members to improve the content and manner of instruction. Departments frequently find a new willingness on the part of highly qualified young teachers to join the faculty when it is apparent that good modern equipment will be available. One department with modern equipment often stimulates other departments to evaluate their own curricula and seek ways to improve their courses.

In the 6 years of its existence, the Instructional Scientific Equipment Program has provided a total of more than $42 million through 4,678 grants to 1,017 institutions. These funds, together with non-Federal matching funds provided by the grantee institutions, have resulted in an investment of at least $85 million in scientific equipment leading to improvement in undergraduate science education.

During fiscal year 1967, 622 grants were made at a cost of $5 million. This provided about 23 percent of the funds requested and accommodated 29 percent of the proposals received. Grants were awarded to a total of 394 institutions.

Special Projects for Undergraduate Education

In general, the Special Projects for Undergraduate Education program provides for: (*a*) Exploring novel activities that may enhance undergraduate science education in colleges and universities if applied on a broad scale; (*b*) carrying out cooperative approaches to instructional improvement which involve established interinstitutional associations, as well as ad hoc groups of individual institutions; or (*c*) conducting activities which, through continued support or expansion, may at some future date provide a basis for a nationwide program. In fiscal year 1967, the Foundation made 39 grants totaling $790,195 to support these varied projects.

A project of particular interest, jointly funded by the National Science Foundation, the U.S. Office of Education, and the Office of Economic Opportunity, is the Institute for Services to Education. This institute is designed to prepare material for introductory 2-year mathematics and science courses for beginning college students who come from intellectually undemanding environments. If successful, this experiment could become a model for many institutions throughout the world that are attempting to deal with college freshmen who enter with inadequate secondary school preparation.

Cooperative efforts involving academic institutions and federally operated laboratories have also been supported. The National Bureau of Standards and Hood College, Frederick, Md., are conducting a project in which the Federal laboratory is providing staff and hardware to aid the college faculty in introducing computer science into formal courses of instruction. The Argonne National Laboratory has increased the number of its workshops and short courses in chemistry, physics, and biology, enabling applicants to be enrolled from colleges and junior colleges across the United States.

Established and ad hoc consortia of small colleges have been very successful in enabling their members to begin projects that individual institutions could not possibly undertake for financial reasons. For example, in fiscal year 1967, Foundation funds were provided to the College Center of the Finger Lakes for an aquatic biology institute, to the Associated College of the Midwest for a summer geology field course for freshmen and sophomores who have had no formal instruction in geology, and to the Mid-Appalachia College Council for establishing on Norris Lake a biological field station for undergraduate teaching, undergraduate research, and faculty research.

The Visiting Scientists (College) Program represents a special kind of activity which has been supported by the Foundation since 1954. It provides for grants to the various professional societies to underwrite the expense of sending competent scientists to undergraduate colleges (including junior colleges) for visits of one or two days' duration. The visitors lecture in the areas of their research competence, counsel with undergraduates regarding educational and career plans, advise the local faculty on questions of curriculum, course content, laboratory equipment and procedures, and generally seek to make a scientific presence felt on the campus. Visitors are senior faculty members, usually from major institutions, whose judgment and experience enable them to offer valuable advice to developing mathematics and science departments.

Fiscal year 1967 grants for Visiting Scientists (College) activities provide for 1,088 visits, totaling 2,132 days, at a cost of $253,635.

College Science Improvement

To provide appropriate support to institutions seeking to improve their scientific capabilities and instructional programs in a comprehensive way, the Foundation established the College Science Improvement Program in October 1966. The main purpose of the program is to encourage predominantly undergraduate institutions to undertake detailed self-studies of their science education practices, identify positively their existing strengths and deficiencies, select long-range improvement goals which are compatible with overall institutional policy, and formulate comprehensive plans for achieving these goals by sequential sets of science improvement projects. A wide variety of activities may be supported by the Foundation within one of these projects.

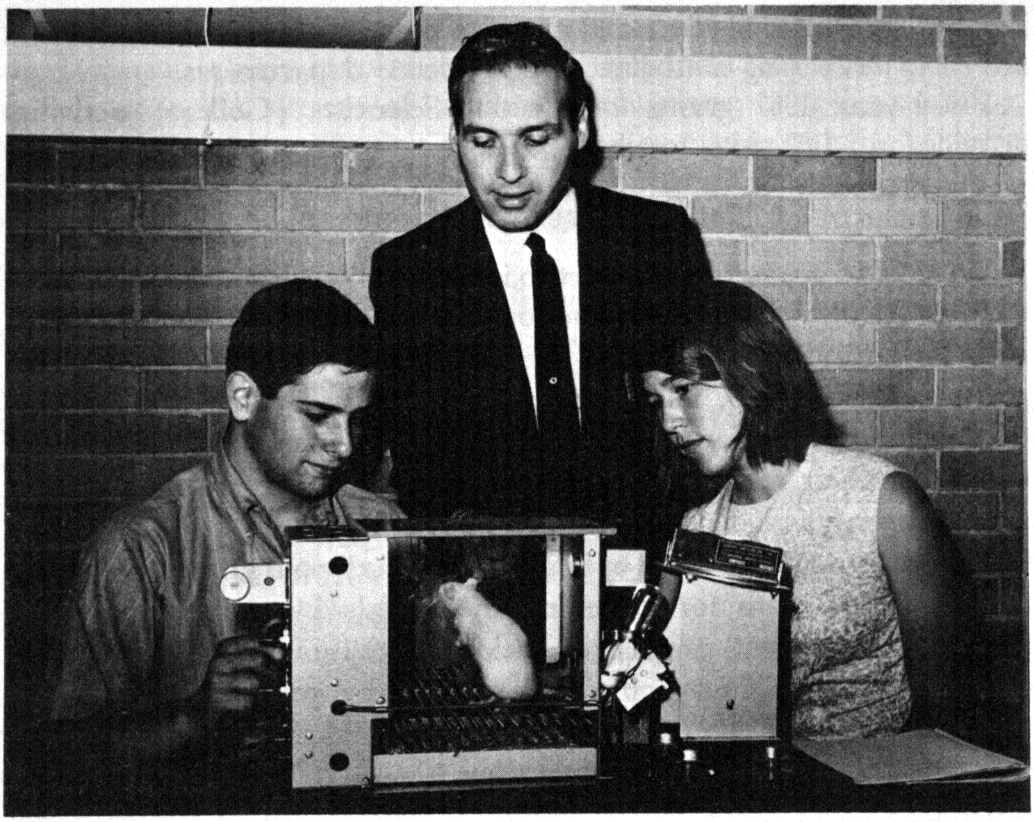
Late in the fiscal year, the Foundation awarded the first grants under this new program. The awards, totaling $2,464,100, were made to 15 institutions in 11 States.

Proposals for projects under the College Science Improvement Program may be submitted to the Foundation at any time. This fiscal year a total of 115 proposals was received. Additional awards will be made in 1967.

The Foundation believes that the College Science Improvement Program offers a much-needed approach to upgrading science in general at predominantly undergraduate institutions. Furthermore, it represents a forward-looking effort in that it can help to improve, among other things, the qualifications of the people who will teach and motivate a new generation of scientists in their formative years.

PRE-COLLEGE EDUCATION IN SCIENCE

As science and technology grow in importance, the necessity for the schools to provide sound instruction in science and mathematics increases. If children are to be motivated and properly prepared for careers in science, the Nation's schools need modern instructional materials, thoroughly competent teachers, and well-designed educational programs. The National Science Foundation supports a variety of activities designed to help schools carry out their responsibilities in the area of pre-college instruction in the sciences. This support has contributed subsantially to the improvement of science education in the United States. Many of these approaches have been successful enough to have served as prototypes for programs of other Federal agencies seeking educational improvement



St. Joseph's College Photo

Figure 23.—***Two participants in a summer training program at St. Joseph's College, Philadelphia, Pa., are introduced to a white rat. The rat will be a subject for laboratory observation during the 6 weeks of in-depth instruction in psychology.***

relevant to their mission. The Foundation desires to share the results of its experimental work that may be helpful to others.

As usual, this year the Foundation faced the problem of providing continued support for activities which have proved their effectiveness, while at the same time supporting innovative work which may develop even more effective approaches to the improvement of pre-college science education. To create the best possible overall program with the funds available, the Foundation terminated its support of institute programs for elementary school personnel and the program of Visiting Scientists for Secondary Schools. Concurrently, it increased its support of a wide variety of experimental projects in areas related to pre-college education. Also, through the Cooperative College-School Science Program, more emphasis was given to curricular reform and teacher training activities in the context of the needs of school systems. This program has considerable potential for developing elementary and secondary school science. Excellent new curricula for these levels are now available for selection and adoption by school systems, which will help close the present gap between innovation and utilization.

Improvement of Instructional Materials

To help give teachers and students instructional materials that are scientifically current, the Foundation encourages the improvement of course content by collaborative efforts of a variety of specialists.

The number of definitive editions of precollege textbooks and other printed materials in science and mathematics which have become available with Foundation support is now approaching 300. Films and other audiovisual aids total about 600. Interest has mounted steadily since the first course-content improvement project at the secondary school level was initiated in 1956, and is not confined to the United States. Nearly 200 translations or adaptations of English language versions of the materials are in use in various foreign countries.

During fiscal year 1967 the Foundation gave increased emphasis to assisting the efforts of major curriculum study groups by awarding grants to the University of Maryland, University of Texas, Michigan State University, Upper Midwest Regional Educational Laboratory, and the Educational Development Center. These grants were for conference-workshops to train people who can work with schools and school systems interested in adopting new curriculum developments. The trainees have diverse backgrounds and have demonstrated interest in elementary science education.

Among the major curriculum groups that have completed or are completing current projects are the following:

- The Biological Science Curriculum Study group (secondary school level activities), which has completed a series of four texts and is now engaged in finishing work on 40 single-concept film loops which will supplement the text and laboratory materials;
- The School Science Curriculum Project at the University of Illinois, which has been developing science units over a broad range of disciplines for grades 5 through 9;
- The Earth Science Curriculum Project, whose materials have reached the commercial publication stage;
- The Introductory Physical Science Project, which has completed a textbook to be used by approximately 150,000 students in 1967–68 and is finishing work on a teachers' guide;
- The University of Illinois Committee on School Mathematics, which is preparing to have its materials for the seventh and eighth grades published;
- The Engineering Concepts Curriculum Project, which will have completed work on a text by the fall of 1968;
- The High School Geography Project, which expects to have a text commercially published in 1969.

Some examples of new activities for course improvement that will be in progress as a result of Foundation support awarded in fiscal year 1967 are:

- The Educational Broadcasting Corporation of New York will plan and test an experiment in televised mathematics education for elementary teachers. The pilot study proposes to develop innovative patterns in the use of mathematically sound materials for furthering both the education of teachers and public understanding of mathematics. Written materials to accompany the TV programs will be prepared.
- Dartmouth University will conduct a project to extend the time-shared computer system available to Dartmouth faculty and students to teachers and students of 20 surrounding high schools. The grant provides for early exposure of secondary school students to computers in conjunction with regular classroom instruction.
- The Education Development Center, Newton, Mass., will begin the development of a second-year extension of a junior high school level course in Introductory Physical Science.
- The University of Illinois will study ways of improving science teaching at the secondary school level through more appropriate use of mathematics. New mathematical treatments will be explored and preliminary work undertaken on a science teachers' handbook.

Currently the Science Curriculum Improvement Study group is arranging for commercial editions of materials for the first and second grades; material for additional grades is in the preliminary development stage and can be expected to appear in print at regular intervals until 1972, when materials for kindergarten through the sixth grade will be available. The Minnesota School Mathematics and Science Teaching Project, devoted to the development of a coordinated science-mathematics curriculum, this year has made the first attempt in the exceedingly difficult task of interweaving separately developed science and mathematics curricula for the first grade. The Elementary Science Study (ESS) group continues to produce study units of high quality and appeal for grades 1 through 6, and to conduct essential investigations into ways in which these units can be taught effectively. Approximately 20 ESS units have undergone revision in the past year prior to commercial publication.

Cooperation in School System Improvement

Effective implementation of advances in curricular reform usually requires the advice of experts in making selections from various alternative courses, assessing the implications of changeover to a new curriculum, and the availability of specialists to help train the teaching staff. These important elements are frequently unavailable to the school administration seeking to bring about immediate improvements on a large scale.

One solution to school system improvement problems is offered through the Foundation's Cooperative College-School Science Program. This program provides for collaboration between the staff of a school system and the science faculty of a college or university. Experts in the subject matter of science and mathematics are thus made available for consultation and to conduct the teacher training needed by the local schools.

An effort supported by the Foundation in fiscal year 1967 will serve to illustrate the kind of cooperation that makes for desired improvement. The Unified School District in Lawrence, Kans., requested assistance from the University of Kansas in planning and implementing a science program in its elementary schools. The university will conduct a project for the elementary teachers and supervisors which will focus on two activities. First, the teacher-participants will be given training, including laboratory work, during a summer phase so that they will have the necessary background material for working with one of the improved elementary science projects. The second phase consists of a coordinated academic-year program of weekly meetings, demonstration classes, and assistance with implementation of the elementary science materials. At the conclusion of the project, the school district will have adopted improved science curricula for the kindergarten through the eighth grade with trained teachers who understand how to use the materials.

Another interesting example of the cooperative effort is a project supported at the University of Colorado. The university operated two identical 5-week programs in cooperation with Boulder Valley School District and Jefferson County School District during the summer of 1967. The major goal of this project was to improve and strengthen the school offerings in mathematics and science by using the computer as an instructional tool. For the Jefferson County Schools this involved operating time-sharing computer consoles in the high schools so that the teachers and students could have direct access to the computer. The teachers and students from the Boulder Valley Schools traveled to the University Computer Center during the academic year to have access to a computer. Materials and techniques developed during the summer are scheduled for use in the 1967–68 academic year.

Implementation of new curricula requires of the elementary school teacher not only increased proficiency in subject matter but often also reorientation in philosophy and methodology. Under the Cooperative College-School Science Program, the work of the Madison Project with the school systems of Chicago, New York City, San Diego, Los Angeles, and Philadelphia is providing a model for the introduction of improved mathematics teaching at the elementary level. More than 600 teachers in each of the school systems underwent intensive instruction with project

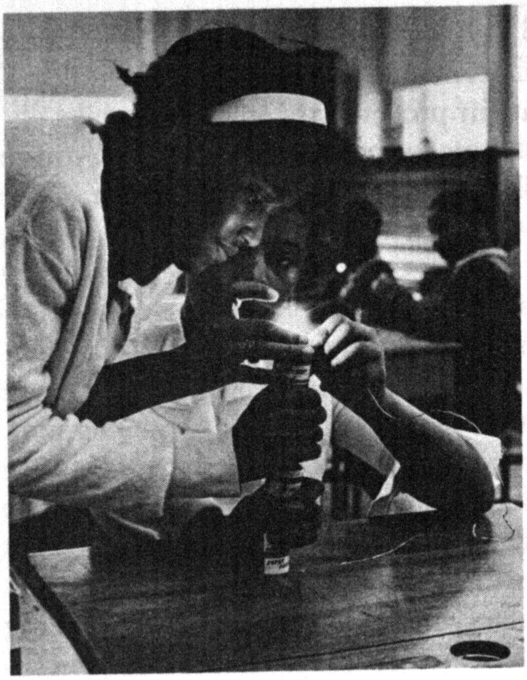


Figure 24

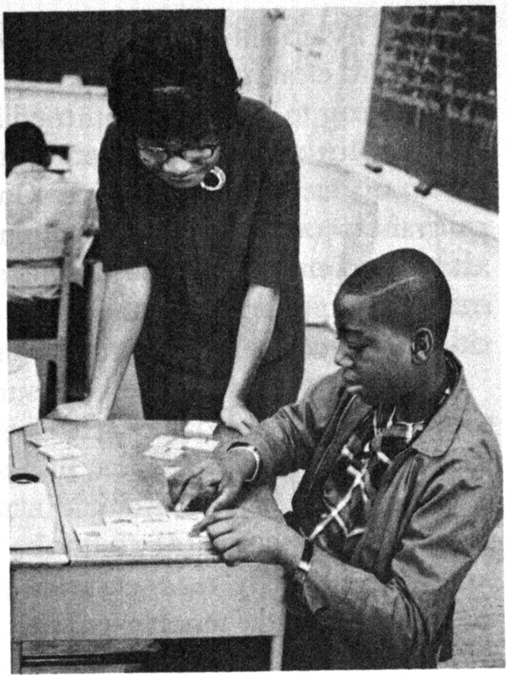


Figure 25

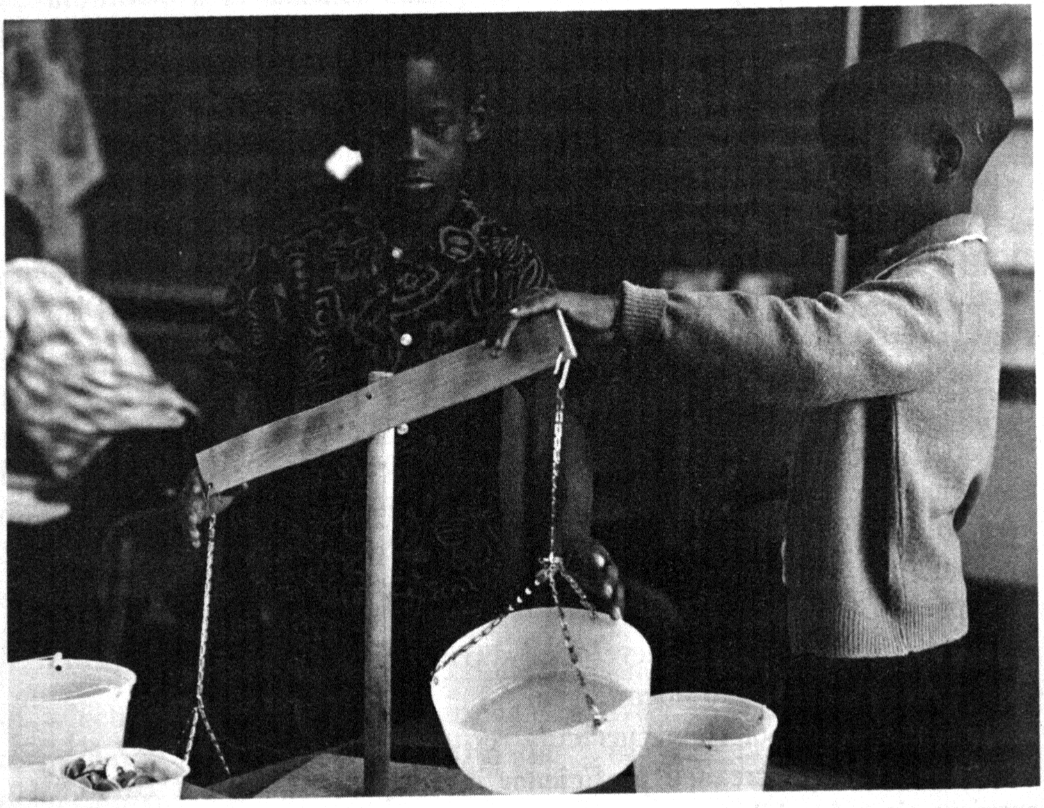


Figure 26

Photos: George Cope, EDC

Figures 24, 25, and 26. *These classroom scenes illustrate special projects being conducted in inner-city schools to combat deficiencies in curriculum and methodology which are contributory causes of high rates of failure and drop-outs. As experience is gained in combating these problems, more school systems can be expected to adopt improved science curricula for the elementary grades with trained teachers who understand how to use the materials.*

materials developed under the Course Content Improvement Program during the summer of 1966 and the following academic year.

From this broad base, key teachers were selected to receive further training so that they can become resource staff for the school system, able to lead their own in-service programs and function as master teachers, supervisors, and curriculum specialists. The experience gained in these continuing "big cities" mathematics education seminars has already been put to use in six workshops held in the summer of 1967 to train similar resource staff for the major elementary science and social science curriculum sequences now being developed under the Course Content Improvement Program.

The Cooperative College-School Science Program has had an extended period of growth, from a few grants for small experimental projects in fiscal year 1961 to a level of 52 grants totaling $2,296,295 in fiscal year 1967. Funds awarded this year represent an increase of 17 percent over the amount awarded in fiscal year 1966.

Activities for High School Students

In seeking to identify high-ability secondary school students and to reinforce their motivation for pursuing careers in science, the Foundation provides opportunities for close personal contacts, in a scholastic environment, between selected students and experienced scientists. Financial support for appropriate activities is made available through the Secondary Science Training Program.

In fiscal year 1967, approximately 5,000 high school students had training experiences of 5 to 10 weeks' duration during the summer. These activities were conducted on college campuses or in qualified research institutions. The students received college-level instruction and, in many cases, worked on research projects in a junior but not menial capacity. Approximately 1,000 additional students are receiving equivalent training on a commuting basis during the academic year, usually meeting on Saturdays for 30 to 35 weeks.

