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LETTER OF TRANSMITTAL

Washington, D.C.,
January 15, 1967.

MY DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1966 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 1966 appears in a separate publication entitled National Science Foundation Grants and Awards, Fiscal Year 1966, NSF 67-2. It is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

THE DIRECTOR'S STATEMENT

This statement is the third I have contributed to the Annual Reports of the National Science Foundation since becoming its Director. In the first (covering fiscal year 1964), I took the opportunity to express some of my own convictions regarding the reasons for, and the appropriate extent of, the support given by the Federal Government to "research and development," calling attention to the wide spectrum and differing objectives of the various activities covered by that term. That statement emphasized the significance of basic research—its importance in the intellectual and cultural sense, its vital role in graduate science education, and its indispensability as the base for the growth of virtually all of modern technological development. It also discussed, briefly, the special role of the National Science Foundation in the support of basic research and science education at all levels, together with some of the problems faced by the Foundation as I then saw them.

The second statement (for fiscal year 1965) formed part of the Foundation's 15th Annual Report. For this reason, and because as the fiscal year ended an intensive review of the Foundation was being conducted by the Subcommittee on Science, Research, and Development of the Committee on Science and Astronautics of the U.S. House of Representatives, the report discussed in some detail the Foundation's history, objectives, organization, and programs. Among other things, it pointed out the fact that the early and successful role played by the Foundation in the support of science education at all levels had been an important precedent for the current massive expansion of Federal support for general education. In particular, the pattern and methods of the Foundation's science education program had gone far toward allaying earlier fears that such support would, in some way, result in undesirable central control of the education process.

Together these statements constitute a fairly comprehensive although in no sense detailed, review of the Foundation's mission within the total framework of the national scientific enterprise, and of the means employed in carrying out that mission. Accordingly, the present statement will be devoted primarily to the events of fiscal year 1966, as they affected or may affect the Foundation, and to the effects of those events, and of further objective analysis on the Foundation's goals and programs.

During the year certain developments affected the context of the Foundation's mission and the background against which its operations are conducted. These have involved both the mounting needs of the educational institutions and scientific communities to which the Foundation gives support, and public and official attitudes toward Federal support of science and its role in the pursuit of national goals. Many of these developments are the consequence of the phenomenal rate of growth of institutions of higher education and the increasing attention being paid by the public and its representatives in government to the vital importance of high-quality education; others relate to a general tightening of many aspects of the Federal budget, including the budget for basic research and science education, as a result of the war in Vietnam and other urgent demands upon the Federal treasury.

Some General Trends

The year saw a continuation of several general trends discussed in previous reports. Among the most important of these are:

1. Increasing interest in and activities on behalf of education by all sectors of society, in particular, the Federal Government. As they affect the Foundation, these involve: the improvement of science education at all levels; the impact of Federal science programs upon universities and colleges as institutions; and recognition of national and regional needs for assisting in the development of more first-class universities and colleges.

2. Increasingly greater recognition of the growing importance of science to national objectives and to the daily lives of our citizens. This recognition, together with substantial outlays of the Federal Government and other public bodies in support of scientific research and science education, has increased the desire of the general public and its representatives, both legislative and executive, to augment and improve the techniques by which scientific knowledge acquired through research can be turned to practical ends. Unfortunately, this understandable and praiseworthy desire is not always accompanied by an understanding of the fact that great caution must be practiced in this area lest attempts to mold basic science in the direction of immediate usefulness not only harm science itself but also, at least in the long run, thwart its every purpose.

3. Increasing concern in the Congress and elsewhere with the development of more effective and progressive Federal policies for science, including the organization of the executive branch with respect to its scientific programs.

The following sections will recount certain actions and proposals of the executive branch and the Congress affecting the Foundation, some of which have already resulted in tangible actions, others of which are still in course.

Policy Statement by the President Regarding Academic Science

On September 13, 1965, the President issued a policy directive to all Federal agencies for the purpose of clarifying and amplifying national objectives for Federal programs concerned with support of academic science. This directive took the form of a memorandum to heads of Federal departments and agencies entitled *Strengthening Academic Capability for Science Throughout the Country.* The formulation of the policy had its origins in discussions initiated by the Foundation within the Federal Council for Science and Technology. The memorandum, which was publicly released through a statement of the President laying great stress on the importance of science, points out that the strength of Government research and development programs and their ability to meet national needs depend on the total strength of the American educational system. It further states that research supported to further agency missions should be administered not only with a view toward producing specific results, but also with a view to strengthening academic research and educational capabilities in general. After defining the specific functions of the Federal agencies in this respect, the memorandum goes on to lay down the following guidelines:

> "To the fullest extent compatible with their primary interests in specific fields of science, their basic statutes, and their needs for research results in high quality, all Federal agencies should act so as to:
>
> a. Encourage the maintenance of outstanding quality in science and science education in those universities where it exists;
> b. Provide research funds to academic institutions under conditions affording them the opportunity to improve and extend their programs for research and science education and to develop the potentialities for high quality research of groups and individuals, including capable younger faculty members;
> c. Contribute to the improvement of potentially strong universities through measures such as:
>   —Giving consideration, where research capability of comparable quality exists, to awarding grants and contracts to institutions not now heavily engaged in Federal research programs;
>   —Assisting such institutions or parts of institutions in strengthening themselves while performing research relevant to agency missions, by such means as establishing university-administered programs in specialized areas relevant to the missions of the agencies."

The significance of this Presidential statement is that it directs the various agencies to take proper cognizance of the importance to the national welfare of strengthening the scientific capabilities of the whole academic community—especially, though by no means exclusively, those institutions not now among the foremost rank—in ways compatible with the specific needs of the mission-oriented agencies, and with the national need to advance the frontiers of science on as broad a front as possible. It should not be construed, as has sometimes been done, as being directed primarily at widening institutional and geographic distribution of Federal research funds without regard to quality.

Committee on Academic Science and Engineering

In direct sequence to the President's memorandum was the establishment of the Committee on Academic Science and Engineering (CASE) under the aegis of the Federal Council for Science and Technology. Chaired by the Director of the National Science Foundation, the Committee includes representatives of all major Federal agencies that support scientific research and education at academic institutions. During the fiscal year CASE initiated several important coordinating actions among these agencies.

As a result of one of these, it is now possible for the first time to measure the extent of the total Federal financial contribution to the research and other scientific activities of the Nation's institutions of higher learning, and to relate these to the general purposes for which the funds were expended. In this program, data collected by the individual departments and agencies are forwarded to the National Science Foundation which compiles, tabulates, and analyzes them to give a Government-wide picture. This information is highly useful for general planning purposes and for evaluating the need to expand or alter existing programs, or to introduce new ones. It also provides a pool of reliable data for use in preparing factual information to meet the various needs of Congress. One report, covering fiscal year 1965, has been published. Others will be issued as they are completed.

Other CASE projects initiated during the year include a planning study directed toward achieving greater uniformity among the agencies in their policies for administering programs in support of facility construction at academic institutions, including, hopefully, reasonable standardization of application forms to be used by institutions in requesting such support. Another action was the establishment of a standing panel with responsibility for seeking methods to achieve better interagency cooperation with respect to institutional development.

It is hoped that these and other projects, together with concerted actions resulting from discussions within the Committee itself, can go far toward alleviating many of the difficulties now encountered by academic institutions in dealing with the Federal Government as a result of differing policies and administrative practices among the various agencies.

Strengthening Institutional Capabilities in Science

The United States is growing so fast and our national needs are mounting at such an accelerated pace that we must expand the institutional base for scientific research and education to maintain our present rate of technological advance. For this reason the Foundation has devoted a progressively increasing part of its budget to what are called institutional programs, both to strengthen the scientific capabilities of a broad spectrum of colleges and universities and, increasingly, to build up those not now quite in the very first rank.

Thus in fiscal year 1960, the Foundation reached the conclusion that the educational institutions of the country required special assistance in improving and enlarging their scientific laboratories. It therefore launched the "Graduate Science Facilities Program." During fiscal year 1966 grants under this program were made to 47 institutions in a total sum of approximately $25 million.

In the following year the Foundation undertook a program known as "Institutional Grants for Science" to provide the institutions participating in Foundation research-oriented programs with some funds awarded on a formula basis for general support of their scientific programs rather than for specific projects approved by the Foundation. The formula, using total research grants as a base, is tapered to favor the less well-supported institutions. During fiscal year 1966, Institutional Grants for Science were awarded to 401 universities and colleges in a total amount of $14.5 million.

More recently the Foundation has placed greater stress on efforts to upgrade the quality of a limited number of institutions with a demonstrated potential for advancement. As a first step, in fiscal year 1965, the Foundation initiated the "Science Development Program" designed to help universities possessing recognized strength, but not now among the 20 or so of highest quality, to markedly improve their scientific programs over a fairly broad front. In fiscal year 1965, the Foundation made Science Development grants to 9 additional universities, bringing the total for the 2 years to 17 institutions, which received a total of almost $64 million.

Looking ahead to the needs of the future, the Foundation is now giving attention to those universities which generally do not yet have the general strength required to excel on a broad front but which, nevertheless, have areas of strength with the potential for attaining high quality. Once attained, such areas of high quality not only will contribute to the vigor of American science but also can form the nucleus for broader development of the respective institutions in the future. During fiscal year 1966, therefore, planning was instituted for a new "Departmental Science Development Program" intended to help institutions already engaged in research and graduate education raise a selected science department or interdisciplinary area to a new and higher level of quality. These grants, which will be for a 3-year period and for a maximum of $0.6 million each, have been funded in a total amount of $15 million for fiscal year 1967.

With the same concern for the future, the Foundation has developed a program aimed at improving the total science enterprise of predominantly undergraduate institutions, with primary emphasis on upgrading their instructional programs. This "College Science Improvement Program" is being funded at a $10 million level in fiscal year 1967. We have also continued our "Undergraduate Instructional Scientific Equipment Program" aimed at helping to equip the teaching laboratories of our colleges and universities with up-to-date apparatus.

In making awards under these programs (other than Institutional Grants for Science) the Foundation has been continuously mindful of the desirability of avoiding undue geographic concentration. Our hope is that these programs will help assure that eventually institutions of the very first class will be found throughout the country. While working towards this end, however, we must of course continue to support—through project, equipment, and facility grants—the institutions which today set the standard for excellence in scientific research and education and on which our present and future strength so heavily depend.