A project conducted at Cornell University this past summer illustrates the types of instruction provided in the Secondary Science Training Program. The university presented a 6-week program, "Adventures in Physics," which exposed 36 high school students (who had completed their junior year) to two theoretical topics in physics and to independent

University of Illinois Photo

Figure 27.—*Thousands of high school students receive college-level training during summer programs on campuses or at research institutions. This group is participating in a program in engineering sciences at the University of Illinois, Urbana, Ill.*

laboratory work with research-grade equipment. Lectures given by faculty members were followed up by group discussions and the working of exercises and problems. The approach emphasized physical phenomena (observations and measurements), and the associated logic that leads to the development of modern concepts in physics. Laboratory work began with an introduction to the use of equipment and the principles of measurement, after which the students engaged in individual projects. In the final days of the session, each student presented a report on his project to the entire group and their instructors.

The Secondary Science Training Program is designed to encourage and to advance exceptionally capable young students who are interested in science. The caliber of the participants is impressive as is indicated by a recent study of students who participated in 1960 summer projects. Facts developed from the more than 5,000 completed questionnaires returned by these students were that: 98 percent of the participants entered college; 81 percent of the boys and 65 percent of the girls majored in science; 85 percent of the boys and 74 percent of the girls are taking, or plan to take, postgraduate work in some subject; and 41 percent of the boys and 22 percent of the girls have active plans to work for a Ph. D. degree.

Pre-college Teacher Education Activities

Keeping pace with changes in scientific knowledge and the use of new materials and techniques in science teaching is a problem for many in-service teachers who once were well prepared as science teachers. Teachers assigned to teach science subjects in which they have inadequate backgrounds are faced with even greater difficulties. In an effort to provide the necessary supplementary training, the Foundation has supported institutes and other teacher education activities for the past 14 years. A significant number of pre-college teachers have received such training, but there are still many more who need and seek appropriate training that will help them to improve the science education provided by the schools.

This year approximately 36,650 secondary school teachers of science and mathematics were afforded study and training opportunities in 851 instructional projects—institutes, research participation, and other special projects. The teacher-participant group represents about 19 percent of the Nation's science and mathematics teachers of grades 7 through 12.

Although significant progress in upgrading the subject-matter competence of teachers is made each year, the training problem becomes further complicated by the constant growth in educational needs of teachers.

Case IT Photo

Figure 28.—***Participants recover printed results during Summer Institute for Secondary School Teachers on digital computing methods at Case Institute of Technology.***

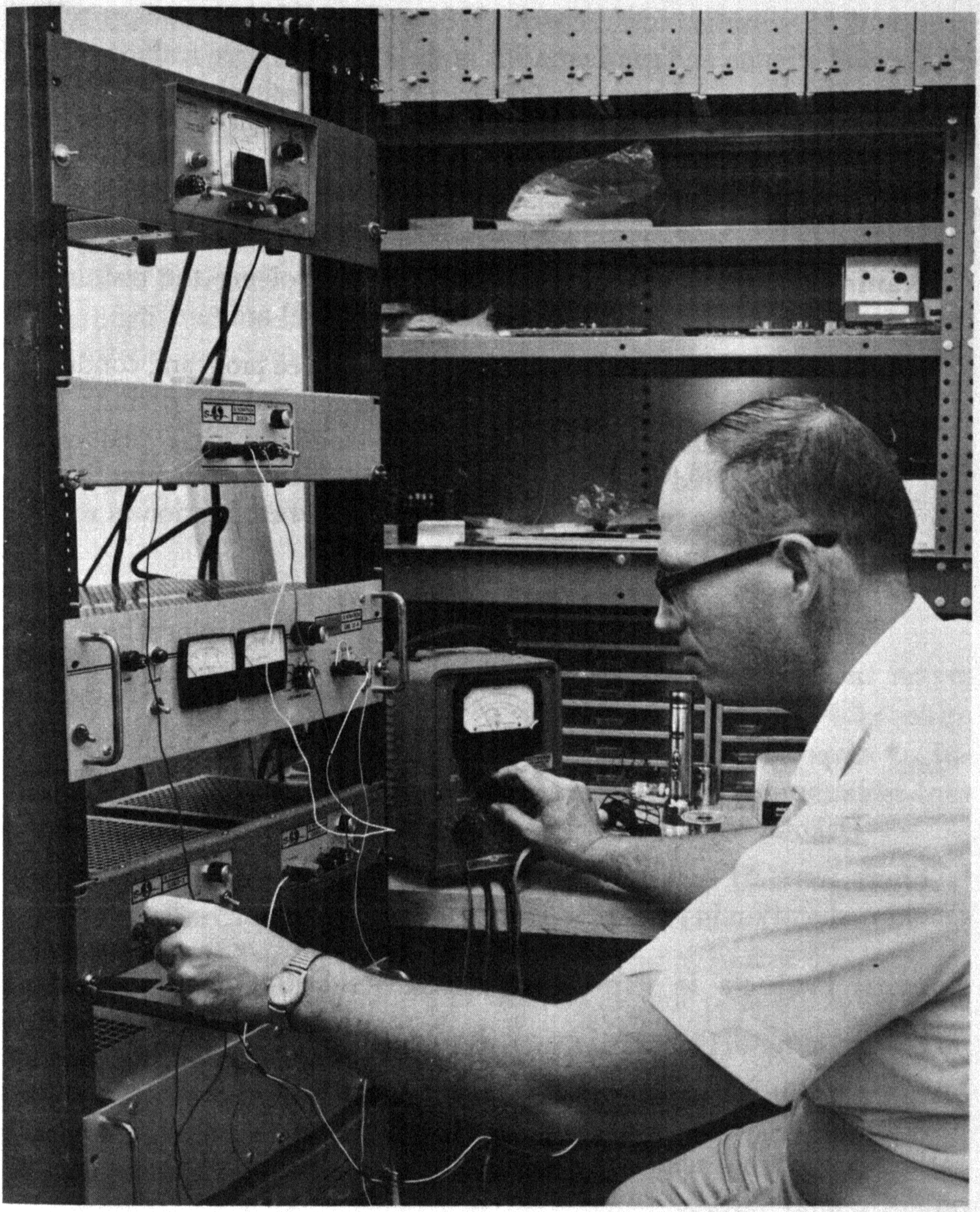
Most of the increased needs stem from the substantial modernization of course materials used in classrooms and the annual recruitment of large numbers of new teachers by the schools—many of these being inadequately trained for teaching science and mathematics.

Training projects for secondary school teachers vary considerably, in both format and content. Institutes may be conducted on a summer, academic-year, or after-school (or Saturdays) basis. Research participation, conferences, and special projects for this group are also supported. Designed to provide sound foundations in subject-matter knowledge for the teachers, these activities focus on one or more of the following objectives:

- Remedial training for teachers who were initially ill-prepared;
- Updating of subject-matter knowledge for those who once were adequately prepared;
- Specific background training to equip teachers to teach the newer curricular materials;
- Training in depth to enable teachers to meet new, higher standards (such as those represented by a master's degree);
- Advanced specialized training for teachers and supervisors preparing for positions of leadership in science education;
- Introduction of teachers to research methodology through participation in scientific research activity.

This year marked the termination of Foundation support of institutes for elementary school personnel. In the 8 years of experimentation with both in-service institutes and summer institutes for elementary school personnel, 529 grants totaling $9,022,774 were made. Primary targets have been those elementary schoolteachers and supervisors who were in positions to lead their schools in revising the elementary science and mathematics curriculum. (The preponderance of grants was awarded in mathematics.) A principal thrust of this effort was to encourage the design and trial of training projects, which were distinct in content from typical undergraduate training for teachers. In supporting the development of these prototype training projects, the Foundation has helped to create a cadre of educational leaders and scientists who are prepared to improve local educational programs through use of the support now available to localities under the Elementary and Secondary Education Act of 1965.

It is of interest that an In-service Institute for Elementary School Personnel, conducted at the University of Georgia under a Foundation grant in fiscal year 1966, received The Distinguished Achievement Award for Excellence in Teacher Education (1967) of the American Association of Colleges of Teacher Education for its project design and effectiveness. This project in elementary mathematics combined the University, the



University of Arizona Photo

Figure 29.—*High school teacher works on experimental relativity project in the physics laboratory of the University of Arizona. Secondary school teachers of science and mathematics in all parts of the country receive training opportunities during summer programs at colleges and universities.*

State Department of Education, the State's educational TV, 30 school districts, neighboring colleges, films developed under another Inservice Institute grant, and the U.S. Office of Education's Regional Educational Laboratory in providing instruction to some 900 elementary teachers throughout the State of Georgia.

A different kind of experimental approach to elementary science and mathematics was supported this year as a special project. Through a group of 11 summer conferences, 328 well qualified secondary school teachers of science and mathematics and supervisors were trained to conduct local training programs for their elementary school colleagues during the academic year. The conferences were designed to give the participants an understanding of modern mathematics and science at the elementary school level and to develop these individuals as resource personnel for training efforts in their home school districts.

Examples of other current special projects involving the training of teachers or supervisors at the secondary school level are:

- A new type of academic-year master's degree program, conducted at California State College at Fullerton, which permits local biology teachers to study on a half-time basis for 2 years while being replaced in their classrooms by fifth-year teaching interns who will also receive master's degrees and certification as regular teachers after completing their training;
- A 1-week conference for State supervisors of science, conducted at the University of Virginia, to enable them to explore the various new science courses in depth with course content project directors;
- A program for retraining retired military personnel who desire to become science teachers, conducted at the University of South Dakota.

There were 23 such awards, totaling $336,560, made for pre-college teacher education in fiscal year 1967.

Special Projects in Pre-college Science Education

Under a new Foundation activity, established in fiscal year 1967, imaginative approaches to science education problems at the pre-college level are encouraged. The Special Projects in Pre-college Science Education program supports small-scale experimental projects, usually one-of-a-kind efforts.

Several unusual projects were awarded grants this year. One will introduce an elementary science education program as a model for the improvement of the elementary curriculum in schools throughout a large area of eastern Kentucky. (This project is supported as a part of a larger effort being funded by the U.S. Office of Education under a title I grant for impoverished schools.) Another interesting activity is a joint project conducted by the University of Pennsylvania and the Philadelphia School System involving a unique method for training elementary science supervisors. The participants will be strongly subject-matter oriented as a result of the training, but also will be thoroughly familiar with the new elementary science curricula, particularly as these new materials may be adapted to inner-city schools.

Another example of projects supported under this program is a study designed to evaluate the adoption of new science course curricula by a number of schools in northern California and Nevada. When it is completed, the study will provide valuable guidance to both the National Science Foundation and the various regional laboratories (supported by the Office of Education) in facilitating the widespread adoption of the new curricula. This grant was awarded to the Far West Laboratory for Education Research and Development.

Through such special projects for pre-college science education both local needs and broader requirements may be served. Fundamental studies, in addition, may shed light on current or new practices that will give direction to further improvement efforts.

Table 11 provides a statistical summary of the fiscal year 1967 pre-college teacher education activities.

PUBLIC UNDERSTANDING OF SCIENCE

Public understanding of science and its role in today's world serves more than a cultural purpose; it is a requisite for effective citizenship. Through support of appropriate projects, the Foundation seeks to increase public knowledge of scientific facts and convey some insight into scientific processes.

Among the projects awarded support in fiscal year 1967 were:

An effort of the Scientists' Institutes for Public Information to aid local affiliates in providing scientific and technical information to their communities (topics of interest include population growth, automation, mental health, and air and water pollution);

A conference to be conducted by Oak Ridge Associated Universities, Inc., to help clergymen understand the nature and trends of contemporary science;

Television projects, including the National Educational Television and Radio Center's production of five television programs for the "Spectrum" series;

Design and preparation of science exhibits, including public exhibits to be developed by the University of Utah for long-term, state-wide use;

Design and evaluation of an experimental curriculum on public understanding of science by the New School for Social Research, New York, N.Y., for use by adult education centers;

A series of three science writers' seminars on atmospheric sciences to be conducted by the American Meterological Society.

A total of $427,205 was awarded in fiscal year 1967 for 17 grants in support of projects on the public understanding of science.

Table 11.—*Pre-college Teacher Education Activities, Fiscal Year 1967*

Program	Proposals received			Grants awarded		
	Number	Partici-pants	Amount	Number	Partici-pants	Amount[1]
Secondary school teachers:						
Academic year institutes	81	2, 115	$14, 408, 935	63	1, 503	$9, 188, 561
Summer institutes	760	32, 015	38, 342, 377	432	19, 393	21, 311, 242
In-service institutes	368	17, 305	4, 706, 068	270	12, 941	2, 953, 796
Subtotal	1, 209	51, 435	57, 457, 380	765	33, 837	33, 453, 599
Research participation for high school teachers	75	562	1, 227, 362	60	377	734, 235
Supplemental projects: Summer conferences	12	361	146, 612	10	299	116, 460
Supplemental projects for secondary school personnel	25	2, 594	374, 650	21	2, 140	216, 505
Supplemental projects for other pre-college personnel	17	1, 430	455, 361	12	1, 193	151, 190
Subtotal	54	4, 385	976, 623	43	3, 632	484, 155
Total	1, 338	56, 382	59, 661, 365	868	37, 846	34, 671, 989

NOTE.—Total number of proposals received and grants awarded include double count on combined activities: i.e., 13 combined summer in-service institutes, 1 combined academic-year institute and supplemental project, 1 combined summer institute and supplemental project, 1 combined conference and supplemental project, and 3 combined special and supplemental projects.

[1] Net obligations.

INSTITUTIONAL PROGRAMS

In addition to the traditional objective of maintaining the strength of academic science at institutions of recognized excellence, the Foundation has recently undertaken new programs to assist selected colleges and universities in upgrading their capabilities in science education and research. The number and variety of programs that provide support on an institutional basis have had a notable impact on the overall program structure of the Foundation.

This trend reflects increasing national concern with the need for more universities and colleges of high quality in every region of the nation—including an enrichment and expansion of national capability in scientific research and education in the sciences. Activities undertaken to meet these needs were further stimulated by the President's memorandum of September 13, 1965, to Heads of Departments and Agencies on the subject "Strengthening Academic Capability for Science Throughout the Country." To administer these programs, an Office of Associate Director (Institutional Relations) was established effective January 23, 1967. Assigned to this office were responsibilities to plan, direct, and administer the NSF programs for University and Departmental Science Development, Graduate Science Facilities, and Institutional Grants for Science. All of these programs are directed predominantly at the graduate level and include assistance to research as well as education per se. The new College Science Improvement Program, which is also institutional in nature, is directed at predominantly undergraduate colleges and is discussed in the context of undergraduate education (see p. 131).

Unlike other programs of the Foundation which support graduate institutions with existing excellence, the University and Departmental Science Development Programs are for institutions which, while they have current strength and the potential to advance, need help to join the ranks of institutions having outstanding capability in science. To receive such help, a realistic plan for scientific improvement must be developed, and the proposing institution must be willing and able to contribute some of its own resources to the development program. These requirements help preserve the autonomy of participating colleges and universities. About sixty percent of NSF's institutional support for science is devoted to programs of institutional science improvement while the balance is allocated to maintaining institutional strength in science.

The growing Federal role in institutional support, to which other Federal agencies also contribute, has given rise to issues which have not

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yet been resolved, and indeed it is reasonable to expect that some of these issues will endure. In addition to the problems of interagency coordination, there are inevitable difficulties in determining the allocation of available resources between research support programs and those for institutional development. Limitations on total resources compel difficult decisions regarding the balance of support among the various kinds and quality of institutions which might be eligible. How should a proper balance be arrived at between maintenance and improvement of high quality in the major universities of recognized quality as compared with universities of lesser prestige, but with a strong drive and a potential towards improvement?

The question of distribution of Federal research funds among the States and regions of the Nation is also receiving increased attention. From the point of view of research productivity, it is evident that it is not fruitful simply to redistribute research support funds without regard to capability. Careful study of this complex problem involving multipurpose objectives indicates that the solution to increasing the base for high-quality research is to help institutions with potential for improvement that have concrete plans for fulfilling that potential and the needs of the region or locality in which they are located. Accordingly, improvement of good departments in average institutions carrying an increasingly heavy load of graduate training must find support.

The largest supporting Foundation program is the "University Science Development Program," which, from its beginning in fiscal year 1965 to the end of fiscal year 1967, has obligated almost $100 million in support of 25 institutions in 13 States. In fiscal year 1967, two additional development programs were started to provide help at the university department level (Department Science Development) and to undergraduate institutions (College Science Improvement). Funding for all these programs totaled about $60 million in fiscal year 1967.

Eligibility criteria for these programs are distinctive in each case, and collectively they extend across the needs for institutional development from the undergraduate to the doctoral level. The University Science Development Program is restricted to the needs of Ph. D. granting institutions. Departmental Science Development grants may be made to institutions offering graduate programs at the master's level, but strengthening of undergraduate science programs may also be included in the development plan. The College Science Improvement Program is expressly designed for 4-year colleges having a meaningful commitment to science among the curricula offered.

The three developmental programs mentioned above—together with programs for Graduate Science Facilities, and Institutional Grants—provide comprehensive support to assist institutions in improving the quality and extent of their scientific activities across a wide front. Four are discussed below. As previously stated, the College Science Improvement Program is included in the section on Science Education.

UNIVERSITY SCIENCE DEVELOPMENT PROGRAM

The purpose of the University Science Development Program is to assist in increasing the number of universities capable of conducting distinguished programs of education and research in the sciences. Through large grants to a relatively small number of carefully selected institutions having doctoral programs and well-developed, long-range plans to achieve general distinction, the Foundation helps them accelerate their efforts to improve their relative standing among universities. Universities which are already recognized for overall excellence are not encouraged to apply for these grants. To the list of 17 institutions awarded University Science Development grants in prior years, 8 were added in fiscal year 1967: Carnegie Institute of Technology, Duke University, Indiana University, University of Maryland, University of North Carolina at Chapel Hill, University of Notre Dame, University of Texas, and Vanderbilt University. The eight grants, each to be used over a 3-year period, totaled $33,169,000. Altogether, the grants to all 25 institutions amount to $96,938,000 and range in amount from $2,390,000 to $5 million. It is expected that several of these universities will advance rapidly enough toward their 5-year goals to qualify for additional supplemental support from the Foundation.

The institutions receiving University Science Development grants undertake to assume a substantial part of the costs of the planned improvement in addition to their normal increments of support for the participating departments. In accordance with the plans submitted by the 25 institutions, the Federal funds made available are allocated on average as follows: personnel (faculty, postdoctoral students, graduate and undergraduate students, and technical and clerical staff), 41 percent; equipment and supplies, 32 percent; and facilities (renovation and new construction), 27 percent. By field of science, the largest amounts of funds have been allocated to physical sciences (39 percent) and interdisciplinary areas (24 percent).

In planning the program the Foundation hoped that it would lead to the growth of major universities in geographic areas now lacking such institutions. There are encouraging signs that this hope will be fulfilled. Without relaxing the objectives of the program or the standards of selection, the Foundation has awarded University Science Development grants to universities in all but one (New England) of the Nation's main geographic divisions. Of the 25 institutions, six are located in the South Atlantic Division, five in the East North Central, four in the Middle Atlantic, four in the West South Central, two in the Mountain, two in the Pacific, one in the West North Central, and one in the East South Central.

The full effect of the program on the Nation's educational institutions will probably not be clear for a generation. But while it is much too early to evaluate the effectiveness of the grants, preliminary assessments encourage the belief that the grants are achieving their objective:

The grants are flexible enough to assist universities in cooperative endeavors with other institutions and in some instances have stimulated such efforts.

The grants have encouraged interdisciplinary activities on the campuses of several institutions and brought greater vigor to departments not included in the development supported by the Federal funds.

Several institutions report that the grants have favorably influenced their ability to attract funds from other sources.

Faculty recruitment—a key to the success of the improvement plans—has been facilitated, largely because of the heavy institutional commitment and the institutional prestige that the grants have come to represent in the academic community; these universities are considered to be "on the move."

There is evidence, too, that the universities receiving the grants are beginning to attract larger numbers of well-qualified graduate and postdoctoral students.

The program has had a salutary effect in accelerating and extending institutional planning, not only for the areas supported by the grants, but for other parts of the universities as well.

The program's emphasis on careful institutional planning has been very beneficial not only to the institutions receiving awards but to many others as well. Many institutions not receiving awards have been led to a careful and objective examination of their own strengths and weaknesses and to the formulation of long range objectives for themselves. Often the aspiration to qualify for an award has helped institutions in enhancing local and State support for their plans.

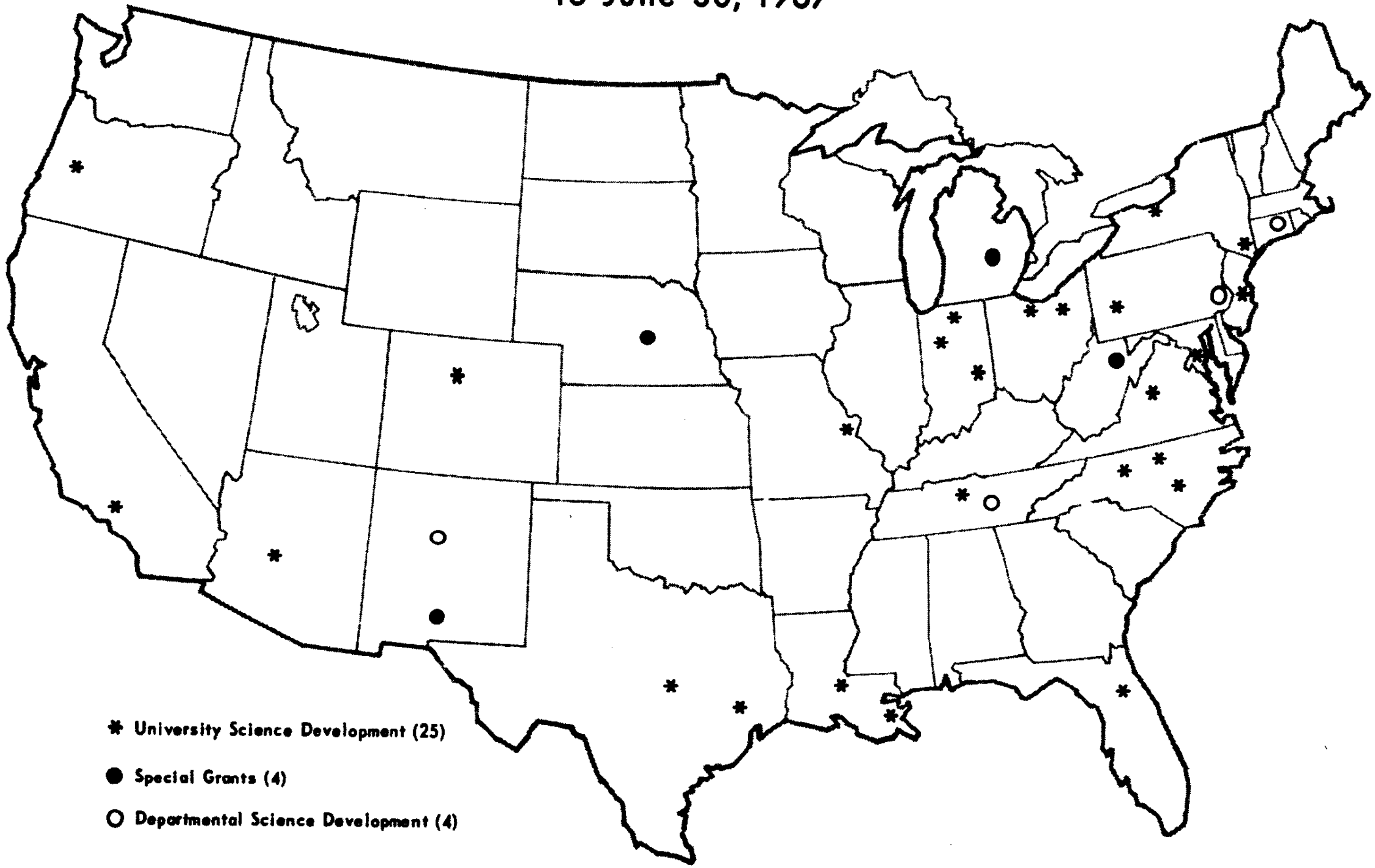
DEPARTMENTAL SCIENCE DEVELOPMENT PROGRAM

There are only a small number of exceptionally strong universities—which the University Science Development Program aims to increase—but there are many other institutions offering graduate degrees in science and engineering and admitting large and increasing numbers of graduate students in these fields. These institutions are performing a vital service, and with rising graduate enrollments, their contribution must continue to grow. Typically, the science program as a whole in these insitutions has not reached high levels of quality, but often one or two departments or interdisciplinary areas can be identified which have appreciable

National Science Foundation

SCIENCE DEVELOPMENT AWARDS

To June 30, 1967



strength. Assistance to these leading activities so that they may achieve a high level of quality in research and teaching will not only enhance the value of their service but also, in many cases, will stimulate improvements in related departments. The good departments give the whole institution a target to aim for, and thus Foundation support has a multiplying effect.

As a means of increasing the number of institutions providing high-quality training in science at the graduate level—and concomitantly improving the quality of undergraduate instruction—the Foundation announced, in fiscal year 1967, a new program directed at assisting the improvement of single departments or interdisciplinary areas and designated, for simplicity, Departmental Science Development. Open to institutions offering master's or doctor's degrees in science or engineering, the program offers the possibility of substantial support for development in institutions not yet having strength in a sufficient number of departments to qualify for grants under the University Science Development Program.

In evaluating a proposal for a Departmental Science Development grant, the Foundation looks at the institution as a whole as well as at the department or area for which support is sought. The evaluation considers the soundness of the plan for the proposed development; the ability of the institution's and the department's leaders and their dedication to the plan; the nature and quality of the department's present faculty, students, facilities and equipment, and research programs; the strength of related departments; the likelihood that the department can attract suitable new faculty and students; and the institution's financial resources for undertaking the expansion and maintaining the higher levels of quality after the grant expires. Like the University Science Development grants, those for departmental development run for 3 years.

Although the new program could not be announced until after the Foundation's appropriation was made in September 1966, it immediately attracted widespread interest. In June 1967 the Foundation made the first awards for departmental development; four grants amounting to $1,945,000 in all were made to Clark University, Drexel Institute of Technology, University of New Mexico, and Tennessee Technological University. Additional proposals already received in considerable number are being evaluated at the time of this writing. Many institutions are now drafting proposals, and the Foundation anticipates that 100 or more insitutions will request support for departmental development in the next fiscal year.

In addition, during the current fiscal year the Foundation awarded three "special" development grants—to the University of Nebraska, the West Virginia University, and Wayne State University. These were similar in concept to the grants awarded under the University Science Development Program and the Departmental Science Development

Program but did not quite fit either category. One such grant had been awarded in the prior fiscal year.

GRADUATE SCIENCE FACILITIES

The oldest of the Foundation's institutional programs—Graduate Science Facilities—has the objective of maintaining and strengthening research and research training through the provision of matching funds for construction or renovation of science buildings and laboratories. Other Federal agencies also support the construction of science facilities—sometimes in cooperation with the Foundation—but the Graduate Science Facilities Program alone has the responsibility for support of graduate academic facilities in all fields except the clinical sciences. Science facilities are also provided by the University Science Development Program, but only as part of a general plan of development rather than for specific needs, and by definition of purpose it excludes the foremost universities. If present national strength in science is to be maintained, institutions of established merit need substantially more help from the Federal Government in meeting their facility needs.

In fiscal year 1967 the Foundation's support of graduate facilities construction was curtailed by a reduction of funds available for this purpose. Consequently, awards were made almost exclusively to very strong universities where needs for expansion or replacement facilities were most urgent. All of the grants were arbitrarily reduced in size—only one grant exceeded $1 million—so that a larger number of institutions could be assisted. Funds for general purpose laboratory apparatus were excluded from all grants. Thus, the average size of the 56 grants (totaling $15.1 million) made in fiscal year 1967 was 44 percent less than the average of the year before. During the 7 years of the program's existence, the Foundation has awarded 898 graduate facilities grants for a total of $164,745,957.

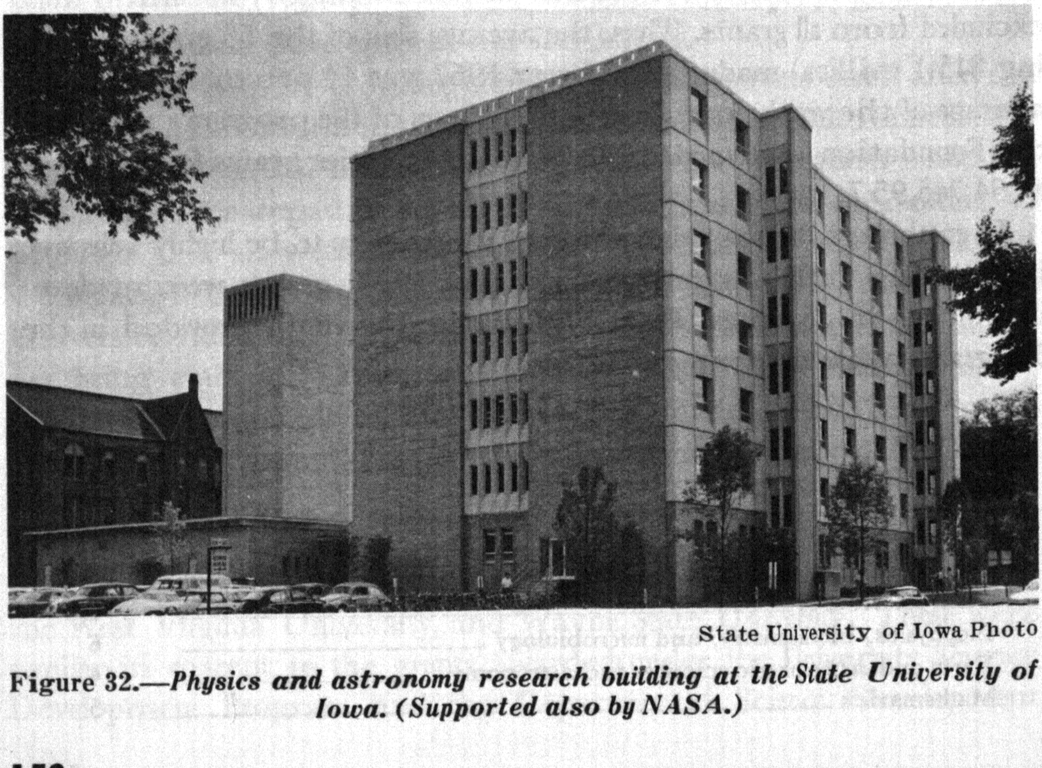
Even though the Foundation found it necessary to be highly selective in awarding facilities grants in fiscal year 1967, grants were made to institutions in 25 States. By field of science the funds provided in the 56 grants were distributed as follows:

	Percent
Chemistry	19
Engineering	14
Physics	18
Behavioral sciences	7
Animal sciences	14
Plant sciences	3
Biophysics, biochemistry, and microbiology	6
Earth and atmospheric sciences and astronomy	14
Mathematics	5

Foundation programs of institutional support are designed to assist in the implementation of plans devised by the institution to meet its particular requirements. The photographs which follow are examples of new facilities in which Foundation support contributed to the science portions.

University of Colorado Photo

Figure 31.—*Engineering Center at the University of Colorado.*

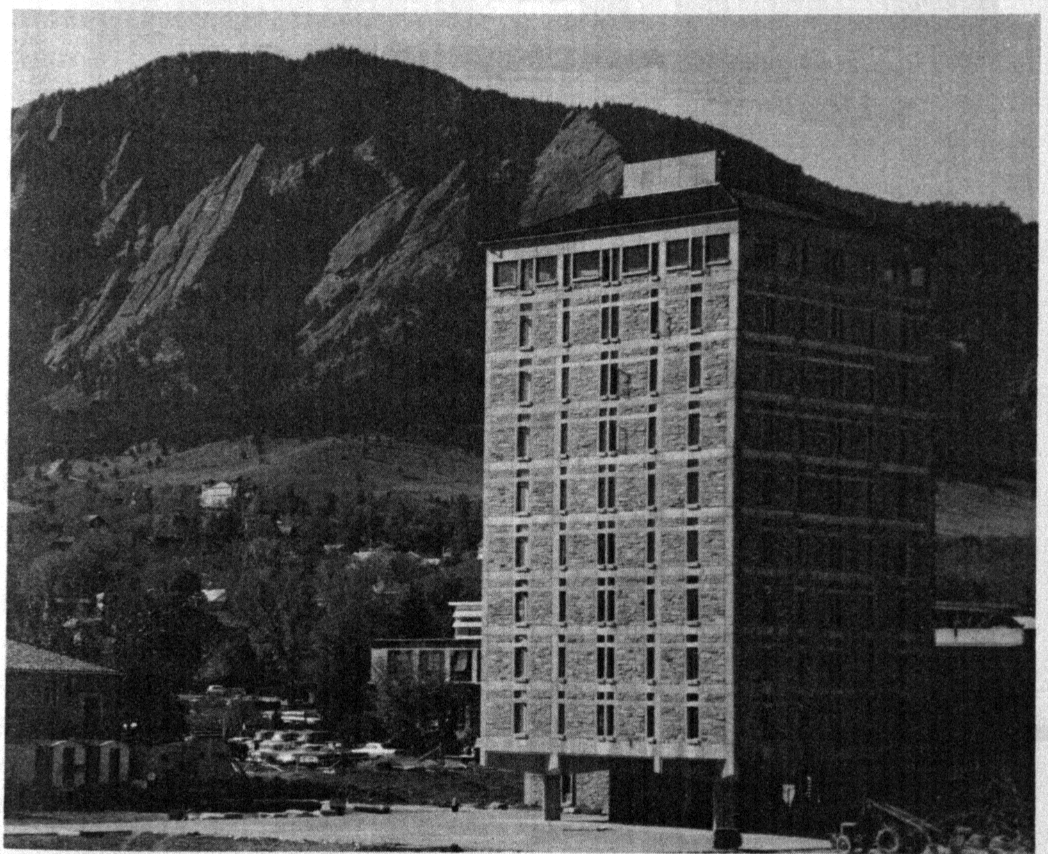


State University of Iowa Photo

Figure 32.—*Physics and astronomy research building at the State University of Iowa. (Supported also by NASA.)*

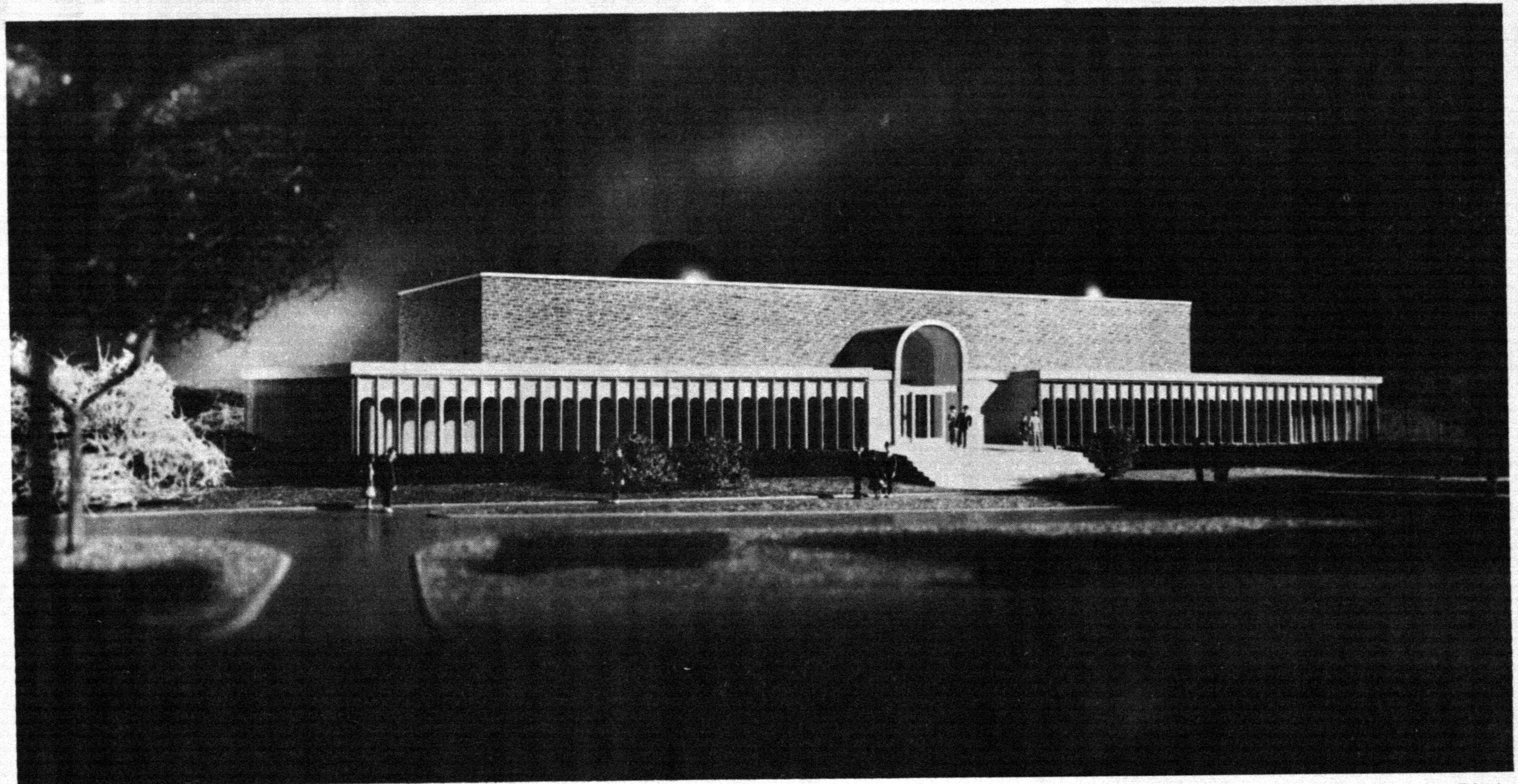
University of Illinois Photo

Figure 33.—*Chemistry building at the University of Illinois.*



University of Colorado Photo

Figure 34.—*Research and research training facility for the Joint Institute of Laboratory Astrophysics, a cooperative research organization formed by the University of Colorado and the U.S. Bureau of Standards.*



Princeton University Photo

Figure 35.—*Astrophysical science building at Princeton University.*

During the year the Foundation completed a study of the probable needs of the Nation's universities for graduate science facilities for the next decade. The results of this study indicate that, as a minimum, an average of $439 million per year will be required for the construction of such facilities, if adequate space for the increasing number of graduate students and faculty members is to be provided. In fiscal year 1967 the total expenditure was approximately $290 million, of which the Federal Government supplied about $90 million. There is serious question as to whether the major universities will be able to continue to increase their share of the expense sufficiently to meet the estimated additional requirements.

INSTITUTIONAL GRANTS FOR SCIENCE

Foundation policy emphasizes that responsibility and decisionmaking for the strengthening of science programs be vested heavily in institutions of higher learning. Seven years ago the Foundation began its program of Institutional Grants for Science to help meet the need of colleges and universities for funds that could be used flexibly to maintain strong, well-balanced programs of education and research in the sciences. The funds provided by these grants are uniquely flexible, allowing institutions maximum freedom in their use. They are for general support of science and may be employed as the institutions themselves decide, excluding only nonscience activities and indirect costs. The Foundation has kept the administration of the program as simple as possible in the interest of protecting institutional freedom. Colleges and universities have demonstrated their responsibility by wise and careful use of the funds.

In fiscal year 1967 the Foundation awarded $15,152,015 in Institutional Grants for Science to 517 colleges and universities in all 50 States, the District of Columbia, and Puerto Rico. The grants, computed by a graduated arithmetical formula based on grants made for research purposes, ranged in amount from $709 to $159,186. Over one-third of the grants were for $20,000 or more, and 55 institutions received grants of more than $100,000.

During the 7 years of the program, a total of $65.3 million has been awarded to 673 different institutions of higher education. Colleges and universities are eligible to receive Institutional Grants if, during the preceding year, they have received Foundation grants for research, undergraduate research participation, or research participation for college teachers. The formula matches equally the first $10,000 of the amount of the applicable grants and then tapers so that the largest Institutional Grants are in the neighborhood of $150,000. Although all institutions receive grants based on the amount of the Foundation's support, the tapered formula especially benefits the institutions in the middle and lower ranges of NSF research and research-training support.

Coverage of the program was extended in fiscal year 1967 to include the academic-year phase of the Undergraduate Research Participation Program. As a result, 117 institutions became eligible for small Institutional Grants. Although grants to these institutions averaged only about $2,000, the flexibility of the funds will enhance their value considerably.

Annual reports from the institutions participating in the program show a wide diversity in the use of Institutional Grant funds, even among institutions that are thought to be much alike. The variability of science needs and opportunities from campus to campus in an especially compelling reason for the provision of flexible funds and the delegation to college and university administrators of the responsibility for meeting local situations. The grants assist the institutions in adjusting to changing conditions, quickly taking advantage of special opportunities, and preserving essential control over their research and educational programs. In their preoccupation with keeping their own science programs strong, college and university officials help achieve the national goal of maintaining a sound academic base for science. The principal uses of the grant funds have been for equipment, faculty research, and faculty expansion and improvement. Nearly half of the expenditures has been for instructional and research equipment and supplies.