The President's statement of September 1965 has, of course, added a new impetus and sense of urgency to all of these programs.

Review of the National Science Foundation by the Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics

As mentioned earlier, during the latter half of fiscal year 1965, under the chairmanship of Rep. Emilio Q. Daddario, the Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics began an intensive review of the National Science Foundation, its objectives, its policies, its programs, and its organization—with the stated purpose of evaluating the effectiveness with which the Foundation was carrying out the purposes of the act by which it was established, of reassessing its role in the light of present circumstances, of making appropriate recommendations to improve its organization and operations, and, if need be, of framing new legislation aimed at achieving these improvements.

Following several months of study by the subcommittee, including lengthy hearings held in June, July, and August 1965, the subcommittee on December 30, 1965, submitted to the chairman of the Committee on Science and Astronautics, a detailed and penetrating report of its findings and recommendations. This report was committed, on February 1, 1966, to the Committee of the Whole House on the State of the Union and ordered to be printed. Although the report speaks, of course, for itself, it seems worthwhile to recount here its principal features.

The main thrust of the report was that on the whole the Foundation has performed its functions well, but that with changing times the growing national importance of science and hence of science education, the greater reliance of Federal programs on science, and changes in the interests and requirements of mission-oriented agencies, the role of the Foundation should be expanded, its internal responsibilities redefined, and its staff organization strengthened. In addition to emphasizing that the Foundation should continue to expand its current programs of support of basic research and science education, the House subcommittee report recommended or suggested attention to the following:

1. That the Foundation, and especially the National Science Board, play a greater role in recommending national science policy, particularly as it concerns basic science and science education, and that the Foundation's responsibilities in this area in relation to the Office of Science and Technology and the President's Science Advisory Committee be clarified. In order to enable the Board to perform the expanded role proposed for it, the report recommended that it be relieved of much responsibility for day-to-day operations of the Foundation and that the responsibilities of the Director be increased accordingly. Briefly put, the concept suggested is that, instead of the Board largely confining itself to being "the Board of the National Science Foundation," it become a National Science Board in the broad sense of that term. The report also recommended that the Foundation staff expand its activities directed at the accumulation of statistics and data, and at the conduct and support of studies bearing on national science policy. Finally, the report recommended that the Board be made responsible for producing an annual report on the state of basic science in the United States—both an accounting and a plan of action for the future.
2. That the Foundation place increasing emphasis on its role as a "balance wheel" in Federal support of basic research and in responsibility for the general health of science, including providing adequate support to programs and disciplines which tend to be bypassed or insufficiently supported by mission-oriented agencies in the light of their specific objectives (e.g., stellar astronomy, systematic biology, pure mathematics). Further, that for this and other reasons the Foundation play a more active role in the administration of its programs and endeavor to discover means of assigning priorities to research areas in the various scientific fields covered by it and other agencies.
3. That the Foundation give considerably greater emphasis to the social sciences and that, in the process, attention be paid to the important role they can play in the development of solutions for the problems of society.
4. That the Foundation take more cognizance of pressing national needs in problem areas of society where solutions or assistance can be accelerated through the help of science; that it endeavor to assist in

the pursuit of such solutions, including the stimulation of studies employing an integrated, interdisciplinary ("systems-type") approach, and that as part of this effort it be authorized to support applied research under appropriate circumstances.

5. That the Foundation pay greater attention and give more support to increasing the total scientific capabilities of academic institutions as such, while continuing to support specific research and education projects within those institutions. That all feasible support be given to the development of additional first-class universities and colleges and that programs for this purpose be administered with due regard to the needs of all regions of the country.

6. That the Foundation plays a more active role internationally and that its authority to engage in activities to this end be broadened.

During fiscal year 1966, Representative Daddario introduced, and the House passed, a bill to provide the necessary legislative authorization to carry out the suggestions of the report. The bill expired with the final adjournment of the 89th Congress.

Developments Relating to the Environment

During fiscal year 1966 there were a number of developments indicating widespread interest among the scientific community and the executive and congressional branches of the Government in the application of science to new areas of both opportunity and danger in relation to our environment. Early in the fiscal year the President's Science Advisory Committee issued a comprehensive report entitled *Restoring the Quality of our Environment,* calling attention to, analyzing, and recommending measures against the degradation of many aspects of our environment as a result of pollution of the air, water, and land that are brought about largely through activities resulting from our technological advances.

Recommendations were made with respect to such activities as the use of pesticides; industrial and urban pollution of the rivers and estuaries; pollution of the atmosphere by the products of combustion from fuels used in industrial processes, heating, automobiles, and airplanes; and so forth. The recommendations include: (a) taking steps to exert greater control over the activities creating these undesirable effects, and (b) acceleration of research and development directed toward both better understanding of the effects of the various pollutants and seeking alternatives to the types of activities that result in their creation or discharge. The President has instructed each agency to give special attention to this report and to make recommendations concerning steps that it could take leading toward solution of the problems.

Special attention was devoted during the year to research and development directed at greater exploitation of the potentialities inherent in modification of the atmosphere (weather modification) and in marine resources.

Weather and climate modification has been of increasing interest to the Congress and the public, largely because of potential benefits to agriculture and to water supplies through the augmentation of precipitation, but the prospect has also excited concern because of possible hazards to the farmer and city dweller resulting from unforeseen climatic change and other possible side effects. As a result, Congress and the public have been urging more attention to weather modification techniques. In 1966, two reports on weather and climate modification were issued, one by the National Academy of Sciences that thoroughly reviewed the state of our knowledge regarding the possibilities of modifying weather or climate, and one by a Special Commission of the Foundation that made a comprehensive review of the subject in the light of the scientific findings of the Academy Report.

These reports reevaluated the technology of weather modification and noted that it had now reached a point where rational programs could be initiated. In particular the evidence seems strong that small increases in rainfall can be induced by artificial means under certain atmospheric conditions, and that substantial increases might be induced under particularly favorable circumstances. The reports reflected concern about inadvertent modification of the atmosphere (pollution) and uttered strong words of warning over the social, ecological, and legal implications of deliberate weather modification activities, stressing the need for careful controls and careful evaluation of effects outside the immediate area of experimentation.

Both reports expressed the belief that the current $7.2 million level for weather and climate modification activities, divided among five Government agencies, was quite inadequate to cover both research and field operations and that the sum ought to be increased to levels above $30 million by 1970. They also recommended increases in funds for support of the more basic aspects of atmospheric science and for developing a better understanding of weather and climate on a global scale. A strong case was made for greater exploitation of computers in the entire field of atmospheric science. The Commission report recommended that an agency other than the Foundation take central responsibility for the development of operational techniques for weather modification.

Congress in turn proposed legislation designed to improve the effort and reallocate research and operational authority. During the fiscal year, two bills were introduced in the Congress aimed at reorganizing the program by clarifying the responsibilities of each Federal agency, including the Foundation. One of these (S. 2916, introduced by Senator Magnuson), which was later passed by the Senate, would, among other things, shift the data collection responsibilities of the National Science Foundation to the Department of Commerce. Both bills expired with the adjournment of the 89th Congress.

There was also a sharp upsurge in public and congressional interest in oceanography during fiscal year 1966. In June 1966 the Panel on Oceanography of the President's Science Advisory Committee issued a comprehensive report entitled *Effective Use of the Sea,* which recommended an expanded oceanographic research effort by the Federal Government, including particular attention toward developing the resources of the seas, especially the food resources. It also recommended the formation of a new agency, combining the marine activities of several existing civilian agencies, to lead the way in the development of marine resources.

Two significant pieces of legislation relating to marine resources were enacted during the second session of the 89th Congress. The Marine Resources and Engineering Act of 1966 (Public Law 89–454), enacted in June, established the National Council on Marine Resources and Engineering Development, chaired by the Vice President and including in its membership a number of department and other agency heads, among them the Director of the Foundation. The Council is charged with making recommendations to the President for the improved utilization of marine resources. The act also created a Commission of distinguished citizens and governmental representatives from the Congress and the executive branch to prepare a report making recommendations to the Council.

Later in the session, Congress enacted the National Sea Grant College and Program Act (Public Law 89–688), introduced by Senator Pell, authorizing and directing the Foundation to support programs of education, of research and development, and of advisory services directed towards improving the Nation's capabilities for exploiting the resources of the seas. The act authorizes expenditures of $5 million in fiscal year 1967 and $15 million in fiscal year 1968. The implementation of this program should provide a major stimulus to a concerted attack on problems related to exploitation of the marine environment.

National Academy of Sciences Reports on Specific Fields of Science

At the same time that much public attention is being focused on the applications of science, the material advances that they make possible, and the problems that are created by technology, careful study is also being given to the objectives, the progress, the promise, and the needs of the underlying fundamental sciences that are so vital to material progress and well-being, as well as forming an integral part of our intellectual, cultural, and educational growth. Of great importance in this area is a series of studies of broad scientific fields being conducted by the National Academy of Sciences under its Committee on Science and Public Policy. During the fiscal year, five such studies, all financially supported in whole or in part by the Foundation, were completed. Four of these concerned particular areas of basic research. The fifth studied the role of computers in all fields of science and engineering. In each case the report was the result of a careful study conducted by a committee of specialists—drawn from the Academy membership and other sources—which devoted many months or even years to its deliberations.

The recommendations of three of the basic science reports covered, within their respective fields, the whole range of needs from the support of the conduct of research to the requirements for large instruments. These reports are:

Chemistry: Opportunities and Needs (committee chaired by Dr. F. H. Westheimer of Harvard University).

Physics: Survey and Outlook (committee chaired by Dr. George Pake of the Washington University of St. Louis).

Plant Science: Now and in the Coming Decade (committee chaired by Dr. Kenneth V. Thimann of Harvard University).

In addition to analyzing past and potential progress in the scientific sense, relating the importance of that progress to practical advances in the achievement of national goals, each report pointed out the important role of university-based research and the essentiality of increasing financial support, not only to advancement in the field but to the education of the rapidly increasing number of students needed and being trained.

A fourth report, *Ground-based Astronomy—a 10-Year Program,* though equally broad in its study of the field, limited its recommendations to the need over the next 10 years for addiitonal major telescopes and other instrumentation. This report, prepared by a committee under the chairmanship of Dr. Albert E. Whitford of the University of California, recommended three large optical telescopes in the 150- to 200-inch class,* at least one to be placed in the Southern Hemisphere; two 300-foot steerable radio telescopes; one or more large radio telescope arrays; and various smaller instruments of both varieties, primarily for individual universities. In addition, it advocated studies directed at even larger telescopes.