COMPUTER SCIENCE PROGRAM

During recent years computers have become increasingly important in both research and education. Their use by colleges and universities has grown rapidly but they remain expensive both to obtain and operate. Institutions generally have been forced to apply a larger portion of their resources to computing and smaller institutions cannot afford the computing power needed to train their students and support the research efforts of faculty members.

Foundation support for academic computational facilities has the dual purpose of providing assistance to institutions in improving and expanding their computational capabilities and of helping them to maintain and upgrade high quality computational capability where it now exists. In addition, it is clearly advantageous to explore means by which the usefulness of computers in academic science can be enhanced. There is a need for more information on alternative approaches to such questions as the relative merits of interinstitutional or regional centers compared to single campus installations, training requirements for computer center staff, and the changes in course content necessary to integrate computer use into the classroom.

Present Foundation support for computational facilities is intended to contribute to more vigorous and efficient research, improved education in the sciences, and to institutional development. It is hoped that this type of support for science can be substantially expanded in the future to help meet the needs of both small and large institutions. The following is an example of work now underway in the development of computational capability.

The University of Wisconsin, with partial Foundation support, is developing an experimental "computer information utility" to provide service to the entire University of Wisconsin system on 13 campuses. Hardware costs for the first 3 years will be nearly $6.0 million. Other operating expenses will bring the total cost during the 3-year period to more than $12 million.

Rather than set up an expensive facility on each campus, the University has decided to install a very large computer, on the campus in Madison, Wis. Nearly 300 terminals, on the Madison campus and scattered throughout the State, will be connected to the main computer by telephone lines. A variety of terminal devices, ranging from simple typewriters to large visual display devices, will allow students and faculty to make use of the computer in as simple or as sophisticated a manner as they desire. This flexibility of use is made possible by the size and sophistication of the central machine.

The computer has a modular organization which allows the system to expand as demand grows. Since up to 16 central processors can be added and one central processor represents 15 times the computing power of the old Wisconsin machine, substantial growth is allowed. During the term of the grant, input-output stations consisting of at least card readers and line printers will be installed at the College of Engineering, the Mathematical Research Center, the Social Science Research Institute, the Milwaukee campus, and several other areas of heavy demand. In addition, satellite computers linked to the central machine will be placed in the computer science department, the chemistry complex, and the Medical School. These terminals will provide much faster data transfer and allow experiments to be tied directly to the computer.

The University of Wisconsin's project is a significant approach to the crucial problem of extending to a greater number of students and faculty access to computers for research and education. If successful, the Wisconsin experiment could be a model for the future development of computing, pointing toward the time when information, and the capacity to process it, becomes a true utility as available and inexpensive as electricity is today.

In fiscal year 1967, the Foundation obligated $12.7 million for computing activities in education and research.

SCIENCE INFORMATION

Scientific research is incomplete until the data obtained and conclusions reached are communicated to other scientists. Although there are many forms of such communication, most scientific data and ideas are recorded in scientific and technical documentation the growth of which is phenomenal—for many fields of science, the volume of literature is increasing exponentially. More than two million scientific and technical articles are published annually in the world's scientific journals. The multibillion dollar annual investment in basic and applied research in the United States results in thousands of pages of scientific and technical data which must be published, abstracted, indexed, and stored for retrieval in order to secure the maximum benefits of research in the most efficient manner.

In recognition of this important aspect of the scientific enterprise, the Foundation supports a number of activities related to both national and international information resources. These include organization, preservation, exploitation, and dissemination of scientific information, as well as indexing, abstracting, translation, and other services. The Foundation also supports the development of new and improved methods of making scientific information available to American scientists and engineers and fosters the interchange of information in the domestic scientific community and between American scientists and their colleagues in other nations.

In fiscal year 1967, three major areas were selected for emphasis in support of science information:

> ***Discipline-Based Information Systems.***—Support for development of comprehensive information systems within the major scientific disciplines;
>
> ***Federal Science Information Activities.***—Support for and coordination of multiagency information programs;
>
> ***General Science Information Activities.***—Support of: (*a*) Research on documentation; (*b*) research and experimentation directed toward improvement of the dissemination of scientific and technical literature; (*c*) undirected research at information research centers in universities; and (*d*) international science information activities.

In the fiscal year ending June 30, 1967, the Foundation awarded 146 grants and contracts, amounting to $10.7 million, in support of scientific information activities. This support went to 32 scientific societies, 24 academic institutions, eight research institutes, eight commercial organizations, one museum, three government agencies, and five foreign organizations (for translation services).

DISCIPLINE-BASED INFORMATION SYSTEMS

Increased emphasis in this area of activity during 1967 resulted in the allocation of 73 percent of available funds ($7.7 million) to support for the science information systems of professional societies, as compared with 52 percent ($6.0 million) during the previous year. Foundation emphasis on the development of discipline-based information systems rests on the fact that the professional societies are, for the most part, operators of information systems serving their active members, who are collectively important producers and consumers of science information. Foundation support for the development of discipline-based information systems for eight fields of science is shown in the accompanying table.

Science information highlights for each field of science listed in Table 12 are discussed below. Support for conventional information services, i.e., translations, monographs, journals, and secondary publications, is not discussed.

Chemistry

Chemical Abstracts Service (CAS) continued development of its computerized registry system for chemical compounds. The American Chemi-

Table 12.—Discipline-Based Information Systems

Program activity and field(s)	Totals	Support of publications and services	Systems development and improvement	Research and studies
Chemistry	$1,201,807		$763,038	$465,769
Biology	1,089,845	$472,545	617,300	
Engineering	1,066,600	521,750	388,000	156,850
Physics	909,965	82,720	466,820	360,425
Mathematics	368,600	129,700		238,900
Social sciences	366,917	208,200	124,990	33,727
Environmental (earth) sciences	1,448,265	509,865	894,000	44,100
Environmental (atmospheric) sciences	262,800	243,200		19,600
	[1] 1,000,000	[1] 1,000,000		
Totals	7,714,799	3,167,980	3,254,148	1,319,371

[1] Translations and other science information activities under Public Law 480.

cal Society and CAS continued efforts to establish specifications for and to design a mechanized system capable of serving the field of chemistry.

Biology

The American Museum of Natural History initiated a bibliographic service for ichthyologists. The University of Colorado began a project to develop a prototype demonstration system for organizing and accessing biological museum specimen data in nondocumentary form. Biological Abstracts continued the pilot project for a specialized abstract bulletin for mycology.

Engineering

Engineering Index, Inc., continued its pilot effort in the development and establishment of a comprehensive, computer-based abstracting and indexing service for engineering.

Physics

The American Institute of Physics (AIP) began to plan for a physics information system. AIP undertook a study of user behavior and user evaluation of innovations in information service as the first phase of a project entitled "Current Communications in Physics."

Mathematics

The American Mathematical Society (AMS) continued development of computer-controlled photocomposition in preparing mathematical copy for journal publication. AMS also began a study on the use of machine aids for editors of scientific translations.

Social Sciences

The Council on Social Science Data Archives continued a program of collaboration in research services among major social science data archives to explore the feasibility of telecommunication links in providing access to and use of several remotely located computerized data banks. The Center for Applied Linguistics initiated a series of developmental planning studies to catalog present information sources in linguistics, study users' needs, and develop a set of requirements for a national linguistics information system. The American Psychological Association completed computerization of its secondary services.

Environmental (Earth) Sciences

The American Geological Institute continued production of *Bibliography and Index of Geology Exclusive of North America* (*BIGENA*), initiated a survey of existing information systems, and established liaison for planning integrated information systems in the earth sciences.

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The American Meteorological Society undertook a management analysis of *Meteorological and Geoastrophysical Abstracts* (*MGA*) to describe and analyze the present *MGA* operational system.

FEDERAL SCIENCE INFORMATION ACTIVITIES

During 1967 the Foundation continued its support to the Smithsonian Institution for operation of the Science Information Exchange (SIE). SIE is a clearinghouse for information on current research projects actually under way. The volume of activity at SIE has grown steadily since its establishment, and it now maintains an inventory of about 100,000 research projects supported by agencies of the Federal Government.

A second major Federal information center that has been supported by the Foundation is the National Referral Center for Science and Technology in the Library of Congress. The Center is intended to facilitate coordinated access to the nation's resources of scientific and technical information. Included in its responsibilities are identification of all significant information resources in the fields of science and technology, and acquisition and cataloging of data defining the nature, scope, and capabilities of these resources. The Center further provides advice and guidance about these resources to any individual or activity requiring access to them, either in response to specific inquiries or requests, or more generally in the form of published directories and guides.

Many of the queries posed to the Center emanate from industry, and in the evolution of this service since 1962 the Center has identified and cataloged more than 10,000 information resources. In the 5 years of its existence, the Center has become a national focal point for questions as to the sources of information on specific scientific and technical subjects.

The Foundation in 1967 continued to participate in the activities of the Committee on Scientific and Technical Information (COSATI), an advisory committee to the Office of Science and Technology, in the continuing effort to assure coordination between contemporary information developments in the Federal and private sectors of the scientific and technical communities.

GENERAL SCIENCE INFORMATION ACTIVITIES

These activities include a wide variety of science information projects, such as acquisition of foreign publications; support and publication of announcement media (translation indexes, guides, directories, *Scientific Information Notes, Current Research and Development in Scientific Documentation*); international travel for science information purposes; the support of committees and secretariats [U.S. National Committee for the International Federation for Documentation (USNCFID), the

Secretariat of the International Association of Technological Libraries (IATUL), the International Council of Scientific Unions Abstracting Board]; and staff support for review and monitorship of science information activities of various international organizations.

In support of library services the Foundation provided support for the development of (1) new means of access to library collection; (2) an integrated, computer-based, bibliographical data system at the University of Chicago; (3) unconventional library catalogs, featuring remote access for users; and (4) a centralized processing service for the acquisition of library materials for Colorado's academic institutions.

The most recent development in research and studies of a general science information character has been the implementation of the concept of supporting undirected research at information research centers established in universities. A third center was established, during fiscal year 1967, at Georgia Institute of Technology with two principal activities:

(1) Construction of mathematical models for information in the scientific disciplines; and

(2) Research on the control of information for problem-solving and decision making in an academic environment.

In addition, the Foundation also supported individual science information researchers who initiated or continued work on (1) the use of machine aids in processing information; (2) the design, development, test, and evaluation of scientific and technical information systems; (3) patterns of communication and information flow in science and technology; and (4) science information planning and data-gathering studies (overlap in secondary services, page charges, manpower requirements in the science information field).

Computer-Based Bibliographic Data System

The computer-based bibliographic data system at the University of Chicago, mentioned above, represents an excellent example of Foundation support of library system development. This project proposes to apply modern computer-based methods to standard library operations in a prototype system which may have a major impact on the modernization of library systems all over the country. A substantial proportion of the project cost is being assumed by the University, and the Foundation has now supplemented its initial supporting grant to assist the project for another 2 years.

The novelty of the project lies in its fitting together a total integrated system out of assorted data-handling systems for various library operations. Traditionally these operations—bibliographic processing, catalog searching, circulation control, and related library service operations—are handled manually. Computerization is expected to increase the efficiency of these operations by improving the response time in providing readers with faster, more current, and more accurate access to library resources. The scope and quality of library services will also be expanded by introducing new services made possible by the capability of the system to process information to fit the specific needs of different groups.

The completed system may have remotely located terminals where questions can be put into the system and answers received immediately. Computer hardware can be expanded as required to meet increasing loads of inquiries and changing service requirements.

Beyond the anticipated improvement in speed and efficiency, the project investigators expect advances in both intellectual and physical access to recorded information. Since the system should be economically feasible for the typical large university library, the results at the University of Chicago should serve as a prototype system for other libraries. Upon completion of the project the University of Chicago will make all computer programs, their documentation, and other pertinent data available to other interested institutions.

Storage and Retrieval System for Nondocumentary Biological Information

Another interesting project supported by the Foundation, and related to the use of computer technology in information systems, calls for development of a prototype storage and retrieval system for nondocumentary biological information.

Much of the accumulated information in biology exists in nondocumentary form. It consists instead of preserved specimens in hundreds of museums, laboratories, etc., along with the host of data associated with such specimens.

The University of Colorado has undertaken to develop a prototype system providing for storage and retrieval of this highly specialized information. The end product of this 2-year project will include a working, computerized file of about 20,000 entries, a set of computer programs specially adapted to the handling and retrieval of biological information, and an evaluation of the cost and utility of this type of system for biological information storage and retrieval.

The projected system will provide a demonstration of a means for organizing and providing access to a part of this nondocumentary store of information with the idea that, if the system proves economical, it can be expanded readily to comprehend any file of specimen data.

The project will require extensive liaison with holders of large collections of specimens (e.g., the Smithsonian Institution), with those responsible for abstracting and indexing functions in biology, and with active researchers in biology, particularly taxonomists. The project will also include a detailed substudy of the costs of programing and coding so that conclusions regarding general adoption can be made on the basis of expected cost as well as anticipated utility.

INTERNATIONAL SCIENCE ACTIVITIES

Science is international—reaching across national boundaries to exchange and acquire knowledge and to merge efforts in the attack on common problems. The international science activities of the Foundation have three principal aspects: Support of projects to strengthen U.S. science in programs funded by the Foundation; support of projects to assist certain foreign countries in developing their scientific capabilities (funded by the Agency for International Development); and international cooperative studies and other activities in conjunction with international science organizations.

STRENGTHENING U.S. SCIENCE

Research-Related Support

In its support of basic research in science, the Foundation regularly cooperates with other nations in broadly based research programs which are international in scope and character. Examples of such programs are the Antarctic Research Program and the International Years of the Quiet Sun. Such programs are undertaken in accordance with international agreements arrived at when important scientific opportunities are recognized as requiring concerted multinational effort. Foundation support is mainly to academic scientists conducting their own research within the framework of the agreed-on international program. In terms of men and money spent, these types of activities comprise the great bulk of science-related international activities of the Foundation. The results of these activities are reported under their respective disciplines.

In addition to joint international programs of a specialized nature, the Foundation also provides funds to U.S. scientists for research which may be conducted abroad or in collaboration with foreign scientists. Also, support is given for attendance at international scientific meetings, science information exchange between cooperating nations, and educational and training programs. Few grants are made to foreign institutions and only when exceptional conditions justify support to the foreign recipient. (In fiscal year 1967, there were 21 research grants to foreign institutions totaling approximately $617,700.)

Two new research-related international cooperative programs were established this year. The Governments of India and the United States signed an agreement on February 14, 1967, for an exchange of scientists and engineers, and an agreement for a cooperative program in science between the United States and Italy was concluded on June 19, 1967. The Foundation, under both agreements, is the implementing or coordinating agency for the U.S. Government.

The United States—India Exchange Program calls for exchange visits for periods of 2 weeks to several months with a total of 800 man-days per year for each country. Under the agreement, individual scientists and engineers are proposed as exchange visitors by the traveler's home country and selected, with the consent of the host country, on the basis of potential contributions which may ensue from work in the two countries. The Exchange Program was initiated in March 1967, and the first Indian visitor arrived in the United States on April 15 for a 2-month visit.

The United States-Italy agreement provides that the two governments will undertake a broad-range program of scientific cooperation for peaceful purposes. Each government will provide financial support for its respective portion of the program. Activities under this program involve participation by scientists of both countries and may include exchange of scientists, pursuit of joint research projects, and seminars to exchange information. The cooperative program was initiated with three projects which were approved by the National Science Foundation and the Italian executive agency, the *Consiglio Nazionale delle Ricerche.* These are:

1. The Establishment of an International Studium of Molecular Biology, University of California, Berkeley, and the International Laboratory of Genetics and Biophysics, Naples;
2. A Cooperative Research and Training Program in Developmental Biology between the Massachusetts Institute of Technology and the University of Palermo; and
3. A Cooperative Research Program between the Istituto di Medicina Sperimentale (CNR) and Washington University, St. Louis, on Analysis of a Specific Nerve Growth Factor, its Antiserum and other Specific Growth Factors.

The United States-Japan Cooperative Science Program was established in 1961 and has been successful in establishing closer cooperation in scientific investigations of mutual interest to the two nations. The program is guided by a joint committee of distinguished scientists from both countries. This group meets annually to review and evaluate the projects under way and to designate new areas of mutual scientific interest especially suited for cooperative study.

Projects under the program are funded cooperatively, each country supporting its own scientists. The National Science Foundation is the implementing agency in the United States and works closely with Japanese agencies to coordinate activities.

There are four types of activities under the program: cooperative research, visits by scientists of one country to the other for research or fact finding in a specific field, scientific meetings, and the exchange of educational materials. During the past year, 16 cooperative research projects were supported on such topics as Microearthquakes of Tohoku and Nevada, Blood Macromolecules, Genetic Origins and Bioclimatic Adaptations of the Japanese Macaque, and the Neurophysiology of Sleep; under the visiting scientists category, four U.S. scientists spent approximately a year in Japanese laboratories and nine U.S. scientists visited Japan for shorter periods of time; 19 United States-Japan seminars and three meetings to review cooperative research projects were held, involving approximately 180 United States and 245 Japanese scientists; and in the area of educational materials, an exchange of scientific films was initiated.

Education-Related Support

In addition to cooperative research projects, contacts between the American and foreign scientific communities are maintained through fellowship and exchange programs.

Contacts between individual American and foreign scientists are encouraged and supported through fellowship and exchange programs. Of the 2,915 fellowships awarded in fiscal year 1967 to U.S. citizens, 168 provided for tenure at a foreign institution. Forty-five U.S. citizens received Foundation-administered North Atlantic Treaty Organization Postdoctoral Fellowships for study for periods of 6 to 12 months in institutions of NATO nations or other cooperating countries. In fiscal year 1967 the NATO Senior Fellowships in Science Program was inaugurated and administered for U.S. citizens by the Foundation, and 20 individuals received these awards. The primary objective of this program is to enable U.S. universities and nonprofit scientific research institutions to send senior staff members to study new scientific techniques and developments for short terms (1–3 months) at research and educational institutions in other NATO nations or in countries that cooperate with NATO. Under the NSF Senior Foreign Scientist Fellowship Program, provision was made for 56 American institutions to be visited by that number of eminent foreign scholars.

Travel grants were provided to 72 young American scientists for attendance at 40 Advanced Study Institutes sponsored by NATO. In addition, travel grants were made to eight American scientists to visit locations abroad, principally for the purpose of participating in international meetings related to science education.

The Foundation supports individual exchanges with the Soviet Union, Czechoslovakia, Poland, Romania, and Yugoslavia. These exchanges are administered by the National Academy of Sciences in this country and by counterpart organizations in the respective foreign countries; they

Table 13.—*U.S.S.R. and East European Exchange of Scientists Program, Number and Duration of Individual Visits Initiated July 1, 1966–June 30, 1967*

	American Scientists Number	Duration (man-months)	Foreign Scientists Number	Duration (man-months)
East Europe:				
Lecture and survey visits	12	12	4	5
Research visits	3	16	5	45
Total	15	28	9	50
Soviet Union:				
Lecture and survey visits	12	12	11	12
Research visits	11	82	12	73
Total	23	94	23	85
Grand total:				
Lecture and survey visits	24	24	15	17
Research visits	14	98	17	118
Grand total	38	122	32	135

are conducted under terms of written agreements or understandings between the National Academy and its foreign counterparts. The agreement with the Soviet Academy is biennially renewed and is incorporated within the exchange agreements between the two governments. Memoranda of Understanding were exchanged between the National Academy of Sciences and its four East European counterparts and were confirmed between January and July 1966. Negotiations have also been conducted with the Hungarian Academy, and initiation of exchanges is anticipated in 1968. In these exchanges, scientists receive international travel support and stipends from their home countries, and local travel and per diem from the host countries.

DEVELOPMENT ASSISTANCE PROGRAMS

There is much interest abroad in the significant advances which have been made in science education in the United States. However, educational methods and content cannot be exported intact for use on arrival. To ease the transition, the Foundation has worked closely with the Agency for International Development (AID), to assist developing countries in their efforts to improve their educational programs in science. From the U.S. experience in this area, supported in part by the Foundation, new materials in course content development and teacher training are being adapted to local foreign needs and conditions.

India.—The international science activities of the Foundation were highlighted this year by the implementation of a project initially undertaken in March 1966. The Agency for International Development (AID) asked the National Science Foundation to assist in the formulation and administration of an AID-financed cooperative program for the improvement of science education in India. The 1967 Summer Institutes in India for College and Secondary Teachers composed the thrust of the new program this year. A total of 172 consultants was selected by the National Science Foundation from 898 candidates. One hundred sixty-three served in 100 institutes, three as short-term supervisors in the New Delhi Office of the Foundation and six as visiting lecturers.

The concept for the program grew out of a series of summer institutes for college and secondary school teachers which had been supported by AID and the Government of India for the previous 4 years. On the basis of this experience, it was decided that the minimum duration of the program should be 5 years and that within this period the main elements of the binational effort would consist of:

1. Further training in both subject matter and methods for school and college science teachers and the provision of supporting services to them;
2. Creation, adaptation, production, introduction and distribution of improved instructional materials, devices and methods, and the development and testing of modern courses and curricula at school and college levels; and
3. Development of improved instructional programs of schools and colleges which will reflect the best of current practices, and which shall provide for faculty and facility development, and for special attention to gifted students.

Latin America.—Under a Participating Agency Service Agreement with AID, the Foundation in 1963 initiated a science education improvement program with the five national universities of Central America (Costa Rica, Nicaragua, Honduras, El Salvador, and Guatemala). These universities, joined in November 1966 by the national university of Panama, are grouped in a regional association called the Superior Council of Central American Universities (CSUCA), with which the Foundation works directly.

During the year, staff training of Central American university professors of Biology, Chemistry, Physics, and Mathematics continued to be a principal activity of th NSF/AID program. Seven in-service seminars of 3 to 6 weeks duration were held with a total participation of more than 150 staff members. In addition, 11 professors from the national universities were in academic-year programs in the United States and Puerto Rico.

To conduct the in-service seminars and to offer advisory services on curriculum planning and other aspects of science education, the NSF/AID program maintained a small scientific and administrative staff in San Jose, Costa Rica. These persons were available for service throughout the Central America-Panama area.

INTERNATIONAL ORGANIZATIONS

International nongovernmental scientific organizations, through sponsorship of international meetings and conferences, provide a forum for scientists from all over the world to gather for the exchange of research results, papers, and new ideas, activities which are vitally necessary to the work of scientists. Because of the worldwide expansion of scientific effort and the broader extent of scientific problems to be solved, these organizations are also needed as a means for coordination and interaction in international scientific activities. The Foundation provides support for the participation of U.S. scientists involved in 25 or so nongovernmental international scientific organizations. This support is channeled principally through the National Academy of Sciences, which, as the United States adherent to most of these international organization (such as the International Council of Scientific Unions and the Pacific Science Association), establishes representative U.S. committees.

Some international governmental institutions, such as the Organization for Economic Cooperation and Development (OECD) and UNESCO, have significant scientific components in their overall program. From time to time U.S. agencies, including NSF, are cooperatively involved with these organizations in activities of a scientific nature. As appropriate, the Foundation coordinates U.S. participation in OECD scientific activities in cooperation with the Department of State.

SCIENCE POLICY PLANNING

One of the responsibilities specifically assigned to the Foundation is that of developing a national policy for the promotion of basic research and education in the sciences. Responsibility for advising the President in achieving coordinated Federal policies toward this end rests with the Director of the Office of Science and Technology (OST). In practice, the Foundation and OST constitute a team in which the Foundation assembles and analyzes data on all aspects of the national science effort in both the governmental and private sectors, and generates program and policy recommendations bearing on the total effort as well as on the Foundation's internal programs. OST uses these data and recommendations as a resource in developing its own plans with regard to the total Federal effort.

In planning the national effort it is useful to distinguish between several qualitatively distinct types of purpose which science serves, since the methods which must be used in assessing the needs and effectiveness of individual programs differ markedly depending upon the purpose. These major purposes (among others) may be cited:

1. Production of new knowledge and understanding of all aspects of the social and material world as an intellectual resource;
2. Provision of all the instrumentalities necessary for the scientific and engineering education of the Nation's labor force;
3. Provision of the basic scientific and engineering knowledge required for the solution of the Nation's economic and social problems.

In its efforts to develop data and to propose plans and policies relating to national science activities the Foundation not only utilizes its own staff, but also depends heavily upon studies (which it sponsors in part or in whole) by expert groups in other Federal agencies, in universities, other nonprofit organizations, and private industry. More than 100 major studies were completed or in progress during fiscal year 1967. In order to convey some idea of their nature, a few are described in the following sections. They are grouped according to the principal purpose (listed above) served by the activity under study.

The Foundation is also responsible for formulation of long-range plans for its own programs and for the evaluation of its current programs. Since the Foundation is the only Federal agency with responsibility for the development of science as an intellectual resource in its own right, a continuing effort is made to determine whether the Foundation's own activities are properly directed toward the achievement of this objective. The first step in doing this is to determine national needs, then to estimate the support which will be provided from other governmental and private sources, and finally to evaluate and plan for the Foundation's operations so that the best combined national effort will result. The annual Program Planning and Budgeting activity of the Foundation is conducted along these lines. Detailed analyses and projections for individual program requirements are carried out in the appropriate program organizations, and general statistical data are then utilized in integrating the individual plans into a consistent whole.

NEW KNOWLEDGE AND UNDERSTANDING

One of the most complex and difficult aspects of planning scientific activities involves decisions on how much investment should be made in major (and expensive) scientific investigations. Traditionally, this has been done by obtaining the opinions of eminent scientists in various fields of science on worthwhile proposals for scientific research. Competition for limited Federal resources has intensified because of new proposals for scientific, social and other governmental programs, as well as the increased costs of on-going programs. As a result, the problem of apportionment of available funds to the various scientific areas of investigation has become more acute. For this reason, the National Science Foundation increasingly in the last few years has sought advice on this subject from the Committee on Science and Public Policy (COSPUP) of the National Academy of Sciences. It would be fair to say that the influence of this Committee also goes beyond the National Science Foundation and is proving very useful to other parts of the executive branch of the Government as well as to the legislative branch.

COSPUP, which is principally supported by the Foundation, has since 1963 provided policy review and counsel on behalf of the President of the Academy for reports to the Federal Government prepared by working groups of the Academy and National Research Council. One such report on plant sciences was published in fiscal year 1967. Noteworthy among its recommendations to Federal granting agencies were that:

1. The annual level of general support of plant science research be increased by a factor of 2 to 3 between 1965 and 1975;
2. $135 million be provided during this period for graduate and postdoctoral training costs;
3. Special projects and facilities needed to exploit recent advances in the plant sciences require $411 million; and
4. New building costs of $65 million be supported.

Analyses and recommendations of this type, when combined with the results of similar COSPUP studies already made in the areas of astronomy, chemistry, physics and digital computers, and with studies currently under way in the areas of mathematics, the life sciences, and social and behavioral sciences, should form a reasonably homogeneous spectrum of informed opinion against which to assess Federal support policies. In addition to providing guidance bearing on the intellectual merit of the various fields of science, these studies also estimate manpower growth potential, and comment on the actual and potential contribution of each field to national purposes external to science itself.

The COSPUP studies might be described as systematic efforts to obtain and organize expert opinion in a conventional fashion. In a less conventional vein the Foundation is supporting two experimental investigations by Abt Associates and the Rand Corp. in an effort to ascertain whether any practical analytic methods of assessing proposed science support programs exist which can be used in conjunction with the use of expert opinion. Is it possible to evaluate the merit of a research finding quantitatively in terms of the numbers of other research inquiries to which it is likely to make a contribution? Going one step further can one find statistical measures of the merit of whole fields of research or of a proposed new research project? In view of the magnitude and importance of overall Federal science support and the very large amounts of time senior scientists currently spend in the evaluation of proposed programs and projects, any new analytical aids to the process would be most welcome. They might also constitute a step in the direction of the quantitative measurement of effectiveness envisaged in the Program Planning and Budgeting procedures.

SCIENCE EDUCATION AND THE DEVELOPMENT OF SCIENTIFIC AND TECHNICAL MANPOWER

National scientific and engineering manpower requirements during the next 5 to 10 years have been the subject of two recent studies. With partial support from the Foundation, the Bureau of Labor Statistics has projected to 1975 the scientific, engineering, and technical manpower level required to maintain the economy at a high level of total employment. Concurrently, the Foundation has studied the science and engineering staff needs at institutions of higher education for the period 1965–75. These studies indicate that during the next 10 years institutions of higher education may have to hire a larger fraction of the country's new doctorates than in the recent past in order to meet their staffing needs. Currently they hire about half the output.

Assuming that it would be a desirable national goal to provide the institutional resources necessary to train these doctorates, the Foundaion has tended to direct much of its planning effort toward assaying the means and costs of achieving this goal. For example, it has been estimated that approximately $300 million is being expended annually for the construction of facilities for graduate education and research in the sciences and engineering (exclusive of the medical sciences), of which approximately one-third is provided by the Federal Government. In order to provide the additional facilities required to meet increasing student load, the annual national investment would have to be increased by $150 million.

Following the same economic-demographic approach it is possible to estimate the rate of increase in direct graduate student support, graduate faculty salary support, and support for other components of the total cost of the research training of doctoral students. Such computations are tending to become one of the principal bases for estimating long-range national needs in many areas of support for science in which the Foundation has responsibility. Continuing efforts will be necessary to ascertain and measure social and economic parameters which can be used to measure the cost and effectiveness of Federal programs.

Almost of necessity most long-range plans for national development of well-established institutions tend to be based on projections of present day ideas of what constitute optimum management parameters. In the case of higher education, these include such numbers as student-faculty ratios, relative faculty effort devoted to teaching versus research, ratios of numbers of undergraduate to graduate students on a well-rounded university campus, and similar factors. New and hopefully better concepts and methods are being constantly developed by the institutions themselves. This process should not only be encouraged, but to the extent possible long-range plans should attempt to anticipate the adoption of promising innovations. Another type of external influence which is difficult to predict with accuracy, but to which Federal plans must be adjusted, is found in the long-range plans of State university systems and of major private institutions themselves. In an effort to obtain a reasonably comprehensive picture of innovative trends and of local university planning, the Foundation has joined with the Office of Education and the National Institutes of Health in supporting a survey of planning and innovative activities at a selected group of more than one hundred institutions. This study is being carried out under the auspices of the Academy for Educational Development.

A trend of particular interest is the very rapid growth in the number of postdoctoral appointments at U.S. institutions. The number of such fellows is estimated now to be in excess of 12,000, and the cost of their activities may exceed $200 million annually. This situation is being intensively studied by a group at the National Academy of Sciences with support from the Foundation and other public and private sources.

In consonance with recent Presidential directives, an effort is being made to assess the impact of science, and to survey science-related activities, at the State and local levels of government. One of the objectives is to improve the exchange of information and useful experience between interested State, regional, and local groups. As a part of this activity, a major study is being supported at Michigan State University on the impact of Federally supported research programs on State colleges and universities in Michigan.

SCIENCE FOR THE SOLUTION OF SOCIAL AND ECONOMIC PROBLEMS

While the Foundation's principal responsibilities lie in the area of non-mission-related basic research and education, increased attention is directed to studies of the manner in which, in the long run, basic research and education contribute to the country's social and economic well-being. As part of a continuing contribution to the data base upon which national planning for research and development is carried out, five specific Foundation efforts may be mentioned:

1. The publication of the 15th annual "Survey of Federal Funds for Research, Development and Other Scientific Activities" (total R. & D. Federal funds obligated in fiscal year 1965 were $14.6 billion);
2. The publication of a study of the "Geographic Distribution of Federal Funds for Research and Development" (in fiscal year 1965, 72 percent of Federal R. & D. funds were obligated in the 10 leading States; the same 10 States provided 40 percent of all State and local funds for academic R. & D. and 60 percent of all State and local funds for State agencies R. & D.);
3. A study of State government expenditures for R. & D. (in fiscal year 1965 total expenditures at other than educational institutions totaled $88 million, of which about half were made by the five leading States);
4. A study of R. & D. expenditures at nonprofit organizations, other than educational institutions (a total of $610 million in fiscal year 1964);
5. The publication of a study of "National Patterns of R. & D. Resources, 1953–68," including funds and manpower (an estimated total of $22.2 billion was expended by all performers in fiscal year 1966 of which the largest component is $15.4 billion performed by industry).

Indirectly through its support of the National Academy of Sciences' Committee on Science and Public Policy (COSPUP), the Foundation helps make available to the public informed advice on problems of applied research and development. A report recently issued by COSPUP (with special support from the Committee on Science and Astronautics of the U.S. House of Representatives) entitled "Applied Science and

Technological Progress" has made a searching inquiry into this subject. One observation made in the report which has a direct bearing on Federal R. & D. policies is that "the most important invention in the pursuit of modern (as opposed to older) applied science is the big mission-oriented industrial or government laboratory."

Another source of advice on R. & D. pertaining to social and economic problems is the recently constituted Committee on Public Engineering Policy of the National Academy of Engineering. Partial support of the activities of this committee is being provided by the Foundation. One of the tasks of the committee will be to conduct surveys of the engineering needs of the United States, and in particular to evaluate technical and manpower resources in a manner similar to that in which COSPUP has evaluated science needs and resources.

In the area of the development of marine resources and engineering the Foundation has been assigned a mission-related responsibility, namely the support of Sea-Grant Colleges and Programs. The purpose of these efforts is to help produce the skilled manpower, facilities, and equipment necessary for the exploitation of marine resoures. As an aid to planning this program, the Foundation is supporting a study by the National Planning Association of methods of government-business cooperation in the field of oceanics, including an analysis of current private enterprises in oceanics and the factors which govern their success or failure. Concurrently, an inhouse staff study is in progress to estimate the existing and projected manpower needs.

In and of themselves, many of the planning activities of the Foundation may be regarded as being in the domain of social science. Extensive data collection and analysis represent a contribution to the national effort to develop systems of economic and social indicators. Since these efforts should be undertaken with a good understanding of the sciences themselves, the Planning organization attempts to maintain a staff having professional competence in all the science areas.

Organization

In terms of staff effort, the major portion of Foundation planning is devoted to the collection and analysis of data, primarily of a statistical nature. This function is performed by the Office of Economic and Manpower Studies. With the accumulation of ever-expanding quantities of information, increasing attention is being given to the storage and processing of data, a responsibility which has been assigned to the newly formed Office of Data Management Systems, which, among other responsibilities, also handles the Foundation's own data processing operations. Studies of specific policy issues and formulation of plans for science both of a national character and pertaining to the Foundation's own programs are carried out by the recently constituted Office of Planning and Policy Studies.

APPENDIX A

National Science Board, Staff, Committees, and Advisory Panels

NATIONAL SCIENCE BOARD

Terms Expire May 10, 1968

*HARVEY BROOKS, Gordon McKay Professor of Applied Physics and Dean of Engineering and Applied Physics, Harvard University, Cambridge, Mass.

RUFUS E. CLEMENT, President, Atlanta University, Atlanta, Ga.[1]

HENRY EYRING, Professor of Chemistry and Metallurgy, University of Utah, Salt Lake City, Utah.

*PHILIP HANDLER (Chairman), James B. Duke Professor and Chairman, Department of Biochemistry, Duke University Medical Center, Durham, N.C.

KATHARINE E. MCBRIDE, President, Bryn Mawr College, Bryn Mawr, Pa.

EDWARD J. MCSHANE, Professor of Mathematics, University of Virginia, Charlottesville, Va.

EDWARD L. TATUM, Professor, The Rockefeller University, New York, N.Y.

*RALPH W. TYLER (Vice Chairman), Director Emeritus, Center for Advanced Study in the Behavioral Sciences, Stanford, Calif.

Terms Expire May 10, 1970

MARY I. BUNTING, President, Radcliffe College, Cambridge, Mass.

H. E. CARTER, Vice Chancellor for Academic Affairs, University of Illinois, Urbana, Ill.

JULIAN R. GOLDSMITH, Associate Dean, Division of the Physical Sciences, University of Chicago, Chicago, Ill.

WILLIAM W. HAGERTY, President, Drexel Institute of Technology, Philadelphia, Pa.

HARVEY PICKER, President, Picker X-Ray Corp., White Plains, N.Y.

MINA S. REES, Dean of Graduate Studies, The City University of New York, New York, N.Y.

JULIUS A. STRATTON, Chairman of the Board, The Ford Foundation, New York, N.Y.[2]

F. P. THIEME, Vice President, University of Washington, Seattle, Wash.

Terms Expire May 10, 1972

CLIFFORD M. HARDIN, Chancellor, University of Nebraska, Lincoln, Nebr.

CHARLES F. JONES, President, Humble Oil and Refining Co., Houston, Tex.

THOMAS F. JONES, JR., President, University of South Carolina, Columbia, S.C.

*ROBERT S. MORISON, Professor of Biology and Director, Division of Biological Sciences, Cornell University, Ithaca, N.Y.

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[1] Deceased Nov. 7, 1967.

[2] Resigned. Appointment of Roger W. Heyns, Chancellor, University of California, Berkeley, announced Aug. 2, 1967.

*Member Executive Committee.

E. R. Piore, Vice President and Chief Scientist, International Business Machines Corp., Armonk, N.Y.

Joseph M. Reynolds, Boyd Professor of Physics and Vice President for Research Louisiana State University, Baton Rouge, La.

Athelstan F. Spilhaus, President, The Franklin Institute, Philadelphia, Pa.

Richard H. Sullivan, President, Association of American Colleges, Washington, D.C.

Member Ex Officio

*Leland J. Haworth, Director, National Science Foundation, Washington, D.C. (Chairman, Executive Committee).

* * *

Vernice Anderson, Secretary, National Science Board, National Science Foundation, Washington, D.C.

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Executive Assistant, Robert W. Johnston

Deputy Director, John T. Wilson

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Head, Milton E. Rose

Special Assistant for Liaison, Richard H. Balomenos

Institutional Computing Services Section

Head, Kent Curtis

Special Projects Section

Head, Arthur S. Melmed

Computer Science Program

Assistant Program Director, Fred W. Weingarten

RESEARCH

Associate Director, Randal M. Robertson

Deputy, Edward P. Todd

Senior Staff Associate, Raymond J. Seeger

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Office of Antarctic Programs

Chief Scientist, Louis O. Quam

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Program Director, Antarctic Atmospheric Physics, Ray R. Heer, Jr.

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Field Requirements and Coordination Program

Program Director, Philip M. Smith

New Zealand USARP Representative, E. E. Goodale

Vessel Coordinating Officer, R. L. Dale

Logistics Coordinating Officer, Jerry W. Huffman

Logistics Liaison Officer-Eltanin, Merle R. Dawson

*Member Executive Committee.

**As of November 1967.

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Program Director, T. A. Seliga
METEROLOGY PROGRAM
Program Director, Eugene W. Bierly

SOLAR TERRESTRIAL RESEARCH PROGRAM
Program Director, D. N. Liebenberg
WEATHER MODIFICATION PROGRAM
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Liaison Officer, Clifford J. Murino

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Acting Program Director, Mary K. Johrde

SUBMARINE GEOLOGY AND GEOPHYSICS PROGRAM
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Program Director, Oren F. Williams

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Program Director, Donald A. Speer
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WALTER W. HAASE, Director, Management Information Systems Division, National Aeronautics and Space Administration Headquarters, Washington, D.C.

H. T. HERRICK, Director, Division of Labor Relations, Atomic Energy Commission, Washington, D.C.

ALBERT KAY, Director of Manpower Resources, Office of Assistant Secretary of Defense (Manpower), Washington, D.C.

ALEXANDER MOOD, Assistant Commissioner for Educational Statistics, U.S. Office of Education, Washington, D.C.

JOSEPH S. MURTAUGH, Chief, Office of Program Planning, National Institutes of Health, Department of Health, Education, and Welfare, Washington, D.C.

ROBERT H. RANKIN, Chief Planning Officer, Selective Service System, Washington, D.C.

O. GLENN STAHL, Director, Bureau of Programs and Standards, Civil Service Commission, Washington, D.C.

CONRAD TAEUBER, Assistant Director, Bureau of the Census, Department of Commerce, Washington, D.C.

MARGARET WEST, Director, Office of Program Planning and Evaluation, Bureau of Health Manpower, Public Health Service, Arlington, Va.

Advisory Panel for Mathematical Sciences

RICHARD D. ANDERSON, Department of Mathematics, Louisiana State University, Baton Rouge, La.

MAURICE AUSLANDER, Department of Mathematics, Brandeis University, Waltham, Mass.

JULIUS R. BLUM, Department of Mathematics, University of New Mexico, Albuquerque, N.M.

ROBERT C. BUCK, Department of Mathematics, University of Wisconsin, Madison, Wis.

ISRAEL N. HERSTEIN, Department of Mathematics, University of Chicago, Chicago, Ill.

MAGNUS R. HESTENES, Department of Mathematics, University of California, Los Angeles, Calif.

VICTOR L. KLEE, Jr., Department of Mathematics, University of Washington, Seattle, Wash.

JURGEN K. MOSER, Courant Institute of Mathematical Sciences, New York University, New York, N.Y.

ELIAS M. STEIN, Department of Mathematics, Princeton University, Princeton, N.J.

Advisory Panel for Metabolic Biology

GENE M. BROWN, Department of Biology, Massachusetts Institute of Technology, Cambridge, Mass.

HAROLD J. EVANS, Department of Plant Physiology, Oregon State University, Corvallis, Oreg.

EDMOND H. FISCHER, Department of Biochemistry, School of Medicine, University of Washington, Seattle, Wash.