The fifth report, *Digital Computer Needs in Universities and Colleges,* analyzed the rapidly growing needs of academic institutions for digital computers to be used in all fields of science and engineering. This report, prepared by a committee under the chairmanship of Dr. J. Barkley Rosser of the University of Wisconsin, recommended among other things that greatly increased support be given for computing activities—including both advances in the techniques of utilization and facilities for actual use—and for markedly expanding the number of undergraduate students trained annually in the use of computers.

With the exception of the one on plant sciences, which was issued late in the fiscal year, each of the above reports has been studied by an interagency panel created to evaluate the report and recommend courses of

*The 150-inch telescope, already underway for the Foundation's Kitt Peak National Observatory, is one of these three.

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action for the Federal Government. Each is chaired by the National Science Foundation. Although not all panels have completed their reports, each has found itself in substantial agreement with the findings of the corresponding Academy committee as to the significance of, and need for, additional support to the respective fields, although, in view of limitations on resources, they do not all recommend the full measure of support suggested by the NAS committees.

In addition to studying the NAS recommendations for new telescopes, the panel considering the astronomy report also analyzed the financial needs for the support of the conduct of astronomical research at all observatories, and made recommendations with respect to total needs. Following a subsequent review and recommendations by the National Science Board, the Chairman of the Federal Council for Science and Technology designated the Foundation as the principal agent within the Government for ground-based astronomical research.

In addition to the Academy report on computers, which emphasized the utilization of such equipment for research, a panel of the President's Science Advisory Committee has been studying specifically their growing usefulness in the field of education. Although this panel has not yet issued its report, its discussions and other mounting evidence show that this type of use will undergo phenomenal growth during the next several years. As a result of both developments, the Foundation is formulating plans to increase markedly its support of computer facilities and activities at universities and colleges with particular emphasis on the development of facilities, techniques, and curricula in the field of education. Our thinking in this whole area is being carefully coordinated with that of the Executive Office, the Office of Education, and other interested agencies.

All the reports alluded to are the result of careful and comprehensive studies by distinguished and competent groups. Each has presented a convincing case for the importance of, the progress in, and the future promise for its field of interest. Each has well expressed the need for substantial increases in support, especially in the academic institutions. They will greatly influence Federal activities in their respective fields for some years to come, although limitations on total resources may well prevent full implementation of the recommendations.

The Committee on Science and Public Policy of the Academy has already initiated, or is planning, studies in other fields of science (including the social sciences) which will eventually provide full coverage of all fields. The new National Academy of Engineering is planning similar studies in its fields of interest.

Some Aspects of Research

It is clear that one of the foremost concerns regarding science on the part of the general public and its representatives in Government is that the fruits of science be utilized to the maximum extent in improving the welfare and comfort of mankind. Specific evidence of this concern is provided by many actions of the Congress, including the legislation mentioned earlier relating to marine resources and weather modification and the most significant programmatic provision of Mr. Daddario's bill, namely, that the Foundation be authorized to support applied research at academic and other nonprofit institutions and, when so directed by the President, to support through other appropriate organizations applied research relevant to national problems involving the public interest.

This is an appropriate concern. The growth of our economy and, indeed, the future of our civilization are now dependent upon ever-increasing knowledge and understanding gained through scientific research, and a fruitful and expanding technology based on that knowledge and understanding. Problems of society arising from such conditions of modern life as urbanization; pollution of water, earth, and atmosphere; rising population here and abroad; the failure of the global food supply to keep up with this population increase; and the dwindling of natural resources, including fresh water and fuel, present such obstacles and in some cases threats to the future of civilized society that we must marshal every available resource to create an environment in which a better life will be possible for both this and future generations. To add to the complexity, it has become evident that many of the most pressing problems arising out of these conditions can no longer be dealt with on a piecemeal basis employing fragmented approaches, but must be attacked by a broad systems-type approach which will draw upon and unite in one common effort all of the intellectual disciplines—including the natural and the social sciences and the humanities—that can fruitfully contribute.

To make satisfactory progress, it is essential that science and technology be in appropriate balance and of reciprocal benefit to each other. New knowledge developed from basic research should be used fully in the shortest time possible to benefit mankind. Conversely, new developments in applied science and technology have a great deal to contribute to basic research by providing insights into better instrumentation, improved methodology, and new areas of exploration. As the one agency of the Federal Government dedicated to the health and welfare of science as a whole, the National Science Foundation has an important role to play in this interface—in helping to link progress in basic research to the goals and concerns of applied science and technology, and vice versa. Within this context the authority to support applied research, especially in the universities, would, in my opinion, provide a significant addition to the Foundation's powers—one which in time would redound to the benefit of both basic research and the national welfare. Even limited support of this nature—and for the time being, at least, I believe it should be relatively limited—would provide opportunities for scientists and engineers, especially the latter, to pursue promising leads resulting from basic research into the applied field. It would eliminate the present restrictions which, except in a few special areas, prevent competent individuals from applying for Foundation funds to undertake applied research, however promising it may appear, and would thus eliminate some undoubted distortion of the programs within departments or schools of engineering. Equally important, it would give advanced engineering students wider scope of opportunity during their formative period, and in general would help broaden the education process. Finally, the support of some applied research would give to the Foundation itself a better understanding of the mechanisms of transfer of knowledge reciprocally between science and technology.

But in pursuing these worthy goals, we must all, including—indeed especially—the Foundation, exert the utmost caution lest in our desire to increase the usefulness of science we impair its own essential progress and hence defeat our very ends. An ever-increasing fund of new knowledge is indispensable to the growth of applied science and technology, as well as to our intellectual and cultural progress. Knowledge implies understanding as well as information. In science this understanding is developed by combining the results of many individual experiments and theoretical deductions to arrive at a combined and general whole, just as the effect of a picture results from its total composition and cannot be achieved from isolated bits of painted canvas. In turn, it is the understanding derived from this process that makes possible the planning and carrying out of further advances into new areas. It is the creative scientist, following the dictates of his own curiosity and intellect, with a driving urge to understand, who makes these advances possible. Even the great discoveries, the broad and brilliant generalizations—such as Einstein's Relativity Theory that is so necessary to our understanding of atomic and nuclear structure, or the fundamental understanding of the structure of solids that made possible the transistor—are not made in isolation, but build upon foundations laid by numerous experimental and theoretical investigations carried out by predecessors and contemporaries of the men who make the spectacular breakthroughs.

It is a fallacy to suppose that these advances in fundamental knowledge will necessarily follow by allowing immediately practical requirements to determine the direction that their pursuit should take. Indeed, they are more likely to suffer as a result. In scientific research there are many possible branches along the paths of inquiry. The most promising branch from a practical standpoint is not necessarily that which will lead to greatest understanding. The scientist impelled by fundamental curiosity should be encouraged and supported in following the latter path, just as others, who desire to do so, should be supported in following the former.

Thus, it is important that basic research—taken here to mean research in which the search for an understanding of nature and her laws, of man and his environment, is the primary objective—continue to be given adequate support, and that the purpose of this support be to assist the scientists in their never-ending quest for scientific truth, without externally imposed restrictions.

This is not meant to say that, even in the support of basic research, the practical need for knowledge should not be one of the criteria in determining relative emphasis among various broad fields, provided competent scientists are available and there is sufficient promise that progress can be made; rather, it is meant to say that, in the process, great care must be taken that other fields of scientific promise also be given adequate support whether or not practical, applicable knowledge is readily foreseeable. Neither is it meant to say that the *uses* to which we put the fruits of science should not be guided by practical needs. Differential levels of support guided by practical goals and, in some instances, even political controls imposed for the public welfare are appropriate and necessary in applying the results of fundamental science. It is in the pursuit of fundamental knowledge and understanding—the search for truth—that science must be untrammeled.

The National Science Foundation was brought into being largely to assure recognition and support by the Federal Government of the essential place of undirected basic research and of science education in the national scientific effort. The same needs that created the Foundation are even greater today, for an ever-expanding base of scientific innovation and discovery and an ever-increasing pool of scientists and engineers are necessary to preserve the rate of technological advance. For this reason the Foundation, in carrying out its present and any future roles assigned to it for the support of applied research, will always be vigilant in safeguarding its mission to encourage and support basic research.

In carrying out this mission, the Foundation will continue to recognize that research has unusual importance in the context of education, especially graduate education. In addition to the results achieved and to the intellectual stimulus given to the faculty, research is an essential element in the training of advanced students, both because it serves as an apprenticeship for some and because, importantly, it arouses and cultivates in all a spirit of inquiry which will both enrich their lives and enhance their usefulness, whether their ultimate careers be in teaching, research, development, or even other spheres. For it is this spirit of inquiry, of striving always to learn more, that has made for progress in the world, whether it be in science, the humanities, the arts, the technical skills, exploration, or almost any other of man's pursuits.

In recognition of the importance of basic research, the Foundation last year secured an increase of about one-third (from approximately $120 million to $160 million) in funds available for the support of basic research projects, almost entirely at educational institutions. This increase, approved by the executive branch and the Congress during a period of stringen budgetary economy, demonstrates the importance attached by all parts of Government to science in general and to the need for a growing basic research effort in particular. That it was the vehicle for this increase is tangible evidence of the Foundation's importance as a "balance wheel" in Federal support for science, particularly in periods when defense and other considerations may cause leveling-off in funds available to other agencies for support of basic research.

Organization

During fiscal year 1966, several changes occurred in the membership and organization of the National Science Board, in the internal organization of the Foundation, and in the number and terms of reference of the Foundation's major advisory committees.

Ten appointments were made by the President to the National Science Board—two to fill unexpired terms and eight as a result of the normal expiration of the terms of one-third of the Board members. At the annual meeting in May 1966 (one of seven 2-day Board meetings held during the fiscal year) Philip Handler, James B. Duke Professor, and Chairman, Department of Biochemistry, Duke University, was elected Chairman and Ralph W. Tyler, Director, Center for Advanced Study in the Behavioral Sciences, Stanford, Calif., was elected Vice Chairman.