DAVID E. GREEN, Enzyme Institute, University of Wisconsin, Madison, Wis.

HOWARD GEST, Department of Microbiology, Indiana University Foundation, Bloomington, Ind.

WAYNE C. HALL, Texas Agricultural and Mechanical University, College Station, Tex.

ROBERT LANGDON, School of Medicine, Johns Hopkins University, Baltimore, Md.

WILLIAM R. NES, Department of Chemistry, University of Mississippi, University, Miss.

HUTTON D. SLADE, Department of Microbiology, Northwestern University Medical School, Chicago, Ill.

PAUL K. STUMPF, Department of Biochemistry and Biophysics, University of California, Davis, Calif.

ELLIOT JUNI, Department of Microbiology, University of Michigan, Ann Arbor, Mich.

JOHN M. WARD, Dean of Science, Oregon State University, Corvallis, Oreg.

Advisory Panel for Molecular Biology

WARREN L. BUTLER, Department of Biology, University of California, La Jolla, Calif.

JOHN R. CANN, Department of Biophysics, University of Colorado Medical Center, Denver, Colo.

MELVIN COHN, The Salk Institute for Biological Studies, P.O. Box 9499, San Diego, Calif.

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WALTER KAUZMAN, Department of Chemistry, Princeton University, Princeton, N.J.

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LEON LEVINTOW, Department of Microbiology, University of California, School of Medicine, San Francisco, Calif.

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Advisory Panel for Oceanographic Facilities

EUGENIE CLARK (Chairman), Cape Haze Marine Laboratory, Sarasota, Fla.

PARKE A. DICKEY, Department of Geology, University of Tulsa, Tulsa, Okla.

JOHN LYMAN, Bureau of Commercial Fisheries, Department of Interior, Washington, D.C.

WARREN C. THOMPSON, Department of Meteorology and Oceanography, U.S. Naval Postgraduate School, Monterey, Calif.

WILLIAM WALTON, Pan American Petroleum Corp., Tulsa, Okla.

Advisory Panel for Physics

JAMES H. CRAWFORD, Jr., Department of Physics, University of North Carolina, Chapel Hill, N.C.

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WILLIAM D. WALKER, Department of Physics, University of Wisconsin, Madison, Wis.

ROBERT W. WILLIAMS, Department of Physics, University of Washington, Seattle, Wash.

Advisory Panel for Political Science

ROBERT E. LANE, Department of Political Science, Yale University, New Haven, Conn.

RICHARD L. PARK, Department of Political Science, University of Michigan, Ann Arbor, Mich.

WILLIAM H. RIKER, Department of Political Science, University of Rochester, Rochester, N.Y.

JAMES A. ROBINSON, Department of Political Science, Ohio State University, Columbus, Ohio

KENNETH N. WALTZ, Department of Political Science, Brandeis University, Waltham, Mass.

Advisory Panel for Psychobiology

GEORGE W. BARLOW, Department of Zoology, University of California, Berkeley, Calif.

DONALD S. BLOUGH, Department of Psychology, Brown University, Providence, R.I.

MICHAEL R. D'AMATO, Department of Psychology, Rutgers—The State University, New Brunswick, N.J.

CARL P. DUNCAN, Department of Psychology, Northwestern University, Evanston, Ill.

FREDERICK A. KING, Division of Neurosurgery, College of Medicine, University of Florida, Gainesville, Fla.

DONALD R. MEYER, Department of Psychology, Ohio State University, Columbus, Ohio.

IRWIN POLLACK, Mental Health Research Institute, University of Michigan, Ann Arbor, Mich.

WARREN S. TORGERSON, Department of Psychology, Johns Hopkins University, Baltimore, Md.

Advisory Panel for Radio Telescopes

RONALD N. BRACEWELL, Radio Science Laboratory, Stanford University, Stanford, Calif.

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PAUL CHENEA, Division of Engineering Sciences, Purdue University, Lafayette, Ind.

L. J. CHU, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

RICHARD M. EMBERSON, Institute of Electrical and Electronic Engineers, Inc., Box A, Lenox Hill Station, New York, N.Y.

WILLIAM E. GORDON, Department of Electrical Engineering, Cornell University, Ithaca, N.Y.

DAVID S. HEESCHEN, National Radio Astronomy Observatory, Green Bank, W. Va.

R. MINKOWSKI, Radio Astronomy Observatory, University of California, Berkeley, Calif.

JOHN R. PIERCE (Chairman), Bell Telephone Laboratories, Inc., Murray Hill, N.J.

GEORGE W. SWENSON, JR., The Observatory, University of Illinois, Urbana, Ill.

JAMES H. TREXLER, Naval Research Laboratory, Washington, D.C.

Advisory Panel for Regulatory Biology

MILTON FINGERMAN, Department of Biology, Tulane University, New Orleans, La.

TERU HAYASHI, Department of Biology, Illinois Institute of Technology, Chicago, Ill.

RILEY HOUSEWRIGHT, Technical Director, Fort Detrick, Frederick, Md.

A. C. LEOPOLD, Department of Horticulture, Purdue University, Lafayette, Ind.

SIDNEY OCHS, Department of Physiology, University of Indiana, Indianapolis, Ind.

ELIJAH B. ROMANOFF, Worcester Foundation for Experimental Biology, Shrewsbury, Mass.

R. P. SCHEFFER, Department of Botany, Michigan State University, East Lansing, Mich.

SIDNEY SOLOMON, University of New Mexico, School of Medicine, Albuquerque, N. Mex.

J. W. UHR, Department of Medicine, New York University, New York, N.Y.

Advisory Panel for Science Development

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ROBERT B. BRODE, Department of Physics, University of California, Berkeley, Calif.

DALE R. CORSON, Provost, Cornell University, Ithaca, N.Y.

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LYLE H. LANIER, Executive Vice President and Provost, University of Illinois, Urbana, Ill.

JOHN R. PIERCE, Executive Director, Research-Communication Sciences Division, Bell Telephone Laboratories, Murray Hill, N.J.

Advisory Panel for Institutional Support, National Sea Grant Program

SANFORD S. ATWOOD, President, Emory University, Atlanta, Ga.

DOUGLAS BROOKS, President, Travelers Research Center, Hartford, Conn.

JOHN C. CALHOUN, Jr., Vice Chancellor, Texas A. & M. University, College Station, Tex.

JOSEPH HENDERSON, Director, Applied Physics Laboratory, Seattle, Wash.

CHALMER G. KIRKBRIDE, Vice President, Research and Engineering, Sun Oil Co., Philadelphia, Pa.

CHARLES OFFICER, President, Alpine Geophysics Corp., Norwood, N.J.

DAVID POTTER, General Manager, Defense Research Laboratory, General Motors Corp., Santa Barbara, Calif.

ROBERT H. ROY, Dean, Engineering Science, Johns Hopkins University, Baltimore, Md.

HENRY B. STEINBACH, Director, Marine Biological Laboratory, Woods Hole Oceanographic Institution, Woods Hole, Mass., and Professor, Department of Zoology, University of Chicago, Chicago, Ill.

Advisory Panel for Sociology and Social Psychology

[1] THEODORE R. ANDERSON, Department of Sociology and Anthropology, University of Iowa, Iowa City, Iowa

DONALD T. CAMPBELL, Department of Psychology, Northwestern University, Evanston, Ill.

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Advisory Panel for Systematic Biology Program

HENRY N. ANDREWS, Jr., Department of Botany, University of Connecticut, Storrs, Conn. (Paleobotany and Plant Anatomy)

KENTON L. CHAMBERS, Department of Botany and Plant Pathology, Oregon State University, Corvallis, Oreg. (Plant Biosystematics)

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EVERETT C. OLSON, Department of Geology, University of Chicago, Chicago, Ill. (Paleozoology and Vertebrate Anatomy)

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ALEXANDER H. SMITH, Department of Botany, University of Michigan, Ann Arbor, Mich. (Mycology and Cryptogamic Botany)

FLOYD G. WERNER, Department of Entomology, University of Arizona, Tucson, Ariz. (Entomology)

Advisory Panel for University Computing Facilities

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JAY M. GOLDBERG, Department of Physiology, University of Chicago, Chicago, Ill.

SIDNEY FERNBACH, Head, Computation Division, Lawrence Radiation Laboratory, Livermore, Calif.

FREDERICK A. MATSEN, Department of Chemistry, University of Texas, Austin, Tex.

ALAN J. PERLIS, Computation Center, Carnegie Institute of Technology, Pittsburgh, Pa.

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Advisory Panel for Weather Modification

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CHARLES L. HOSLER, Dean of Mineral Industries, Pennsylvania State University, University Park, Pa.

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ROBERT L. FERNALD, Department of Zoology, University of Washington, Seattle, Wash.

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HERBERT FRIEDMANN, Exposition Park, Los Angeles County Museum, Los Angeles, Calif.

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ROBERT HIATT, Vice President for Academic Affairs, University of Hawaii, Honolulu, Hawaii

THEODORE H. HUBBELL, Museum of Zoology, University of Michigan, Ann Arbor, Mich.

BOSTWICK H. KETCHUM, Woods Hole Oceanographic Institution, Woods Hole, Mass.

F. F. KOCZY, The Marine Laboratory, University of Miami, Miami, Fla.

HARLAN LEWIS, Dean of Life Sciences, University of California, Los Angeles, Calif.

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GEOFFREY NORMAN, Vice President for Research, University of Michigan, Ann Arbor, Mich.

JOHN L. PATTERSON, Department of Medicine, Medical College of Virginia, Richmond, Va.

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ALBERT C. SMITH, University of Hawaii, Honolulu, Hawaii

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STANLEY WATSON, Woods Hole Oceanographic Institution, Woods Hole, Mass.

APPENDIX B

Financial Report for Fiscal Year 1967

SALARIES AND EXPENSES APPROPRIATION

RECEIPTS

Appropriated for fiscal year 1967	$479, 999, 000	
Unobligated balance from fiscal year 1966	21, 777, 180	
Total availability		$501, 776, 180

OBLIGATIONS

Basic Research and Supporting Facilities:		
Basic Research Project Grants:		
Biological and medical sciences	51, 729, 635	
Mathematical and physical sciences	59, 767, 051	
Social sciences	14, 415, 159	
Environmental sciences	22, 713, 748	
Engineering	19, 244, 391	
Subtotal	167, 869, 984	
National Research Programs:		
Antarctic research programs	7, 577, 012	
Arctic ocean research program	134, 027	
Deep crustal studies of the earth (Mohole)	58, 576	
Weather modification program	2, 911, 847	
International Years of the Quiet Sun	708, 176	
International biological program	497, 700	
Subtotal	11, 887, 338	
Specialized Research Facilities and Equipment:		
Biological sciences research facilities:		
Specialized biological facilities	1, 668, 076	
Oceanographic research vessels and facilities	321, 558	
Environmental sciences research facilities:		
Oceanographic research facilities	1, 695, 771	
University atmospheric research facilities	954, 246	
Physical sciences research facilities:		
Chemistry research instruments	3, 121, 285	
University astronomy research facilities	1, 860, 000	
University physics research facilities	5, 797, 477	
Engineering research facilities	943, 450	
Specialized social sciences research facilities	309, 273	
Subtotal	16, 671, 136	

Basic Research and Supporting Facilities—Continued

National Research Centers:		
National Radio Astronomy Observatory	$4,985,000	
Kitt Peak National Observatory	5,505,000	
Cerro Tololo Inter-American Observatory	1,713,000	
National Center for Atmospheric Research	12,300,656	
Subtotal	24,503,656	
Subtotal, basic research and supporting facilities		$220,932,114
Science Education Support:		
Advanced science training for individuals:		
Fellowships and traineeships	45,874,427	
Improvement of quality of instructional programs:		
Course content improvement	18,355,444	
Instructional equipment for undergraduate education	4,906,120	
Cooperative college school program	2,212,537	
Subtotal	71,348,528	
Improvement of quality and competence of instructional staff and students:		
Supplemental training of teachers:		
Institutes	37,928,937	
Research participation	3,406,072	
Supplemental projects	484,155	
Science education for students	6,804,080	
Special projects	3,388,394	
Subtotal	52,011,638	
Subtotal, science education support		123,360,166
Institutional Support for Science:		
Institutional science development:		
University science development	33,169,000	
Departmental science development	4,390,440	
College science improvement program	2,464,100	
Subtotal	40,023,540	
Institutional grants for science	15,152,015	
Graduate science facilities	24,547,572	
Subtotal	39,699,587	
Subtotal, institutional support for science		79,723,127
Computing Activities in Education and Research		12,690,598
Science Information Activities:		
Support of publication and services	3,858,564	
Systems development and improvement	3,997,901	
Science information research and studies	2,168,272	
Subtotal, science information activities		10,024,737
Planning and Policy Studies		2,393,034

International Cooperative Scientific Activities	$2,000,847
Program Development and Management	14,044,400
Less: Reimbursement for research support services	—65,221
Total, NSF	465,103,802
Transfer to other Government agencies	15,132
Unobligated balance carried forward to fiscal year 1968	36,657,246
Total	501,776,180

TRUST FUND

Receipts

Unobligated balance from fiscal year 1966	7,907
Donation from private sources	1,178
Total availability	9,085

Obligations

Total obligations fiscal year 1967	2,396
Unobligated balance carried forward in fiscal year 1968	6,689
Total	9,085

APPENDIX C

Patents Resulting From Activities Supported by the National Science Foundation

The Foundation, since its last annual report, has received notification of the issuance of the following five patents by the U.S. Patent Office covering inventions arising out of Foundation-supported activities on each of which the Government has received a nonexclusive, irrevocable, nontransferable, royalty-free worldwide license:

Patent No. 3,272,434 entitled "Nucleating Process" was issued on September 13, 1966, on an invention made by Albert C. Zettlemoyer, John J. Chessick, and Noubar Tcheurekdjian during the course of research supported by a grant to Lehigh University, Bethlehem, Pa. This invention relates to freezing nucleating agents especially of the type which nucleate hydrogen-bonding crystals such as ice from liquid or from gaseous media, such as water clouds, and to processes of nucleation of hydrogen-bonding crystals.

Patent No. 3,297,590 entitled "Pyrophoric Lead Composition and Method of Making It" was issued on January 10, 1967, on an invention made by Sidney Toby and Joseph Charles during the course of research supported by a grant to Rutgers, The State University, New Brunswick, N.J. This invention relates to a novel pyrophoric lead composition of high pyrophoric activity and to a method of making it.

Patent No. 3,303,333 entitled "Error Detection and Correction System for Convolutional Codes" was issued on February 7, 1967, on an invention made during the course of research conducted by James Lee Massey when he was an NSF Fellow. This invention relates to methods of and apparatus for processing signal information, and more particularly, to the correcting and/or detecting of signal errors or other changes, as produced in transmission.

Patent No. 3,320,328 entitled "Permselective Membranes" was issued on May 16, 1967, on an invention made by Alan S. Michaels during the course of research supported by a grant to the Massachusetts Institute of Technology, Cambridge, Mass. This invention relates to diffusion processes for separating a mixture of compounds into fractions relatively enriched and depleted with respect to one or more of the compounds and in particular to permselective membranes for use in such processes.

Reissue Patent No. 26,065 entitled "Polybenzimidazoles and Their Preparation" was issued on July 19, 1966, on an invention made by Carl S. Marvel and Herward A. Vogel during the course of research supported by a grant to the University of Illinois, Urbana, Ill. This invention relates to a novel and useful class of high molecular weight and condensation polymers and to a process for the preparation of such polymers. More particularly, it relates to high molecular weight condensation polymers which are characterized by high melting points and a high degree of stability at elevated temperatures.

APPENDIX D

National Science Foundation-Supported Scientific Conferences, Symposia, and Advanced Science Seminars Held During Fiscal Year 1967

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE BIOLOGICAL AND MEDICAL SCIENCES

CARBON METABOLISM AND PHOTOSYNTHESIS.—College Park, Md.; Aug. 17, 1966; Chairman: Dr. Martin Gibbs, Brandeis University; Sponsor: American Society of Plant Physiologists.

PHYSIOLOGY AND BIOCHEMISTRY OF THE HEMOCYANINS.—Naples Zoological Station, Naples, Italy; Aug. 30-31—Sept. 1, 1966; Chairman: Dr. Francesco Ghiretti, Naples Zoological Station; Sponsor: Naples Zoological Station.

EXTRACELLULAR AND CYTOPLASMIC INFLUENCES ON NUCLEAR BEHAVIOR.—Marine Biological Laboratory, Woods Hole, Mass.; Aug. 31–Sept. 3, 1966; Chairman: Lester Goldstein, University of Pennsylvania; Sponsor: Society of General Physiologists.

SYMPOSIUM ON ORGANIZATIONAL BIOSYNTHESIS.—Rutgers University, New Brunswick, N.J.; Sept. 8–10, 1966; Chairmen: J. O. Lampen, Henry Vogel, and Vernon Bryson, Rutgers University; Sponsor: Rutgers University.

CONFERENCE ON CHEMISTRY, PHARMACOLOGY, AND CLINICAL APPLICATIONS OF PROTEINASE INHIBITORS.—New York, N.Y.; Sept. 12–13, 1966; Chairman: Nathan Back, State University of New York, Buffalo; Sponsor: National Academy of Sciences.

SYMPOSIUM ON BIOPHYSICAL CHARACTERIZATION OF INTERACTION MACROMOLECULAR SYSTEMS.—New York, N.Y.; Sept. 11–16, 1966; Chairmen: John R. Cann, University of Colorado and S. N. Timasheff, Brandeis University; Sponsor: American Chemical Society.

SYMPOSIUM ON THE MYELIN SHEATH.—New York, N.Y.; Sept. 11–16, 1966; Chairman: Gerhardt Schmidt, Tufts University; Sponsor: American Chemical Society.

SYMPOSIUM ON IMMUNITY AND CHEMOTHERAPY.—Buffalo, N.Y.; Sept. 20–23, 1966; Chairman: Enrico Mihich, The Research Foundation of the State University of New York, Albany, N.Y.; Sponsor: The Research Foundation of the State University of New York.

A SYMPOSIUM OF SYSTEMATICS: SYSTEMATICS AND NATURAL AREAS.—St. Louis, Mo.; Oct. 14–16, 1966; Chairmen: Dr. Pierre Dansereau, New York Botanical Garden; Dr. Theodore H. Hubbell, University of Michigan; Sponsor: Missouri Botanical Garden.

CONFERENCE ON HEAT CAPACITY OF PROTEINS.—Stillwater, Minn.; Oct. 21–22, 1966; Chairmen: Rufus Lumry, University of Minnesota and John Brandts, University of Massachusetts; Sponsor: University of Minnesota.

INTERNATIONAL SYMPOSIUM ON ENZYMATIC ASPECTS OF METABOLIC REGULATION.—Mexico City, Mexico; Nov. 28–Dec. 1, 1966; Chairman: Dr. J. Laguna, University of Mexico; Sponsors: University of Wisconsin; University of Mexico; Center for

Research and Advanced Studies, Politecnico Nacional; and, Biology Division, Oak Ridge National Laboratory.

COLLOQUIUM ON NITROGEN FIXATION.—Sanibel Island, Fla.; Dec. 1–4, 1966; Chairman: Warren S. Silver, University of Florida; Sponsor: University of Florida.

SUPPORT OF THE REGIONAL CONFERENCES IN DEVELOPMENTAL BIOLOGY.—Sponsor: The Society for the Study of Development and Growth.

I. Ohio State University, Columbus, Ohio; May 11–12, 1967; Chairman: John W. Price, Ohio State University;

II. Marquette University, Milwaukee, Wis.; Mar. 22–23, 1967; Chairman: Norman W. Klein, Marquette University;

III. Tulane University, New Orleans, La.; Mar. 17–18, 1967; Chairman: S. Meryl Rose, Tulane University;

IV. Rocky Mountain Regional Conference, Idlewild Guest Ranch, Winter Park, Colo.; Oct. 14–17, 1966; Chairmen: Meredith N. Runner and Joseph C. Daniel, Jr., University of Colorado;

V. West Coast Conference, Asilomar, Calif.; Nov. 25–27, 1966; Chairman: Norman K. Wessells, Stanford University.

ROLE OF PUNISHMENT IN BEHAVIOR CHANGE.—Princeton University, Princeton, N.J.; May 31–June 4, 1967; Chairman: Bryon A. Campbell, Princeton University; Sponsor: Princeton University.

THIRTY-SECOND COLD SPRING HARBOR LABORATORY SYMPOSIUM ON ANTIBODIES.—Cold Spring Harbor, Long Island, N.Y.; June 1–7, 1967; Chairmen: Gerald Edelman, Rockefeller University; Gustav Nossal, Melbourne, Australia, and Niels Jerne, Frankfurt, Germany; Sponsor: Cold Spring Harbor Laboratory of Quantitative Biology.