To fill unexpired terms ending in 1970, the President appointed Mary I. Bunting, President of Radcliffe College (a biologist) and Harvey Picker, President, Picker X-Ray Corporation (an engineer). For the eight full-term vacancies expiring in 1972, the President late in the fiscal year renominated Robert S. Morison, Professor of Biology, and Director, Division of Biological Sciences, Cornell University and E. R. Piore, Vice President and Chief Scientist, International Business Machines Corporation (a physicist), each of whom had been filling unexpired terms on the Board, and nominated as new members: *

Clifford M. Hardin	Chancellor, University of Nebraska (agricultural economist).
Charles F. Jones	President, Humble Oil & Refining Co. (chemical engineer).
Thomas F. Jones, Jr	President, University of South Carolina (electrical engineer).
Joseph M. Reynolds	Vice President for Research, Louisiana State University (physicist).

*All eight persons were unanimously confirmed by the Senate on July 25, 1966 and formally appointed by the President on July 27, 1966.

Athelstan F. Spilhaus ----	Professor, School of Physics, University of Minnesota (meteorologist and oceanographer).
Richard H. Sullivan -----	then President of Reed College and now President, Association of American Colleges (educator).

The National Science Board made several changes in its method of operation during the year. The functions of the Executive Committee were restated to include responsibility for: acting for the National Science Board on nonpolicy matters during intervals between Board meetings; serving as the Committee on the Budget; coordinating the activities of the other committees of the Board; considering legislative proposals and participating, when appropriate, in congressional hearings directly bearing on the mission of the Foundation.

In addition, as a step towards enhancing its ability to concentrate on major problems and issues of policy, the National Science Board, late in the fiscal year, restructured its standing committees as follows: Committee I was assigned cognizance over the research and science information activities of the Foundation. Committee II was assigned responsibility for institutional relations, including the impact of Foundation programs on institutions. (This committee also has cognizance over the Foundation's international activities.) Committee III was charged with surveillance of all the educational activities of the Foundation.

The Board's Science Development Program Committee, established at the end of fiscal year 1965, was in fiscal year 1966 renamed as the Committee on Science Development Awards. This committee has been of inestimable value to the Board and the Director in reviewing and furnishing advice on general criteria for the Science Development Program. It has also been of great assistance to the Director in reviewing proposals for science development grants. Since the purpose of this program is to assist in raising a few promising institutions, as rapidly as feasible, to the level of excellence attained by our truly outstanding institutions, our leading universities are not eligible to participate. The affiliations of the members of this committee are with institutions, including industrial organizations, not expected to participate in the program.

The major change in staff organization was the creation of a new Division of Environmental Sciences, incorporating the Atmospheric Sciences and Earth Sciences Sections—both by transfer from the Division of Mathematical and Physical Sciences—and the Office of Antarctic Programs, which had not previously been within a divisional structure. The former Head of the Office of Antarctic Programs, Dr. Thomas O. Jones, became Director of the new division and also Special Assistant to the Director for Antarctic Affairs, in view of the special nature of the latter activity.

The National Science Foundation Act of 1950, as amended and as modified by Reorganization Plan No. 2 of 1962, provided that there be for each division of the Foundation a "divisional committee" appointed by the Board and directed to "make recommendations to and to advise and consult with the Director with respect to matters relating to the programs of its division." With the growth in the number of divisions over the years, and the various interrelations between their activities, a more flexible arrangement was needed, so these committees were abolished by Reorganization Plan No. 5 of 1965.* In their place there has been established a system of functional "advisory committees" appointed by the Director in consultation with the Board under his general authority to appoint consultants. Although each advisory committee has as its focal point a division or group of divisions, each has been requested to take cognizance of all activities bearing on its field of interest throughout the Foundation. Each committee has also been asked to maintain awareness of the activities and points of view of the other committees. Staff responsibility for supporting the activities of the advisory committees, and promoting coordination between them, is lodged with the appropriate associate directors of the Foundation, who delegate to their division directors such of these responsibilities as they deem appropriate.

Each advisory committee has been asked to prepare a written annual report to the Director, including such comments, recommendations, and questions as desired, and each advisory committee chairman makes an oral presentation before the National Science Board annually. In addition, from time to time the advisory committees may make recommendations on specific topics to the Director, to the cognizant Associate Director, or on occasion to the appropriate Division Director. The greater scope given to these committees under the new arrangement has already broadened their overall view of the problems with which the Foundation is concerned and consequently enhances the value of their advice to the Foundation. The advisory committees are listed, together with their membership, in appendix A.

The above is intended to offer a few observations highlighting several significant policy and administrative matters and concerns and reflecting some of the views of the Director. The substance of the Foundation's scientific and educational programs is set forth in the body of the report which follows.

LELAND J. HAWORTH

*No change was made in the status of the Science Information Council established in 1958 by Public Law 85–864.

PROGRAM ACTIVITIES
of the
NATIONAL SCIENCE FOUNDATION

INTRODUCTION

This 16th Annual Report of the National Science Foundation reviews progress and accomplishments for the fiscal year, and accounts for expenditure of funds appropriated for these purposes. In addition, and in accordance with the custom of previous years, the report discusses events that may have preceded or followed the year covered by the Report where these have relevance to the activities described.

In fiscal year 1966, the Foundation obligated $466.4 million through 9,184 grants and contracts, primarily to colleges and universities. The distribution was as follows:

	Amount (millions)	*Percent*
Scientific Research	$236.1	50.6
Science Education	124.3	26.7
Institutional Support for Science	78.4	16.8
Science Information Activities	11.6	2.5
International Science Activities	.9	.2
Planning and Policy Studies	2.0	.4
Program Development and Management	13.1	2.8
Total	$466.4	100.0

Because of the increasing interest in the distribution of Foundation funds on the basis of scientific discipline, a table has been prepared that presents this information. (See table on following page.)

As previously, 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 1966" (NSF 67–2).

Table 1.—*National Science Foundation Obligations, by Discipline Fiscal Year 1966*

[Thousands of dollars]

Discipline	Total	Scientific Research	Science Education	Institutional Support of Science	Science Information Activities	International Science Activities	Planning and Policy Studies	Program Development and Management
Mathematics	$45, 520	$12, 913	$27, 809	$4, 449	$270	$79	......	....
Physics	50, 120	26, 630	13, 650	9, 536	229	75	......	....
Chemistry	40, 962	18, 828	15, 658	5, 719	666	91	......	....
Biology	79, 040	45, 323	20, 417	12, 843	282	175	......	....
Social Sciences	29, 732	12, 995	11, 048	3, 893	816	43	$937	....
Engineering	47, 241	19, 203	20, 247	6, 276	1, 439	76	......	....
Astronomy	24, 032	20, 616	752	2, 638	15	11	......	....
Atmospheric Sciences	26, 693	23, 620	768	2, 155	124	26	......	....
Earth Sciences	36, 885	26, 939	7, 275	1, 417	1, 178	76	......	....
Oceanography	29, 883	29, 062	645	168	....	8	......	....
All Other [1]	56, 320	....	6, 036	29, 282	6, 601	240	1, 072	$13, 089
Total	466, 428	236, 129	124, 305	78, 376	11, 620	900	2, 009	13, 089

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

RESEARCH SUPPORT ACTIVITIES

The National Science Foundation supports basic research in all the sciences. Included are programs in support of basic research projects, primarily at universities and colleges, programs to provide specialized research facilities and equipment, and a group of special programs identified as national research programs. All of these are discussed in this chapter. In addition, the Foundation maintains four national research centers owned by the Federal Government, operated for the Foundation by private nonprofit contractors, and available to all qualified U.S. scientists. The operations of these centers are described in a later chapter.

BASIC RESEARCH PROJECTS

In fiscal year 1966, final action was taken on 6,776 research proposals in which $511.5 million was requested. The Foundation made 3,647 grants in response to these proposals. Thus 56 percent of those requesting funds received some support. However, grants made totaled $157.8 million, or only 32 percent of the total funds requested in all proposals.

Funds requested in the successful proposals totaled $327.9 million, so that on the average grants provided 49 percent of the amount asked. Some of this reduction, however, was due to cutting back the duration of support requested. When this factor is eliminated, the percent provided is 77 percent.

During the year, basic research grants were made to 307 academic institutions in every one of the 50 States, the District of Columbia, and Puerto Rico—19 more institutions than in fiscal years 1964 and 1965. Two hundred of these institutions received 2 or more grants, and 116 received at least $200,000 each in grants.

Continuing Grants

During fiscal year 1966, a new procedure was instituted for support of stable, continuing research programs of high quality. A new type of grant arrangement called a Continuing Grant was announced on January 11, 1966. Under this arrangement the Foundation can respond to a 3- to 5-year proposal by making a 2-year grant, together with an assurance that additional support will be given on an annual basis for up to 5 years, provided appropriated funds are available. Extension is based on a simple letter request, and no new proposal need be submitted during the term of the continuing grant. A full-scale review will be required only every fifth year for this type of program.

This new arrangement should eliminate unnecessary proposal writing, and will relieve reviewers and panel members of unnecessarily frequent reviews of high-quality, long-range programs.

To prevent program funds from becoming overcommitted to continuing grants, an internal requirement has been established that the total of assurances for any future fiscal year shall not exceed half the funds available in the current year. This limitation is expected to insure adequate funds for new proposals.

Cost-Sharing

The National Science Foundation has always considered its awards of basic research grants to colleges and universities to be in furtherance of the scholarly activities that are an essential part of the academic program of the institutions. The intention is not to buy research, but rather to enter into partnership with the institutions to enable them more effectively to carry out programs of mutual interest.

There has always been a large degree of participation by the universities in the cost of the research supported by the Foundation. Records are not complete enough to establish the degree of participation accurately, but a conservative estimate is that institutions have on the average provided between 25 and 30 percent of the cost of the research carried out under NSF grants.

In the Foundation's fiscal year 1966 appropriation, the Congress included a provision that Federal funds could not be used to pay the entire cost of any basic research supported by a grant. The Bureau of the Budget Circular A–74 of December 13, 1965 transmitted and further defined the requirement. On January 24, 1966, the Foundation notified all institutions of its cost-sharing requirements, which went into effect on March 1, 1966.

Requirements for cost-sharing by colleges and universities are related to the cost of faculty time devoted to research in the following manner. Where the institution is on an academic year basis, cost-sharing by the institution must be at least equal to the NSF contribution to academic year salaries plus fringe benefits and associated indirect costs. Where the institution is on a calendar year basis, its minimum contribution must be equal to at least half the Foundation's contribution to annual faculty salaries.

Special negotiations become necessary when the formula given above does not provide for more than token participation by the institution. In the case of nonacademic institutions, suitable cost-sharing arrangements are worked out on an individual basis.

The Foundation believes that these cost-sharing ground rules will preserve a substantial part of the participation previously in effect, and at the same time will provide that cost-sharing be more equitably applied. During the months of April, May, and June 1966, 1,203 grants were made under the cost-sharing rules. Average cost participation for these grants was about 17 percent of total costs identified in the grants. It is possible that this percentage would be substantially higher if all applicable costs were listed.

Indirect Costs

In the same notice that outlined requirements for cost-sharing, the Foundation announced that the indirect cost procedures described in Bureau of the Budget Circular A-21 would be applicable to all research grants. Accordingly, instead of a uniform indirect cost allowance of 20 percent of direct costs, an overhead rate, generally expressed as a percentage of salaries and wages, is now negotiated separately with each institution. This is a more equitable, but considerably more complex procedure. Hereafter, the indirect cost percentage used for any grant will be the most recent figure established by the Foundation, and will not be subject to change for that grant after it has been accepted by the institution. Because the average overhead so calculated is substantially greater than would be 20 percent of total direct costs, the new plan requires more total funds to support the same amount of research. At the present level of basic research support, the increase in indirect cost payment amounts to about $10 million a year.

Distribution by Fields of Science

The research support program is managed by five divisions corresponding to five major subject matter areas. Each division is further divided into sections and program units. Table 2 shows the funds obligated and number of grants made in fiscal year 1966 by each of these organizational units.

Social Sciences

The social sciences seek to explore the nature of man and to understand individual and group behavior. Because the social sciences are still less well developed than the natural sciences, the potential for new ideas, new techniques, and new paths of inquiry is very great.

The basic physical, biological, and social sciences deal with the behavior of matter and energy organized at three different levels of com-

Table 2.—*National Science Foundation Research Projects, by Field of Science, Fiscal Year 1966*

	Proposals Received		Awards	
	Number	Amount	Number	Amount
Social sciences:				
Anthropology	240	$9, 780, 260	125	$3, 840, 093
Economics	99	8, 574, 900	51	2, 211, 839
Economic and social geography	13	463, 700	5	215, 300
History and philosophy of science	69	2, 211, 500	49	1, 009, 861
Political science	47	1, 937, 800	17	335, 650
Sociology and social psychology	196	15, 348, 800	83	3, 589, 142
Special projects	19	2, 371, 500	15	1, 021, 570
Subtotal	683	40, 688, 460	345	12, 223, 455
Biological and medical sciences:				
Cellular biology	445	39, 121, 100	273	9, 872, 100
Environmental and systematic biology	372	17, 140, 100	186	7, 011, 200
Molecular biology	417	45, 334, 100	295	10, 900, 100
Physiological processes	647	52, 426, 641	208	7, 580, 000
Psychobiology	252	17, 512, 300	131	4, 750, 045
Biological oceanography	292	22, 060, 000	196	10, 026, 273
Subtotal	2, 425	193, 594, 241	1, 289	50, 139, 718
Mathematical and physical sciences:				
Astronomy	116	12, 968, 870	94	6, 707, 803
Chemistry	707	57, 873, 030	405	16, 467, 550
Mathematical sciences	471	42, 892, 477	368	12, 912, 822
Physics	500	65, 745, 366	253	20, 134, 551
Subtotal	1, 794	179, 479, 743	1, 120	56, 222, 726
Environmental sciences:				
Atmospheric sciences	118	18, 995, 025	81	6, 409, 295
Earth sciences	346	18, 709, 217	227	7, 529, 652
Physical oceanography	100	12, 138, 298	59	7, 202, 597
Subtotal	564	49, 842, 540	367	21, 141, 544

Table 2.—National Science Foundation Research Projects, by Field of Science, Fiscal Year 1966—Continued

	Proposals Received		Awards	
	Number	Amount	Number	Amount
Engineering sciences:				
Engineering chemistry	130	$9, 133, 286	49	$2, 773, 654
Engineering energetics	126	9, 935, 480	64	3, 193, 807
Engineering materials	137	8, 542, 893	61	2, 441, 942
Engineering mechanics	244	20, 812, 895	114	4, 544, 651
Engineering systems	123	9, 459, 650	57	2, 806, 433
Research initiation grants	521	9, 285, 596	150	1, 973, 900
Special engineering projects	50	2, 588, 400	31	293, 457
Subtotal	1, 331	69, 758, 200	526	18, 027, 844
Total	6, 797	533, 363, 184	3, 647	157, 755, 287

plexity. Biological organization represents a vast increase in complexity over physical organization, and social organization represents a still vaster increase in complexity over both physical and biological organization. Yet it is the essence of scientific thinking that there exists no discontinuity between levels. Each brings forth complexities unique unto itself, but each necessarily incorporates the complexities of those below. While the concepts and explanatory principles formulated by the social sciences may not, therefore, depart from the concepts and principles established by the physical and biological sciences, neither are the discoveries achieved by the phyical and biological sciences sufficient to produce meaningful explanations of behavior at the level of social organization. In the scientific study of man's social behavior the search begins with the knowledge available from other sciences, but the goals lie in another dimension.

In addition, scientific and engineering progress has created a number of social problems that the natural sciences alone cannot be depended on to solve. New developments in science and engineering must be absorbed and optimally used by an increasingly complex society whose institutional and organizational arrangements may not be capable of meeting new challenges. Pollution may be regarded as typical of a new class of problems brought about by the application of technological developments, and by an increasing population. Technical steps alone have proven inadequate to correct the situation. On the other hand, poverty has been a long-lived problem of societies, and no single "invention" can hope to erase it. Technological progress has led people everywhere to expect their living standards to rise, and has made them less willing to accept present conditions. Solutions to the problem of poverty, therefore, lie in a combination of scientific and social developments.

These cannot be produced on order. Not only are the tasks enormous, but there is the need to learn more about man before the knowledge can be usefully applied. Decades of seemingly impractical theoretical research lie behind many of our spectacular scientific achievements. The basic research supported by the Foundation in anthropology, political science, economics, demography, linguistics, sociology, psychology, and geography seeks to identify and analyze that most complex of all relationships, the relationships among individuals and among social groups. To the degree that it is successful these scientists provide knowledge that can be used to make technological change more acceptable to society. Man must not only know his world in order to better it, he must know himself. The past year has brought renewed attention to this effort.

As social scientists search for a deeper understanding of the interactions between man and his environment, they strive for increasing precision in their data. They, like other scientists, have two basic ways of approaching their material—they may observe an existing situation, or they may set up a model experimental situation. Studies of existing situations help show how man actually behaves under conditions that the scientists cannot control. Model situations permit social scientists to vary conditions, and find out how individuals or groups react to the variations. Both types of study are necessary, and both have produced results of interest and significance.

The following examples of recent research findings in the social sciences illustrate both the observational and the experimental approach.

Committee Decisionmaking

James D. Barber, a political scientist at Yale University, attempted to transfer the sophisticated measurement and observation techniques of small group research to the study of the behavior of government committees. In government, committees abound and are critically important at all levels of the decision process. It is relatively easy to study the decision products of committees (by the statistical examination of votes, decisions, etc.), but the study of the actual process by which a committee makes a decision is more difficult.

Dr. Barber's subjects were local government committees—boards of finance—who came as a group to the Yale University Small Groups Laboratory. The problems they confronted in the experimental sessions were highly realistic. In one instance they were presented with their town budget for the previous year and asked to alter it by a specified amount in a specified time period. Another task concerned the relationship of the board of education to the town government, a hypothetical problem not based on the situation in any one town but one which probed a real area of controversy.

The groups were observed (with their knowledge) during their discussions. The participants felt that the laboratory situation had not significantly changed the committees' method of operation. Tape-recorded sessions of actual regular meetings of boards of finance as well as minutes of such meetings provided another check on the degree of accuracy that had been achieved in the laboratory.

Analysis of the data centered on the following questions: What criteria are used in allocating resources among competing demands? What factors shape committee members' perceptions of community power? What is the role of the chairman and the impact of his behavior on the other members of the group? The findings were reported to the local boards of finance and have resulted in specific suggestions on organizing the process of budgeting.

Political scientists have applauded this pioneering venture as opening a new research possibility, since Dr. Barber demonstrated that it is possible to exploit the advantages of controlled laboratory procedures, to measure fairly accurately the impact attributable to the constraints of the laboratory, and to obtain from the findings new results of relevance to the understanding of political behavior.

Child Rearing in Different Cultures

Cross-cultural research, though difficult and costly, is essential to ascertain which aspects of behavior are "culture-bound," and which are more universal. An outstanding example is the research of Urie Bronfenbrenner of Cornell University, who has been studying child-rearing patterns in different cultures and their effects on two aspects of the child's value system: (1) The extent to which he alines himself with the values of peers versus those of adults; and (2) the extent to which these value orientations are maintained or modified in response to social pressure from either adults or peers.

Comparative studies have been conducted among preadolescents in the United States, England, Switzerland, the U.S.S.R., and West Germany.

It was found that U.S. parents are more emotionally involved with their children than are English parents; U.S. parents make greater use of such psychological forms of discipline as withdrawing support and evoking guilt, while English parents resort more often to physical punishment. English parents are less involved with child-rearing than their U.S. counterparts, and English fathers, in particular, are especially cool and punitive with boys. The two sexes are treated more equally by American parents.

In the Soviet Union, the official youth organizations play a special role in the child's upbringing. It was expected that Russian youngsters were less likely to experience peer pressure as conflicting with adult values and would, therefore, be more responsive to adult influence. With the cooperation of Soviet colleagues, this supposition was tested by asking school children in the United States and the U.S.S.R. to respond to a series of hypothetical situations in which they were forced to make a choice between behavior approved or desired by adults and behavior preferred or requested by peers. Responses were obtained from the children under three conditions. They were told that their answers would be known only to the experimenter and: (1) themselves, (2) their parents and teachers, or (3) classmates.

American youngsters revealed a much greater readiness to engage in peer-instigated, antisocial behavior than their Soviet counterparts, while Soviet youngsters were more responsive to adults. Peer pressure increased adult-approved responses in the U.S.S.R. and antisocial reactions in the United States.

These results demonstrate that social pressure can have appreciable but predictably different effects in different social systems. With respect to problems of education and upbringing, the findings emphasize the importance of utilizing to constructive ends the power of the peer group to influence the behavior and personality development of the child.