SYMPOSIUM ON EUTROPHICATION.—University of Wisconsin, Madison, Wis.; June 11–16, 1967; Chairman: Gerald Rohlich, University of Wisconsin; Sponsor: National Academy of Sciences-National Research Council.

THE FOURTH INTERNATIONAL SYMPOSIUM ON LIGHT AND VISION.—Ohio State University, Columbus, Ohio; June 14–15, 1967; Chairman: Glenn A. Fry, Ohio State University; Sponsors: Ohio State University and Illuminating Engineers Research Institute.

INTERNATIONAL CONFERENCE ON SYSTEMATIC BIOLOGY.—University of Michigan, Ann Arbor, Mich.; June 14–17, 1967; Chairman: Dr. Lincoln Constance, University of California, Berkeley; Sponsor: National Academy of Sciences.

GORDON RESEARCH CONFERENCE ON NUCLEIC ACIDS.—New Hampton, N.H.; June 19–23, 1967; Chairman: Robert Holley, Cornell University; Sponsor: Gordon Research Conferences, Inc.

ANNUAL GROWTH SYMPOSIUM FOR 1967.—University of California (San Diego), La Jolla, Calif.; June 19–21, 1967; Chairman: Sam Granick, Rockefeller University, New York; Sponsor: The Society for the Study of Development and Growth.

GORDON RESEARCH CONFERENCE ON PROTEINS.—New Hampton, N.H.; June 25–30, 1967; Chairmen: Irving Klotz, Northwestern University and Emanuel Margoliash, Abbott Laboratories; Sponsor: Gordon Research Conferences, Inc.

1967 GORDON CONFERENCE ON CELL STRUCTURE AND METABOLISM.—Kimball Union Academy, Meriden, N.H.; June 26–30, 1967; Chairman: Paul R. Gross, Massachusetts Institute of Technology; Sponsor: Gordon Research Conferences, Inc.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE ENGINEERING SCIENCES

CONFERENCE ON AXIOMATICS OF MECHANICS.—Chicago, Ill.; Oct. 21–22, 1966; Chairman: Dr. Peter Chiarulli, Illinois Institute of Technology; Sponsor: Illinois Institute of Technology.

Conference on Earthquake Engineering Research in Universities.—Pasadena, Calif.; Mar. 10–11, 1967; Chairmen: Drs. D. E. Hudson and C. W. Housner, California Institute of Technology; Sponsors: Universities Council for Earthquake Engineering Research and California Institute of Technology.

University Research: Its Role in the Solution of National Civilian Problems.—Bromwoods (Ozark foothills); Mar. 24–25, 1967; Chairman: Dr. George W. Hazzard, Washington University; Sponsor: Washington University.

Third International Heat Transfer Conference.—Chicago, Ill.; Aug. 8–12, 1966; Chairman: Dr. F. J. Van Antwerpen, American Institute of Chemical Engineers; Sponsor: American Institute of Chemical Engineers.

Third Systems Symposium.—Cleveland, Ohio; Oct. 20–21, 1966; Chairman: Dr. Mihajlo D. Mesarovic, Case Institute of Technology; Sponsor: Case Institute of Technology.

Symposium on the Engineering Significance of the Biological Sciences.—Pittsburgh, Pa.; January 1967; Chairman: Dr. George Bugliarello, Carnegie Institute of Technology; Sponsor: Carnegie Institute of Technology.

The 1966 Rochester Conference on Data Acquisition and Processing in Biology and Medicine.—Rochester, N.Y.; July 25–27, 1966; Chairman: Mr. Kurt Enslein.

International Conference on Stratified Fluids.—Ann Arbor, Mich.; Apr. 11–14, 1967; Chairman: Dr. Chia-Shun Yih, University of Michigan; Sponsor: University of Michigan.

Conference-Lens Design With Large Computers.—Rochester, N.Y.; July 1966; Chairman: Dr. W. Lewis Hyde, University of Rochester; Sponsor: University of Rochester.

Technical Conference on Work Hardening in Metals.—Chicago, Ill.; Oct. 30–Nov. 3, 1966; Chairmen: Drs. J. P. Hirth and J. Weertman, Ohio State University; Sponsor: The Metallurgical Society of AIME.

Fourth Bioengineering Symposium.—Terre Haute, Ind.; Oct. 17–18, 1966; Chairman: Dr. Robert M. Arthur, Rose Polytechnic Institute; Sponsor: Rose Polytechnic Institute.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE ENVIRONMENTAL SCIENCES

National Clay Minerals Conference.—Pittsburgh, Pa.; Oct. 11–13, 1966; Chairman: James W. Earley, Gulf Research & Development Co., Pittsburgh; Cosponsor: Clay Minerals Society.

Symposium on Magmatic Ore Deposits.—Stanford University, Stanford, Calif.; Nov. 12–17, 1966; Chairman: H. D. B. Wilson, Geology Department, University of Manitoba, Winnebag, Canada; Cosponsor: The Society of Economic Geologists.

Conference on Meteorological Investigations Above 60 km.—Miami Beach, Fla.; May 31–June 2, 1967; Chairman: Kenneth C. Spengler, Executive Director, American Meteorological Society; Cosponsor: Committee on Atmospheric Problems of Aerospace Vehicles (CAPAV) of the American Meteorological Society.

Surtsey Research Conference.—Reykjavik, Iceland; June 24–28, 1967; Cochairmen: Steingrimur Hermansson, President of the Surtsey Research Society and John R. Olive, Executive Director, AIBS; Cosponsors: American Institute of Biological Sciences (AIBS); The Smithsonian Institution; Air Force Office of Scientific Research; and the Surtsey Research Society.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE MATHEMATICAL AND PHYSICAL SCIENCES

INTERNATIONAL ASTORONOMICAL UNION WORKSHOP CONFERENCE ON ATOMIC COLLISION CROSS SECTIONS AND LINE BROADENING DATA.—Boulder, Colo.; July 11–15, 1966; Chairman: Lewis M. Branscomb, Joint Institute for Laboratory Astrophysics, University of Colorado, Boulder; Cosponsors: International Astronomical Union, National Bureau of Standards, and University of Colorado Joint Institute for Laboratory Astrophysics.

1966 GORDON CONFERENCE ON PLASMA PHYSICS.—Crystal Mountain, Wash.; Aug. 8–12, 1966; Chairman: Dr. Betsy Ancker-Johnson, Staff Member, Plasma Physics Laboratory of Boeing Scientific Research Laboratories, and Associate Professor of Electrical Engineering, University of Washington, Seattle, Wash.; Vice Chairman: Dr. J. E. Drummon, Head, Plasma Physics Laboratory, Boeing, Cosponsor: Gordon Research Conferences (Director, Dr. W. George Parks, University of Rhode Island, Kingston, R.I.)

ELEVENTH INTERNATIONAL SYMPOSIUM ON COMBUSTION.—Berkeley, Calif.; Aug. 14–20, 1966; Chairman: Professor E. S. Starkman, University of California, Berkeley, Calif.; Cosponsors: The Combustion Institute, Pittsburgh, Pa.; Ballistic Research Laboratories, Department of the Army; National Aeronautics and Space Administration.

XIIITH INTERNATIONAL CONFERENCE ON HIGH-ENERGY PHYSICS.—Berkeley, Calif.; Aug. 31–Sept. 7, 1966; Cochairmen: Drs. Edwin M. McMillan and Leroy T. Kerth, Department of Physics, University of California, Berkeley; Cosponsors: Atomic Energy Commission; International Union of Pure and Applied Physics (Paris, France); and the University of California.

INTERNATIONAL CONFERENCE ON NUCLEAR PHYSICS.—Gatlinburg, Tenn.; Sept. 12–17, 1966; Chairman: Alexander Zucker, Oak Ridge National Laboratory; Cosponsors: International Union of Pure and Applied Physics; Oak Ridge National Laboratory, Atomic Energy Commission.

INTERNATIONAL CONFERENCE ON SUPRAMOLECULAR STRUCTURE IN FIBERS.—Boston, Mass.; Sept. 21–23, 1966; Chairman: Emery I. Valko, Massachusetts Institute of Technology; Cosponsors: International Wool Secretariat, Australia; Imperial Chemical Industry, England; British Nylon Spinners, Pontypool, England; and the Fiber Society, Inc.

CONFERENCE ON CONSTRUCTION AND USE OF STAR CATALOGS.—Center for Adult Education, University of Maryland, College Park, Md.; Oct. 2–5, 1966; Chairman: Dr. K. Aa Strand, U.S. Naval Observatory; Cosponsors: Yale University, New Haven, Conn.; U.S. Naval Observatory, Washington, D.C.

SYMPOSIUM ON YLID-CHEMISTRY.—Cincinnati, Ohio; Oct. 18–19, 1966; Chairman: Hans Zimmer, Department of Chemistry, University of Cincinnati; Cosponsors: National Institutes of Health; National Aeronautics and Space Administration; and private industrial chemical firms.

FIFTH ANNUAL EASTERN UNITED STATES THEORETICAL PHYSICS CONFERENCE.—Providence, R.I.; Nov. 25–26, 1966; Chairman: David Feldman, Department of Physics, Brown University; Cosponsor: Brown University.

SYMPOSIUM ON MOUNTING OF LARGE ASTRONOMICAL MIRRORS.—Tucson, Ariz.; Dec. 4–6, 1966; Cochairmen: Drs. D. L. Crawford, Kitt Peak National Observatory and A. B. Meinel, Steward Observatory-Optical Sciences Laboratory, University of Arizona; Cosponsors: University of Arizona, Tucson, and Kitt Peak National Observatory.

INTERNATIONAL SYMPOSIUM ON RELATIVISTIC ASTROPHYSICS.—New York, N.Y.; Jan. 23–27, 1967; Cochairmen: A. G. W. Cameron, Belfer Graduate School of Science, Yeshiva University; Ivor Robinson, Southwest Center for Advanced

Studies; Alfred Schild and E. L. Shucking, Department of Physics, University of Texas; Cosponsors: Yeshiva University, The Goddard Institute for Space Studies, the Southwest Center for Advanced Studies, the University of Texas, the Atomic Energy Commission, National Aeronautics and Space Administration, and the Office of Naval Research.

FOURTH CORAL GABLES CONFERENCE ON SYMMETRY PRINCIPLES AT HIGH ENERGY.—Coral Gables, Fla.; Jan. 25–27, 1967; Chairman: Behram Kursunoglu, Center for Theoretical Studies, University of Miami; Cosponsors: University of Miami, Atomic Energy Commission, National Aeronautics and Space Administration, Office of Naval Research, Air Force Office of Scientific Research.

THERMAL NEUTRON SCATTERING APPLIED TO CHEMICAL AND SOLID STATE PHYSICS.—Atlanta, Ga.; Jan. 25–27, 1967, in conjunction with the winter meeting of the American Crystallographic Association; Chairman: Harold G. Smith, Oak Ridge National Laboratory, Oak Ridge, Tenn.; Cosponsor: American Crystallographic Association, New York, N.Y.

1967 U.S. NATIONAL PARTICLE ACCELERATOR CONFERENCE.—Washington, D.C.; Mar. 1–3, 1967; Chairman: R. S. Livingston, Oak Ridge National Laboratory; Cosponsors: Institute of Electrical and Electronics Engineers, Inc., New York; American Physical Society; Atomic Energy Commission; National Bureau of Standards.

EIGHTH EXPERIMENTAL NUCLEAR MAGNETIC RESONANCE CONFERENCE.—Pittsburgh, Pa.; Mar. 2–4, 1967; Chairman: Professor J. B. Stothers, Department of Chemistry, University of Western Ontario, London, Ontario, Canada; Cosponsor: Mellon Institute, Pittsburgh, Pa.

CONFERENCE ON POINT SET TOPOLOGY.—Tempe, Ariz.; Mar. 21–25, 1967; Co-Chairmen: Professors Edward E. Grace and Robert W. Heath, Department of Mathematics, Arizona State University; Cosponsor: Arizona State University.

INTERNATIONAL CONFERENCE ON THE NUCLEON-NUCLEON INTERACTION.—Gainesville, Fla.; Mar. 23–25, 1967; Chairman: Alex E. S. Green, Graduate Research Professor, Department of Physics, University of Florida; Cosponsors: University of Florida; Air Force Office of Scientific Research, Army Research Office, Durham; National Aeronautics and Space Administration, Office of Naval Research, and Atomic Energy Commission.

SECOND INTERNATIONAL CONGRESS FOR STEREOLOGY.—Institute for Medical Research, Chicago Medical School; Apr. 8–13, 1967; Chairman: Hans Elias, Department of Anatomy, Chicago Medical School and President, International Society for Stereology; Cosponsors: The Chicago Medical School and the International Society for Stereology.

CONFERENCE ON ORTHOGONAL EXPANSIONS.—Edwardsville, Ill.; Apr. 27–29, 1967; Chairman: Dr. Deborah Tepper Haimo, Science and Technology Division, Southern Illinois University; Cosponsor: Southern Illinois University.

CONFERENCE ON DIATOMIC COLLISIONS AND ELECTRONIC STRUCTURE.—Menlo Park, Calif.; May 2–4, 1967; Chairman: Felix T. Smith, Stanford Research Institute; Cosponsor: Stanford Research Institute.

MIDWEST CONFERENCE ON THEORETICAL PHYSICS.—Urbana, Ill.; May 26–27, 1967; Chairman: L. P. Kadanoff, Department of Physics, University of Illinois; Cosponsor: University of Illinois.

GORDON RESEARCH CONFERENCE ON NUCLEAR CHEMISTRY.—New London, N.H. (Colby Junior College); June 19–23, 1967; Cochairmen: G. Davis O'Kelley, Oak Ridge National Laboratory and Raymond K. Sheline, Florida State University; Cosponsor: Gordon Research Conferences, Inc.

SYMPOSIUM ON NUCLEAR PHYSICS RESEARCH WITH LOW ENERGY ACCELERATORS.—University of Maryland, College Park, Md.; June 19–24, 1967; Chairman: Jerry

B. Marion, Department of Physics and Astronomy, University of Maryland; Cosponsor: University of Maryland.

CONFERENCE ON PROJECTIVE PLANES.—University of Illinois at Chicago Circle, Chicago, Ill.; June 19–July 7, 1967; Chairman: Reuben Sandler, Department of Mathematics; Cosponsor: University of Illinois.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE SOCIAL SCIENCES

CONFERENCE ON COMPARATIVE STUDY OF AMERICAN POLITICAL BEHAVIOR.—Ann Arbor, Mich.; Aug. 1–12, 1966; Chairman: Warren E. Miller, University of Michigan; Sponsor: Interuniversity Consortium for Political Research.

CONFERENCE ON COMPARATIVE STUDY OF LOCAL COMMUNITIES.—Athens, Ga.; Nov. 16–19, 1966; Chairman: Thomas R. Dye; Sponsor: University of Georgia.

CONFERENCE ON CROSS-CULTURAL RESEARCH.—New Haven, Conn.; Feb. 9–10, 1967; Chairman: Clelland S. Ford; Sponsor: Human Relations Area Files, Inc.

CONFERENCE ON INDUSTRIAL COMPOSITION OF INCOME AND PRODUCT.—Washington, D.C.; Dec. 1–2, 1966; Chairman: John W. Kendrick, George Washington University; Sponsor: National Bureau of Economic Research.

CONFERENCE ON SIZE DISTRIBUTION OF INCOME AND WEALTH.—Philadelphia, Pa.; March 1967; Chairman: Irving B. Kravis; Sponsor: National Bureau of Economic Research.

CONFERENCE ON THE CURRENT STATE OF ECONOMETRICS.—Columbus, Ohio; May 18–19, 1967; Chairman: Karl Brunner; Sponsor: Ohio State University.

RESEARCH CONFERENCE ON SOCIAL FACILITATION AND IMITATION BEHAVIOR.—Oxford, Ohio; Mar. 23–24, 1967; Chairman: Edward C. Simmel; Sponsor: Miami University.

ADVANCED SCIENCE SEMINARS

ADVANCED SCIENCE SEMINAR IN LINGUISTICS.—Ann Arbor, Mich.; June 26–Aug. 17, 1967; Director: H.H. Paper, The University of Michigan; Grantee: American Council of Learned Societies.

RECENT DEVELOPMENTS IN ENDOCRINOLOGY.—College Park, Md.; Aug. 16, 1966; Director: A. Gorbman, University of Washington; Grantee: American Society of Zoologists.

REGIONAL CONFERENCES IN COMPARATIVE ENDOCRINOLOGY.—Baton Rouge, La., mid-February 1967; Seattle, Wash., late March 1967; Williamsburg, Va., Mar. 10–11, 1967; Director: W. Chavin, Wayne State University; Grantee: American Society of Zoologists.

ROCKY MOUNTAIN REGIONAL SUMMER SYMPOSIUM IN ORDINARY DIFFERENTIAL EQUATIONS.—Boulder, Colo.; June 19–Aug. 11, 1967; Director: R. W. McKelvey, University of Colorado; Grantee: Associated Rocky Mountain Universities, Inc.

SPECIAL COURSE ON ROCK MECHANICS FOR COLLEGE TEACHERS OF STRUCTURAL GEOLOGY.—Chestnut Hill, Mass.; June 26–July 30, 1967; Director: E. G. Bombolakis, Boston College; Grantee: Boston College.

ADVANCED SEMINAR IN ALGEBRAIC FOUNDATIONS OF ALGEBRAIC GEOMETRY.—Brunswick, Maine; June 20–Aug. 10, 1967; Director: D. E. Christie, Bowdoin College; Grantee: Bowdoin College.

A SUMMER FIELD PROGRAM IN ANTHROPOLOGY.—Caribbean Area; June 15–Sept. 15, 1967; Director: R. A. Manners, Brandeis University; Grantee: Brandeis University.

SUMMER SEMINAR IN THEORETICAL PHYSICS.—Waltham, Mass.; June 19–July 28, 1967; Director: S. S. Schweber, Brandeis University; Grantee: Brandeis University.

SEMINAR IN SOLID MECHANICS.—Providence, R.I.; June 8–17, 1967; Director: A. C. Pipkin, Brown University; Grantee: Brown University.

SIXTH SUMMER SEMINAR ON HIGHER MATHEMATICS.—Montreal, Canada; June 26–July 28, 1967; Director: J. J. McNamee, Canadian Mathematical Congress; Grantee: Canadian Mathematical Congress.

BIOPHYSICAL APPROACHES TO THE STUDY OF PHOTOSYNTHESIS.—Ithaca, N.Y.; June 5–9, 1967; Director: R. K. Clayton, Cornell University; Grantee: Cornell University.

A SPECIAL SUMMER SESSION ON STATISTICAL AND MATHEMATICAL THEORY.—Atlanta, Ga.; June 16–July 28, 1967; Director: M. W. Turner, Jr., Emory University; Grantee: Emory University.

TRAINING PROGRAM IN COMPARATIVE SOCIOLOGY.—Bloomington, Ind.; June 19–Aug. 11, 1967; Director: A. D. Grimshaw, Indiana University; Grantee: Indiana University.

LATIN AMERICAN SCHOOL OF PHYSICS.—Caracas, Venezuela; July 4–29, 1966, Director: M. Bemporad, Institute Venezolano de Investigaciones Cientificas; Grantee: International Travel Grants to individual scientists.

SEMINAR ON COMPARISON OF RECENT AND ANCIENT DELTAIC SEDIMENTS.—Baton Rouge, La.; May 20–24, 1967; Director: J. M. Coleman, Louisiana State University; Grantee: Louisiana State University.

SUMMER INSTITUTE OF GLACIOLOGICAL SCIENCES.—Juneau Icefield, Alaska; July 17–Sept. 3, 1966; Director: M. M. Miller, Michigan State University; Grantee: Michigan State University.

SYMPOSIUM ON MOLECULAR STRUCTURE AND SPECTROSCOPY.—Columbus, Ohio; Sept. 6–10, 1966; Director: H. H. Nielsen, The Ohio State University; Grantee: The Ohio State University Research Foundation.

STABILITY IN CELESTIAL MECHANICS.—Lafayette, Ind.; June 19–July 14, 1967; Director: H. Pollard, Purdue University; Grantee: Purdue University.

ADVANCED SCIENCE SEMINAR IN COMPUTATIONAL LINGUISTICS.—Santa Monica, Calif.; Sept. 1, 1966–Aug. 31, 1967; Director: D. G. Hays, The Rand Corp.; Grantee: The Rand Corp.

SUMMER SEMINAR OF SYSTEMATICS.—Washington, D.C.; June 26–July 14, 1967; Director: E. L. Yochelson, U.S. Geological Survey; Grantee: Society of Systematic Zoology.

WORKSHOP ON THE STANFORD WATERSHED MODEL.—Stanford, Calif.; July 11–15, 1966; Director: R. K. Linsley, Stanford University; Grantee: Stanford University.

FIELD TRAINING FOR ANTHROPOLOGISTS.—Oaxaca, Mexico; June 24–Sept. 2, 1967; Director: J. C. Hotchkiss, Stanford University; Grantee: Stanford University.