Laboratory "Games"

Social psychology, more than any other social science, uses laboratory experiments in its research. The skillful experimenter designs simplified behavior situations relevant to real life, while the independent variables of interest can be carefully controlled.

One productive and very popular technique of experimentation is the study of interaction in "game" situations. "Games" are a strategic device for studying certain types of behavior, because variables can be easily controlled and quantified. The players are placed in an interdependent relationship analogous to a variety of real social relationships. The experimenter may then observe the effects of variables, such as the degree of past interaction between opponents, whether or not there is an expectation of future interaction, or differences in status.

Games are employed by several grant-supported investigations of the processes of cooperation, competition, and negotiation and bargaining. The use of this technique is illustrated in the following brief description of one of the games used in the research of Morton Deutsch, a Columbia University social psychologist—the "Acme-Bolt" Trucking Game.

Acme and Bolt are two trucking firms. Each has a truck that is to be moved along a road from a starting point on one edge of a board to a destination on the opposite edge. This may be accomplished by taking either a short direct route accessible to trucks of both firms or a longer private route. The short route has a central segment which is single lane. Profits are based on the time it takes to complete the trip; the shorter the time, the greater the profits. Subjects play the game in separate booths and their moves and respective positions are displayed before them on a control panel mounted on a sloping-front cabinet. In some cases, subjects are allowed to communicate directly by talking over an intercom.

In this (and other) laboratory situations, Dr. Deutsch is trying to discover what determines whether or not people will resolve a situation of conflict so that mutual gain results. His first answer is a self-evident one: If people have a preexisting cooperative orientation toward one another, they are likely to resolve a conflict of interest by a cooperative process; if they have a prior competitive orientation, they are likely to resolve the conflict competitively.

A third type of orientation to the games, individualistic, was not predominantly cooperative or competitive, but was characterized by mutual indifference to the other's fate. The instructions did not stress helping or defeating the other, but simply the injunction to win as much as possible for oneself. The cooperativeness or competitiveness of the subject's approach generally rested on such factors as problem size, threat capabilities, communication facilities and skills, inspection procedures, and behavioral strategies.

Different orientations have been elicited by a variety of procedures: (1) by the experimenter's instructions; (2) by the payoff structure, as when a player's profits and losses are consonant with those of the other player, on the one hand, or when his gains are in proportion to the other's losses, on the other hand; (3) by inducing a perception of the other as one similar or dissimilar in values and attitudes to the subject.

There is good evidence for the commonsense notion that small conflicts are more easily resolved than large conflicts. The size of the conflict was manipulated by changing the length of the one lane path which the trucks in the Acme-Bolt game were to traverse. In the small conflict, players resolved the problem with less deadlock and struggle, less use of threat, and greater mutual gain than in the larger conflicts.

A subject can be given the means to threaten the other player. For example, in the trucking game, this can be done through the use of gates by which one player can block the other. When this was done, the likelihood of the subject using this power varied with the circumstances. He was less likely to use threat power when his opponent had equal power than when the balance was one-sided. Under conditions of equal power, the subject was more likely to use his power when the threat was of medium intensity than when it was of very high or low intensity. In general, however, subjects use such weapons when they are available, and their use makes it more difficult to resolve the conflict cooperatively.

In a number of experiments, the effects of having or not having communication facilities were examined. It was consistently found that cooperatively oriented pairs did not need such facilities to work out effective agreements, and competitively oriented pairs could not use them effectively or with honest intent. Individualistically oriented subjects were more likely to benefit from the opportunity for communication of intentions and expectations.

It is also of interest to note that communication was more effectively utilized if it was allowed only after the players had experienced a series of deadlocks, than if it was initiated prior to the deadlock.

The introduction of inspection procedures, it was found, facilitated coöperation, for it enabled the players to reveal to one another their cooperative efforts and prevented them from concealing competitive efforts. There was most competition, least cooperation, and smallest joint payoff in the no-inspection condition.

Analysis of International Trade

H. G. Georgiadis of the National Bureau of Economic Research has been engaged in a systematic analysis of international trade data in an effort to assess objectively the competitive position of the United States in world trade.

The first part of his research effort involved finding the most appropriate concepts and statistical techniques for identifying shifts in the competitive position of a given country, and the development of a feasible "end-use" commodity classification system. After these measures were worked out and used, several important findings emerged. "Price-rise" countries are defined as those which experienced a rate of price increase higher than that observed in the United States. "Price-fall" countries are those which experienced a lower rate of price increase. The analysis of data demonstrated that when the United States share of the market in the leading foreign countries changed, the change in both "price-rise" and "price-fall" countries was in the same direction.

This observation suggested that:

- Factors other than relative price changes contributed to gains and losses in the U.S. share of export markets.
- There was no significant positive correlation between rates of growth of domestic production and rates of growth of domestic prices on the one hand, and of changes in imports on the other.
- The original export share of a market supplied by a given country did not prejudice the subsequent behavior of the market shares of that country in any significant way.

An investigation was also made to determine whether the products in which individual exporting countries registered their highest market gains were those in which they also registered their highest expansion in domestic production. In the event this proved to be true, further research would be undertaken to determine whether the ranking of domestic rates of production would be considered as a good proxy for technological innovation.

Food-Gathering in a Primitive Society

In a recent study, Richard Lee and Irven DeVore of Harvard University lived in southern Africa among 430 Bushmen of the Kalahari Desert, Bechuanaland. The Bushmen comprise one of the few groups left in the world among whom hunting and gathering—once the way of life for all men—still persists as the basic means of subsistence. Agriculture is lacking, and there are no domesticated animals except the dog.

Figure 1.—*A Harvard anthropologist has found that African Bushmen such as those shown gathering ostrich eggs live a relatively routine and secure life in spite of the fact that their existence depends solely upon hunting and gathering. Surprisingly little is as yet known about this kind of economic system, though modern man as a species developed in groups with hunting and gathering economies.*

As one part of the research, the daily food habits of two groups were recorded over a period of 15 months. Detailed observations were made on the seasonal activity cycle, including what foods were eaten and what movements about the countryside were necessary in the quest for food. Bushmen food resources were found to be both varied and abundant, including 85 edible plant and animal species. The basic food staple, the wild mongongo nut, alone accounted for two-thirds of the vegetable diet. Meat was of secondary importance in the diet, comprising between 20 and 40 percent by weight.

The Bushmen were highly selective in their food habits, eating only the tastiest of their foods and bypassing the less desirable ones. Most birds, small mammals, reptiles, and insects were virtually ignored as food. Wild foods were so plentiful that, for most of the year, the Bushmen could satisfy their subsistence requirements within a few miles of standing water.

Theirs was not a free-ranging nomadic way of life. They moved out to seasonal water sources during the summer rains and each year returned to permanent waterholes. Although the Bushmen did not amass a food surplus, securing a food supply was not a matter of daily necessity. The women were observed to gather foods only 2 or 3 days each week, and the men hunted 3 or 4 days each week. Most of their time was spent in visiting, resting, talking, and working around the camp.

Previous observers of the Bushmen have tended to focus on their arduous and dramatic subsistence techniques, fostering the notion that the Bushmen live precariously close to the starvation level. They can survive terrible privation, but according to Lee's and DeVore's observations, except for a few weeks each year, Bushmen subsistence is routine and secure.

In short, their findings suggest that there has been an underestimation of hunting and gathering as a persistent and substantial way of life. This study is significant—as well as interesting in its own right—because for the greater part of human history by far (until 12,000 years ago), all men were hunters and gatherers, and the biological evolution of modern man as a species took place when every human society was dependent on this type of economy. Yet we still know surprisingly little about the comprehensive effects of this kind of economic system on human groups.

The Effectiveness of Language in Communication

Language as a social phenomenon is an area of interest for many social scientists. Not only is the structure and analysis of the world's various tongues of scientific interest in itself, but the language of a people tells the anthropologist much about its culture and origins. To the sociologist and psychologist the language of an individual speaker reveals much about him—his social status, his geographic origin, his personality.

Social scientists are interested in such questions as: How does a child learn his language? How do children or adults learn more than one language? How are thought patterns translated into speech? (It will be recalled that one of the criteria of mastering a foreign language is that "you can think in it.")

Thesaurus of World Languages—Languages are universally used as the basic unit of classification of linguistic science, yet there exists no comprehensive or satisfactory listing of the languages of the world. Just as the scientific classification of plants and animals gave order to the biological sciences and made possible fruitful research efforts, the systematization of language including dialects, language families, and areal groupings will fill a major research need in linguistic studies. A major award was granted to Thomas Sebeok at Indiana University to prepare a thesaurus of the languages of the world, necessary for the evolution of a computerized bibliography and retrieval system in linguistics. Four thousand languages will be covered, with a total of about 50,000 entries, representing such items as phyla, area groupings, and local variants. Now nearing completion, the thesaurus will enable an investigator not only to identify a language or language group but to locate literature relevant to the item in question.

The Uses of Hesitation—Collaboration between linguists and psychologists on problems of verbal phenomena and language learning is one of the most active areas of research. Percy Tannenbaum of the University of Wisconsin has been working on "the hesitation phenomenon."

He has found that silences in speech tend to both precede and follow words of low predictability. This suggests two reasons for hesitation in speech. One appears to be a groping phenomenon where the speaker is faced with a critical decision. The other may be a feedback result, that is, the speaker is reacting to something he himself has just said.

Dr. Tannenbaum has also investigated the occurrence of hesitation phenomena in the speech of people who speak two languages well. He has noted that the relative frequency and locus of hesitations vary from one language to the other, and that these phenomena were in agreement with other indices of relative language proficiency. Preliminary results indicate a relationship between relative hesitation occurrences in two languages and interlingual word association. A bilingual person who changes his hesitation pattern when he moves from one language to the other is likely to be a person who is inclined to give different word association responses in each language. On the other hand, if he maintains a constant hesitation pattern, he also tends to give word association responses in one language that are translation equivalents of their responses in the other language.

Biological and Medical Sciences

New concepts and techniques promise an understanding of life at more profound levels than had been previously thought possible. The kinds of life being studied range from the smallest virus to the giant redwood, from the simplest bacterium to man in all his complexity. These studies may deal with the life processes of a single cell, of a whole organism, or of a community of organisms.