CONFERENCE ON COMPACT TRANSFORMATION GROUPS AND THEIR APPLICATIONS.—New Orleans, La.; May 8—June 2, 1967; Director: P. S. Mostert, Tulane University; Grantee: Tulane University.

FIELD SCHOOL IN ANTHROPOLOGY.—Ixmiquilpan, Mexico; June 20–Aug. 31, 1967; Director: H. R. Bernard, Washington State University; Grantee: Washington State University.

SEMINAR ON PHASE TRANSITIONS OF THE SECOND KIND.—Cleveland, Ohio; June 19–23, 1967; Director: P. R. Zilsel, Western Reserve University; Grantee: Western Reserve University.

POSTDOCTORAL RESEARCH TRAINING PROGRAM IN BIOLOGICAL OCEANOGRAPHY.—Woods Hole, Mass.; Sept. 1, 1966–Aug. 31, 1967; Director: J. H. Ryther, Woods Hole Oceanographic Institution; Grantee: Woods Hole Oceanographic Institution.

SUMMER PROGRAMS IN GEOPHYSICAL FLUID DYNAMICS.—Woods Hole, Mass.; June 19–Aug. 25, 1967; Director: G. Veronis, Yale University; Grantee: Woods Hole Oceanographic Institution.

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FIELD COURSE IN MARINE ECOLOGY FOR PALEONTOLOGISTS.—Woods Hole, Mass., and Timber Lake, S. Dak.; June 15–Aug. 5, 1967; Director: D. C. Rhoads, Yale University; Grantee: Yale University.

ADVANCED FIELD TRAINING IN ARCHAEOLOGY.—Grasshopper, Ariz.; June 9–Aug. 4, 1967; Director: R. H. Thompson, University of Arizona; Grantee: University of Arizona.

SUMMER SEMINAR IN THEORETICAL PHYSICS AND CHEMISTRY.—San Diego, Calif.; Aug. 1–26, 1966; Director: K. A. Brueckner, University of California, San Diego; Grantee: University of California, San Diego.

INSTITUTE FOR THEORETICAL PHYSICS.—Boulder, Colo.; June 12–Aug. 18, 1967; Director: W. E. Brittin, University of Colorado; Grantee: University of Colorado.

SEMINAR ON THE PHYSICS OF THE SOLAR CORONA.—Boulder, Colo.; June 12–July 15, 1967; Director: D. E. Billings, University of Colorado; Grantee: University of Colorado.

ENERGETICS IN METALLURGICAL PHENOMENA.—Denver, Colo.; June 19–Aug. 11, 1967; Director: C. B. Magee, University of Denver; Grantee: University of Denver.

FOURTH GRADUATE WINTER INSTITUTE ON ADVANCED CONTROL.—Gainesville, Fla.; Feb. 20–25, 1967; Director: O. I. Elgerd, University of Florida; Grantee: University of Florida.

WINTER INSTITUTE IN QUANTUM CHEMISTRY, SOLID-STATE PHYSICS AND QUANTUM BIOLOGY.—Gainesville, Fla.; Dec. 5, 1966–Jan. 21, 1967; Director: P. O. Lowdin, University of Florida; Grantee: University of Florida.

MEDICINAL CHEMISTRY SEMINAR.—Lawrence, Kans.; Mar. 27–29, 1967; Director: E. E. Smissman, University of Kansas; Grantee: University of Kansas.

FIELD METHODS FOR SYSTEMATIC VERTEBRATE ZOOLOGISTS AND PALEONTOLOGISTS.—Western United States; June 6–Aug. 1, 1967; Director: E. R. Hall, University of Kansas; Grantee: University of Kansas.

ARCHAEOLOGICAL FIELD SCHOOL.—White Cloud, Kans.; June 12–Aug. 4, 1967; Director: A. E. Johnson, University of Kansas; Grantee: University of Kansas.

ADVANCED SCIENCE SEMINARS IN QUANTITATIVE POLITICAL SCIENCE RESEARCH.—Ann Arbor, Mich.; June 12–Aug. 4, 1967; Director: W. E. Miller, The University of Michigan; Grantee: The University of Michigan.

GREAT LAKES LIMNOLOGY.—Ann Arbor, Mich.; June 26–Aug. 4, 1967; Director: D. C. Chandler, The University of Michigan; Grantee: The University of Michigan.

FIELD TRAINING FOR ANTHROPOLIGISTS.—Pacific Northwest; June 24–Sept. 2, 1967; Director: W. L. d'Azevedo, University of Nevada; Grantee: University of Nevada.

FIELD TRAINING FOR ANTHROPOLOGISTS.—Puebla, Mexico; June 17–Aug. 26, 1967; Director: D. Landy, University of Pittsburgh; Grantee: University of Pittsburgh.

SUMMER TRAINING INSTITUTE IN CROSS-CULTURAL RESEARCH.—Pittsburgh, Pa.; July 5–Aug. 27, 1966; Director: G. P. Murdock, University of Pittsburgh; Grantee: University of Pittsburgh.

MODERN CONTROL THEORY.—Los Angeles, Calif.; June 5–16, 1967; Director: P. A. White, University of Southern California; Grantee: University of Southern California.

SYSTEMS ECOLOGY SEQUENCE PROJECT.—Knoxville, Tenn.; Sept. 1, 1966–Aug. 31, 1967; Director: J. S. Olson, University of Tennessee; Grantee: University of Tennessee.

SEMINAR ON PHYSICS OF THE UPPER ATMOSPHERE.—El Paso, Tex.; June 19–30, 1967; Director: M. C. Bolen, University of Texas at El Paso; Grantee: University of Texas at El Paso.

SIXTH SUMMER INSTITUTE FOR THEORETICAL PHYSICS.—Madison, Wis.; June 19–Aug. 19, 1967; Director: K. W. McVoy, University of Wisconsin; Grantee: University of Wisconsin.

APPENDIX E

Publications of the National Science Foundation, Fiscal Year 1967

1. Scientific Information Activities of Federal Agencies, No. 32, Department of Defense—Part I (NSF 66–8).
2. Scientific Information Activities of Federal Agencies, April 1966, No. 33, U.S. Army—Part I (NSF 66–10).
3. Basic Research, Applied Research, and Development in Industry, 1963 (NSF 66–15).
4. Current Research and Development in Scientific Documentation, No. 14 (NSF 66–17).
5. Current Projects on Economic and Social Implications of Science and Technology, 1965 (NSF 66–21).
6. Course and Curriculum Improvement Projects, Mathematics, Science, Engineering (NSF 66–22).
7. Scientific Information Notes, Vol. 8, No. 3—June–July 1966 (NSF 66–23).
8. Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1965, 1966, 1967—Vol. XV (NSF 66–25).
9. Reviews of Data on Science Resources, Number 9—Resources for Scientific Activities at Universities and Colleges, 1964 (NSF 66–27).
10. Scientific Information Notes—Vol. 8, No. 4—August–September 1966 (NSF 66–26).
11. Basic Research, Applied Research, and Development in Industry, 1964 (NSF 66–28).
12. American Science Manpower, 1964 (NSF 66–29).
13. Federal Support for Academic Science and Other Educational Activities in Universities and Colleges, Fiscal Year 1965 (NSF 66–30).
14. Scientific Information Notes, Vol. 8, No. 5—October–November 1966 (NSF 66–31).
15. Reviews of Data on Science Resources, No. 10—Basic Research, Applied Research, and Development in American Industry, 1965 (NSF 66–33).
16. Reviews of Data on Science Resources, No. 11—Salaries and Selected Characteristics of U.S. Scientists, 1966 (NSF 66–34).
17. Scientific Information Notes, Vol. 8, No. 6—December 1966–January 1967 (NSF 66–35).
18. 16th Annual Report, 1966, National Science Foundation (NSF 67–1).
19. Grants and Awards, 1966, National Science Foundation (NSF 67–2).
20. Scientists and Engineers From Aboard, 1962–64 (NSF 67–3).
21. Scientific Information Notes, Vol. 9, No. 1—February–March 1967 (NSF 67–4).
22. Scientific Information Notes, Vol. 9, No. 2—April–May 1967 (NSF 67–7).
23. Weather Modification, Eighth Annual Report, 1966 (NSF 67–9).

APPENDIX F

CRITERIA
FOR THE SUPPORT OF RESEARCH
BY THE NATIONAL SCIENCE FOUNDATION

As Approved by the National Science Board
at its Seventeenth Annual (112th) Meeting,
May 18–19, 1967

In order to make explicit the policies of the National Science Foundation concerning the support of research in educational institutions and in national centers, the National Science Board has adopted the following statement. It is intended as a clarification and reaffirmation of the general philosophy that has guided the Foundation since its establishment and which, the Board believes, properly implements the intent of the Act which created the National Science Foundation. The statement will serve as a guide to the staff and to the advisory groups which assist the Foundation in these endeavors. It is presented as a service to the scientific community and for the consideration of other bodies and administrators responsible for the support and conduct of scientific research.

The cultivation of science, the arts and the humanities has been accepted by the executive branch and by the Congress of the United States as an appropriate function of Government, in the conviction that such a course will lead to a more rich and meaningful life for our people. Concomitantly, the contribution of fundamental research to the development of the new technologies essential to the attainment of our national goals has become ever more evident, while the need for understanding the behavior of individual humans and their social groupings has never been more imperative.

In fostering the cultivation of the natural and social sciences, the Federal Government shares responsibility with individual citizens, private foundations, industry, local and State governments, as well as the universities. For most of the agencies through which the Government conducts and supports scientific research the cultivation of sciences, per se, is not a primary objective even though, in the pursuit of their specific missions, they find it necessary and appropriate to support fundamental investigations in academic institutions and elsewhere. As delineated in the National Science Foundation Act of 1950, however, the furthering of basic research is, itself, part of the specific mission of the National Science Foundation. Moreover, the Foundation is unique among all Federal agencies which support scientific research in that it must also be continuingly concerned with the nature and quality of education in all aspects of science and at all academic levels from grade through graduate school. Accordingly, the welfare and development of the institutions within which research and science education are conducted are also major considerations in the Foundation's programs and planning.

Basic research in universities is primarily motivated by curiosity concerning the nature of man and his environment. It is, in short, part of man's never ending quest for new knowledge and understanding; and participation in such research is an essential aspect of the training of young scientists. It insures continuity in the exploration of the frontiers of science and it gives assurance that competent scientists will be available to support the Nation's goals in education and in the development of science-related technology. Only infrequently can support of research which is thus motivated be justified by certain anticipation of a defined application. But the history of science provides striking instances of the development of technology in which the essential contribution was knowledge which had been attained by such investigations. The successful damping of what would otherwise probably have been major oscillations in the national economy further testifies to the eminent practicality of fundamental studies. It is the judgment of history, therefore, that the national enterprise is best furthered by encouraging each field of the natural and social sciences to develop in accordance with its own intellectual needs and potentialities while encouraging each individual scientist engaged in fundamental research to select the subject matter of his investigation in accordance with the structure and developing opportunities of his own field.

The National Science Foundation has developed a variety of programs in support of research, each of which was designed to meet specific requirements. Among these may be noted:

(1) A broad program of support of the research projects of individual scientists, most of whom are members of university faculties.

(2) (a) National centers have been established to make possible research by university and other scientists in fields such as radio and optical astronomy and the atmospheric sciences where very large and expensive equipment is required.

(b) Large ventures in which success is conditioned upon skillful management of logistical support and interdigitation of the activities of otherwise independent investigators, as in the Antarctic, are identified, funded and managed as coherent national programs.

(3) To encourage development of additional scientific strength at academic centers throughout the Nation, so that the opportunities available to our people will be enhanced wherever they may live, the Foundation has begun to provide support for planned development of universities and colleges, matched to their potential as judged by qualified scientists and administrators. As these developments succeed, additional scientists qualified to advance the Nation's purposes in science and technology will emerge, thus engendering a requirement for additional support of academic research in the new centers of excellence.

There are two principal measures of the effectiveness of the Nation's effort in basic research:

(1) The total undertaking must add significantly to the knowledge and understanding that is part of our cultural heritage. In the long run, this will also contribute to the development of new technology and to solution of the major problems of our society.

(2) It must provide a setting in which students are stimulated and trained to carry on the great tradition of the scientific search and produce scientifically trained manpower in numbers adequate for the Nation's many requirements.

Since the support of basic research by other Federal agencies must be pursued within a framework consonant with their missions, it is the obligation of the National Science Foundation to manage its research programs in such a way as to permit the development of science along lines dictated by the internal needs of science itself. However, total Federal support for science, the sum of the programs of all agencies so engaged, should be so balanced as to assure the continuing development of science essential to our national purpose.

Before considering the criteria which should apply in selecting among research proposals for Federal support, it is useful to classify the types of institutions within which research is conducted, since somewhat different criteria appear to be appropriate among them. The categorization below encompasses virtually all research institutions, of which one major category is usually considered inappropriate for support by the National Science Foundation.

CLASSIFICATION OF INSTITUTIONS IN WHICH RESEARCH IS CONDUCTED

Category I: Academic Institutions.

Category II: National Centers and Fundamental Research Institutes.

Category III. Nonacademic Mission-oriented Institutions.

I. **Academic Institutions** comprise institutions, or those parts thereof, in which research is intimately related to the process of undergraduate, graduate or postdoctoral education. (Postdoctoral education is the further training of young investigators who are on short-term appointments.) This category coincides approximately with the classification entitled "Educational Institutions Proper" used by the National Science Foundation in compilations of statistics. Separately organized research centers, even when operated by a university, should be considered to be in category III if they are primarily mission-oriented or in category II if they are primarily dedicated to pure science. In some cases, distinction between categories I and II will be difficult, but since the criteria for research support in institutions of categories I and II differ only slightly precise drawing of this line is not of major significance. Research in institutions of category II frequently includes a large component of "big science" and usually involves a higher ratio of support personnel to independent scientists than in institutions of category I.

II. **National Centers and Fundamental Research Institutes** are institutions whose objectives are largely defined in terms of fundamental scientific research accomplishments rather than the development of new technology or other societally determined purpose. In this sense they are intermediate between institutions of category I and those of category III since their objectives are neither educational nor technological but scientific. Such institutions divide themselves into two types: (*a*) Private or public research institutes devoted largely to research; and (*b*) research institutes, such as the national centers supported by the National Science Foundation, in which education and/or service to academic user groups are primary or major secondary objectives. There is no sharp separation between these subcategories; research institutes have often tended later to develop a strong secondary commitment to advanced training and occasionally have evolved into universities. The National Science Foundation should deliberately give priority in its support to those research institutes or national centers with strong secondary commitments to education or to utilization of their facilities by academic users.

III. Nonacademic Mission-oriented Institutions are primarily concerned with the development of technology or contribution to some major problem of society rather than with education or the advancement of science, per se. This category includes most industrial laboratories, Government laboratories and mission-oriented Federal contract research centers (whether operated by industry or universities) as well as many nonprofit research institutes. The mission may be either quite specific or rather general, serving diverse technical needs of an agency. Some national centers include subdivisions which may be regarded as in category II while others, more properly, should be assigned to category III, with little interaction between them. In these instances, it will be useful to consider support of activities within these subdivisions as if they were independent institutions. In category III also may be included those nonprofit research institutes which engage in diverse research areas according to the needs of the clients, including the Government, who utilize their services.

To be sure, laboratories in category III frequently engage substantially in fundamental research which is indistinguishable in character from that in institutions of categories I and II. The present distinction arises from the fact that this research is conducted in a technological environment and is motivated, in part, by scientific necessities perceived within that environment. Decisions concerning the fraction of the total effort of such a laboratory which should be devoted to fundamental investigations are the responsibility of the management of the institution and will reflect the long-range responsibilities of the laboratory and the total funds available to it. The total allocation to an institution must be established by higher authority after considering the long-range importance of its mission and its success in accomplishing it. Although the quality of the fundamental research performed in a mission-oriented institution is an important factor in its achieving its other objectives, it cannot be the primary justification for funding. Detailed criteria applicable to the support of research in institutions in this category are not presented, since they receive little support from the National Science Foundation.

CRITERIA FOR RESEARCH SUPPORT

Institutions of Category I

The financing of academic research should bear some rational relation to the magnitude of the national educational enterprise. Planning for support of research in colleges and universities should be consistent with other forms of support for related educational activities, both Federal and non-Federal, including fellowships, traineeships, construction of facilities, development grants, etc. *The total constellation of support should permit appropriate research experience for all qualified students and faculty.* This policy implies significant, original research experience for all graduate students capable of advancing to the Ph.D. level, as well as some research experience for highly talented undergraduates. Because graduate enrollment as a fraction of total college and university enrollment is growing, and because graduate training, including its research component, is intrinsically more expensive than is undergraduate instruction, the growth rate of support of research in institutions of category I may reasonably be expected to exceed that of total expenditures for higher education.

The particular strength of academic research should lie in its individualistic character and its relative freedom from constraints outside the intellectual structure of science itself. To be sure, not all academic research need necessarily be of this character, but it should be predominant; nor is it implied that such individualistic research should be confined to academic institutions. Nevertheless, the criteria for support of academic research, especially by the National Science Foundation, should stress the merit of individual research projects, whether these are selected by external committees of peers, internally within the academic institution, or by some other mechanism. This assessment of merit should include consideration of the following questions:

(1) What is the promise of significant scientific results from the proposed project? What is the past record of performance of the investigators who will do the work and their potential for future accomplishment as estimated by colleagues or peers? Here, the term "significant" may refer either to intrinsic scientific interest or to potential application, or both, but it does imply some fundamentality and generalizability.

(2) What is the potential scientific impact of the proposed work? How is the information sought likely to influence other workers in the same field, in related fields, or even distant fields?

(3) To what extent does the proposed work open a new field, exploit novel techniques, or provide a critical test of current theory or understanding? What is the degree of novelty, originality, or uniqueness involved?

(4) What is the educational value of the proposed research, as judged by the number and quality of students or other temporary colleagues involved, the record of past success of students of the principal investigator, and the general impact of the research on the academic environment in which it is to be performed? How is the work likely to influence science through the subsequent career patterns of the scientists trained under the proposed program?

(5) What is the relevance of the proposed work to potential applications? To what degree might it contribute toward assessing future technological capabilities? This criterion is, of course, more relevant in the case of engineering research than in other programs of the National Science Foundation. But the question deserves consideration and might, on rare occasions, serve as a criterion for preferring a project which is not markedly superior in scientific merit to others near the cutoff line for support.

Institutions of Category II

Largely because institutions of category II are generally funded by block-grant support, they may confront the National Science Foundation with three types of program choices:

(1) The most important decision is the determination to create a new research institution.

(2) More frequent are decisions to augment the facilities or the programs of national centers already in existence.

(3) Occasionally there may arise necessity for a decision to phase out, or transfer elsewhere, programs already in being in such centers when it appears that they are no longer appropriate.

The questions listed below are applicable, in some measure, to each of these types of decision and should be regarded as a constellation of criteria whose relative weight and applicability must, inevitably, involve a considerable element of subjective judgement. Failure to meet some of the criteria would not necessarily imply a negative decision, but all of the questions listed are appropriate for discussion preliminary to formulation of program judgments.

(1) Does the laboratory meet a real scientific need and an opportunity to attack important problems in a way, or on a scale, not otherwise feasible or promising? Is there a broad mission which is sufficiently specific to offer a continuing challenge to the laboratory with consequent assurance of high scientific productivity over an extended period? Have the requirements for continued evolution

of capabilities and facilities been given adequate consideration in preliminary planning?

(2) Is there and will there continue to be a significant number of first-class scientists (as judged by their peers) who believe deeply in the proposed program and are willing to stake their personal scientific reputations on its success, including direct involvement in the program on both a full-time and a long-term basis?

(3) Are there convincing arguments that the program objectives can better be achieved through the organization of a new program at a national center than through existing academic or other research institutions? To what degree would the new capability under consideration be unique on a national basis?

(4) Will the center or its programs strengthen or detract from related work in the universities? Will the center provide new research opportunities for academic and other scientists? Is there assurance that user scientists will be accepted into the facility primarily on the basis of the scientific merit of their projects?

(5) What contributions will the work of the laboratory make to the training of future scientists and/or technologists, including the training of future potential faculty members and industrial investigators as well as students generally? Will the laboratory foster transfer of new basic research techniques into technology and into other areas of science?

(6) What impact is the work of the laboratory likely to have on other areas of science?

(7) To what degree may tangible social benefits ultimately emerge from the work of the laboratory? The ultimate social benefits of fundamental research are extremely difficult to foresee; hence, significant fundamental research programs should not be rejected because of inability to apply this criterion in a meaningful manner. By the same token, proposals for major programs which argue their cause on the basis of intrinsically dubious forecasts of social benefits require the most careful evaluation.

Application of these criteria will constitute no major departure from current practice. It is hoped that their explicit statement may be of some service.

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