A new era in biology was opened in the 1950's with determination of the structure of DNA (deoxyribonucleic acid—the molecular carrier of hereditary traits). Many of the remarkable and rapid achievements in molecular biology that occurred during this period were supported by the Foundation. The consequences of this expansion of fundamental knowledge, particularly in molecular genetics, are now a concern not only of science, but of public policy, because of man's potential, but as yet undemonstrated, ability to control his heredity, development, and evolution.

As a result of the rapid advances in molecular biology, disciplinary boundaries are breaking down. Many biologists are extending their interests from population or whole organism levels to the molecular level; and conversely, molecular biologists are anxious to apply their knowledge and techniques to problems of whole organisms or populations. Increasingly, biologists are becoming oriented to the problems that must be solved irrespective of disciplinary boundaries—in fact more and more noteworthy advances are coming from multidisciplinary approaches. Each new discovery meshes with the interest of investigators in different areas.

Seemingly scattered and distinct pieces of information can be interrelated and used to simplify man's view of nature. In the realm of practical affairs, each advance in understanding life processes gives mankind additional tools to use in solving the problems of increasing populations, food production, and environmental pollution.

In the following discussion of research findings, a number of examples have been selected that show how these advances in fundamental knowledge can contribute to the well-being of mankind.

Juvenile Hormones as Insecticides

Carroll Williams of Harvard University is investigating the behavior of juvenile hormone, an insect substance essential for larval growth. Metamorphosis of the larva requires that production of this hormone cease, allowing another hormone, ecdysone, to initiate transformation to the adult form. Application of juvenile hormone to a larva can prevent its metamorphosis into a sexually mature adult. This suggests a method of controlling insect populations that is safe because the hormone is inactive on other forms of life. Possibly of great practical importance is the fact that there is little chance of resistance developing, as is the case with such insecticides as DDT. Insects can scarcely afford to develop resistance to their own hormones on which they are dependent for growth and development. To date, juvenile hormone is difficult to ob-

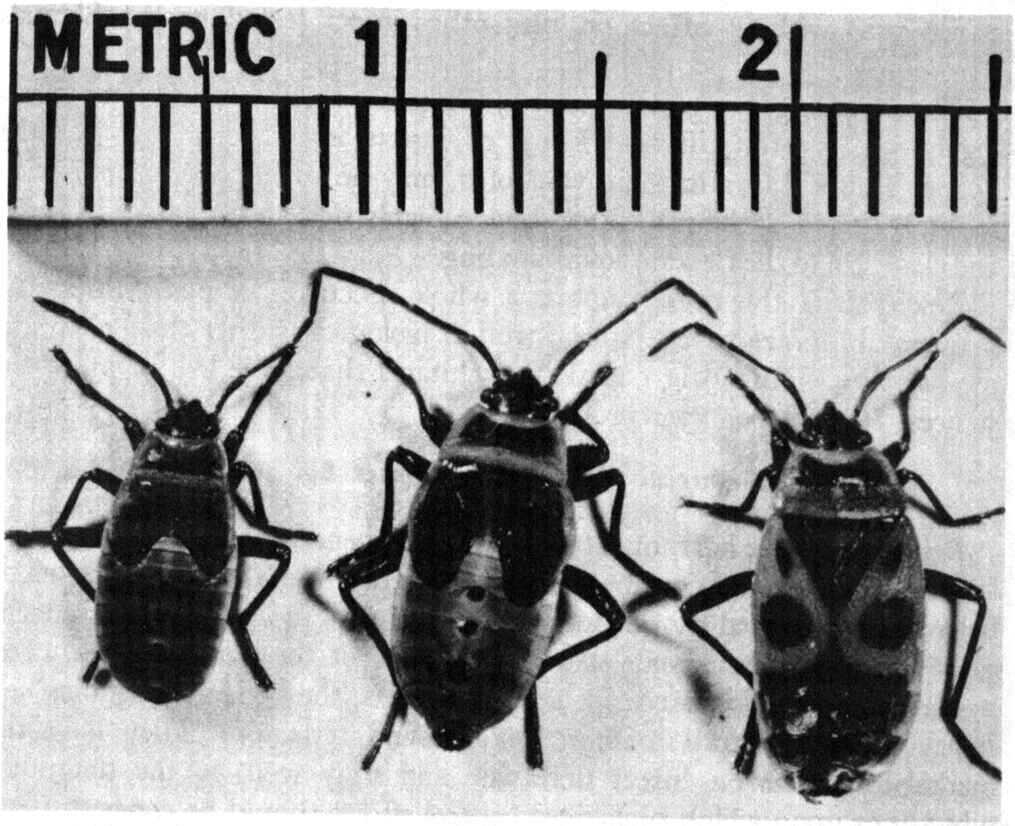

Figure 2.—***A Harvard scientist working with a Czechoslovakian colleague has extracted from balsam-fir paper a compound with very high juvenile hormone activity that has a deadly effect on an insect related to pests such as the "red cotton bugs" of India, Africa, and Australia. Normally, an advanced larva (left) of the insect,* Pyrrhocoris apterus, *develops into the winged, sexually mature adult (right). However, when exposed to the "paper factor," the larva grows larger (center) and invariably dies without maturing to the stage where it can reproduce.***

tain in quantity, and it has not yet been synthesized. But its potential utility assures a great increase in efforts to make it available.

The Czechoslovakian scientist, Slama, who works with an insect species similar to that used by Williams, found that applications of juvenile hormone obtained from Williams did not interfere with the metamorphosis of his European form, *Pyrrhocoris apterus.* Slama came to Harvard and found, to his amazement, that here his Czechoslovakian insects reacted like American forms and failed to become adults. But it was not Williams' juvenile hormone that prevented the metamorphosis.

Careful study revealed that the basic difference between the Prague and Harvard experiments was in the rearing of the animals. Harvard-raised insects were grown in jars with paper toweling, whereas Prague-raised insects were not. The paper was made from common balsam fir, which strangely enough contains a product with extremely high juvenile hormone activity. Equally astonishing was the discovery that the substance was without effect on any other insect tested except Slama's *Pyrrhocoris*.

These findings suggest that: (1) Preparation of hormone materials highly specific for different kinds of insects is possible, and (2) the "paper factor," or a modification of it, may be an important insecticide for such insects as the red cotton bug, a highly destructive insect in India and close kin to the Czechoslovakian bug.

Research of this nature opens a whole spectrum of possibilities that may revolutionize pest control through biological rather than chemical means, thus eliminating chemical pollutants that have led, in many instances, to grave pollution problems.

Chemically Influencing Insect Behavior

Related to these hormone studies are the recent advances in our understanding of chemical communicators or pheromones that influence insect behavior. Secreted by one individual, these social chemical messengers elicit specific responses in other individuals of the same species. Examples of these substances are sex attractants, the "queen substance" of honey bees, and trail markers of ants and termites. They have remarkable effects on insect behavior and may well be the definitive substances upon which biological control efforts should be concentrated.

Pheromones of only a few harmful insects have been isolated thus far. The amounts available for field testing are extremely small. The gypsy moth sex attractant, studied for 30 years, has only recently been identified. It required 500,000 females to obtain 20 milligrams (0.0007 ounce) of the substance.

Interest centers on the chemical structure of these compounds, their modes of action within insects, and possible methods for their synthesis. The entire gamut of biology is concerned with the development of such knowledge, and a number of NSF-supported laboratories are actively involved, including that of W. L. Raelofs and E. G. Taschenberg, of Cornell University, working on the chemistry of pheromones in moths; E. J. Eisenbaum and W. A. Drew, at Oklahoma State University, investigating ant pheromones; and R. Barth, at the University of Texas, studying behavioral responses of sexual attractants in cockroaches.

J. Law of the University of Chicago is studying the pheromone cycle between queen and worker bees by means of radioactive labeling. The fatty acid being studied is not only used by the virgin queen bee as a sex attractant but is also distributed by her to worker bees to prevent development of their ovaries and thus their ability to compete with the queen's rearing activities.

These broadly based attacks, oriented primarily toward a fuller understanding of the biological role of pheromones, will certainly lead to significant practical contributions relating to insect control.

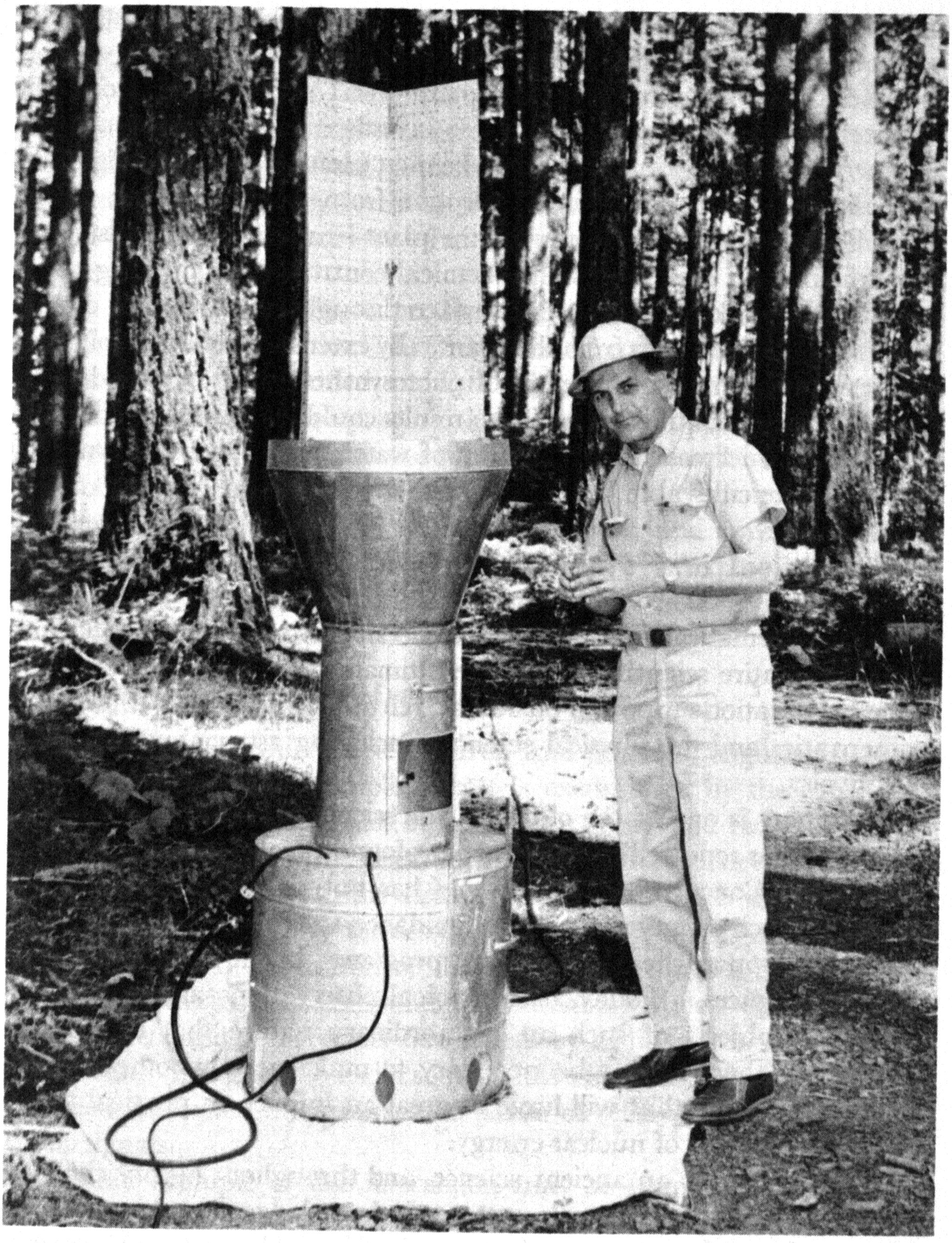

Figure 3.—*An Oregon State University scientist uses this trap in the study of attractant substances of the Douglas-fir beetle, an insect that kills a large number of valuable trees each year.*

Controlling Leaf Metabolism

One of the keys to ensuring an adequate supply of food for the world's increasing population is a comprehensive knowledge of the molecular mechanisms involved in photosynthesis—the primary energy-converting reaction essential to all life. Recent developments have elucidated the ultrastructure of the membrane systems making up the chloroplast, the cell organelle responsible for the photosynthetic process, and the mechanism by which chloroplasts convert light to energy.

I. Zelitch of the Connecticut Agricultural Experiment Station, who has been using enzyme inhibitors for investigation of leaf metabolism, unexpectedly found some of these to be most useful in gaining insight into the control of carbon dioxide absorption from the atmosphere and of water loss by the plant. Spraying the plant leaves with alkenylsuccinic type compounds makes possible chemical control of the opening of the stomates—tiny pores on the leaf surface through which carbon dioxide enters and water escapes from the plant. By extension such control might well result in a greater efficiency of photosynthetic carbon dioxide fixation and of water utilization. The results could be more food per acre and a radical decrease in the amount of water needed, thus, enormously extending the cultivable land areas of the world.

Mathematical and Physical Sciences

The mathematical and physical sciences constitute the bedrock upon which the entire scientific enterprise ultimately rests. About one-third of the Foundation support in basic research during fiscal year 1966 was in mathematics and the physical sciences, including astronomy, chemistry, and physics.

Astronomy is one of the oldest of the sciences. Throughout history, astronomy has repeatedly occasioned profound revolutions in man's view of nature. Concurrently, astronomy has not only provided practical dividends, such as navigation aids, guidance systems, and the data that guide and support the present space programs, but it has also enriched all other sciences. Today, astronomical observations are being made of celestial objects of such an extraordinary nature that in order to account for them it may be necessary to make new hypotheses about the laws of nature that will have as great an impact on physical theory as did the discovery of nuclear energy.

Chemistry is also an ancient science, and throughout history chemical research has produced much systematic knowledge that has been incorporated into the structure of other scientific fields, such as biochemistry, geochemistry, atmospheric chemistry, and the practical arts of medicine, industry, and agriculture. Today chemical research is undergoing a veritable renaissance, largely because of the effective use of concepts and instrumentation drawn from modern physics, and in turn is increasingly providing guiding concepts to the interpretation of biology.

Physics already underlies most of modern engineering and serves as a source from which much new technology springs. Physics research continually provides insights, instrumentation, and techniques of central importance to other scientific disciplines; physicists are presently finding a host of developing connections between physics and other areas of the modern natural sciences. Indeed, in several of the brief accounts of recent research which follow these introductory paragraphs, it is clear that physics as well as other major disciplines was involved in a fundamental manner. For example, in the study of the expanding universe, physics, astronomy and engineering played a part. The study of the energy levels of organic molecules was carried out in a solid state physics laboratory, but the results are clearly of interest to chemists.

The past 20 years have produced a noticeable flourishing in all branches of mathematics. As mathematicians have pushed in the direction of a more unified understanding of mathematical structures, they have evolved techniques and ideas that have permeated not only the natural sciences but also the social sciences, as well as the management of large business organizations.

The research findings in the mathematical and physical sciences reviewed here are indicative of the manner in which these most central of sciences reinforce and systematize their interactions among themselves and with other areas of science and technology.

The Exploding Universe

The manner in which basic research and practical engineering benefit from each other's accomplishments is exemplified by the interaction between activities in the fields of radio astronomy and radio communication over the past three decades. Indeed, the science of radio astronomy owes its origin to the discovery of the existence of cosmic radio sources made in the early thirties by Karl Jansky, an engineer attempting to understand and minimize the effect of extraneous radio noise in decameter-wavelength transatlantic communication circuits. Conversely, the sensitive receivers developed by radio astronomers for use in detecting faint celestial radio sources have been highly useful to radio engineers interested in equipment capable of receiving weak communication signals.

Another example of this interaction may be found in recent studies of the origin of the universe which tend to confirm the hypothesis that the universe is exploding. The possible models of the origin and structure of the universe permitted by the Einstein equations of general relativity have led scientists to two sharply conflicting views regarding the origin of the universe. One holds that the universe at an earlier stage in its history was highly contracted and possessed a temperature in excess of 10 billion degrees; it is thought that it then expanded rapidly from this highly condensed state. The second view of the history of the universe holds that it has been steadily expanding for all time.

The latter view constitutes the basic model for the "steady state universe" proposed by H. Bondi, T. Gold, and F. Hoyle, while the former has been called the "exploding universe" or the "big bang" theory. Up until the last several years astronomical observations provided little information with which to choose between these models.

During the past year R. H. Dicke and his colleagues at Princeton University pointed out that another research group led by A. A. Penzias and R. W. Wilson of the Bell Telephone Laboratories may have observed cosmic radio noise which was generated at the beginning of the expansion of the universe some 10 billion years ago. The Bell Laboratories group had been conducting satellite communications experiments in the microwave region of the radio spectrum in an effort to track down and compensate for all extraneous sources of radiation that obscure the signal under study. After all known sources of noise had been taken into account, there remained an unexpected background signal. The Dicke group showed that this residual noise is of the strength which would be expected if the universe has evolved from a high-density, high-temperature state of the sort proposed by the proponents of the exploding universe hypothesis. They then carried out their own experiments, which confirmed and extended the Penzias-Wilson result.

The hot radiation of the primordial fireball is thought to have expanded rapidly, and as it did so the temperature of the photon gas decreased, essentially as an ordinary gas cools upon free expansion. An important test of this theory is whether or not the amounts of radiation at different frequencies in the cosmic background noise all correspond to the same present temperature of the now ancient fireball. The Bell Telephone Laboratories and Princeton University results are in agreement that this temperature appears to be about 3 degrees above absolute zero. This result is confirmed by recent measurements (at NSF's Kitt Peak National Observatory) of the spin temperature of interstellar cyanogen gas, which is thought to have about the same temperature as the cosmic background radiation at optical frequencies. It may also be noted that computations by P. J. Peebles, also at Princeton University, connect the present temperature of the fireball with the relative abundance of helium created in the earliest moments of the cosmic expansion. The result is in agreement with the abundance now observed in outer layers of certain stars (where the abundances are believed not to have been significantly altered from the original values by subsequent thermonuclear reactions).

Image Intensifiers

An image intensifier is a device capable of converting an optical image, such as that produced by a camera lens, into another much brighter (i.e., intensified) image. Using a camera that contains an image intensifier, one can take a picture in a much shorter exposure time than would be possible without the intensifier.

Since astronomers frequently wish to observe very faint celestial objects, image intensifiers can be particularly useful to them. Representative of such faint celestial objects are the very distant quasistellar radio sources, often called quasars. Approximately 50 of these strong emitters of radio energy have now been identified on optical photographs. In appearance they are essentially starlike in character except when examined with the largest telescopes, where, in some cases, faint gaseous material is seen to be present in their vicinity.

The bright lines in the spectra of the quasars, which indicate their gaseous character and identify the chemical constituents of the gas, are found to be strongly displaced toward the red end of the spectrum. If, as most astronomers believe, this line shift is the result of rapid motion of the object away from the earth, it is possible to infer something about the distances of the quasars. In the spectra of ordinary galaxies, a similar redward shift has been noted which increases with the distance of the galaxy. Distances of the quasars derived from the red shifts in the same way suggest that they are the remotest objects known. Thus, if in fact, quasars are at these distances, to be seen they must also be the brightest objects in the observable universe.

If they are, indeed, at great distances, the quasars may well furnish information bearing on the question of the type of universe we live in. Of equal interest is the problem of the nature of the quasars themselves and especially the source of the tremendous energy which they would have to radiate in order to be observed at such distances. This would exceed by many times the output of a great galaxy such as the Milky Way.

It is particularly timely that a new image-intensifying device, which is especially designed to intensify the telescopic images of faint astronomical sources, is now being made available for use by the Image Tube Committee of the Carnegie Institution of Washington. This device has been developed by several industrial groups under the guidance of the Department of Terrestrial Magnetism of the Carnegie Institution, headed by Merle A. Tuve. As an example of its performance, 6 hours were needed to photograph the spectrum of the quasar 3C48 (No. 48 in the third catalog of radio sources by the Cambridge University radio astronomy team) with the 200-inch Palomar telescope, whereas the same result could be obtained with the smaller 72-inch Perkins telescope at Flagstaff, Ariz., in less than 50 minutes with the aid of an image intensifier. As a consequence of this, astronomers using these image intensifiers on moderate-sized telescopes have already made many contributions to the study of the spectra of quasars and other faint astronomical sources.

The Behavior of Carbonium Ions

A major goal of chemical research is to understand in detail the structure and reaction properties of intermediate chemical products which exist very briefly during chemical reactions. Such knowledge is important both in developing and refining theories of chemistry, and in allowing careful control of chemical processes which are used in chemical technology. Techniques for studying short-lived chemical species have improved markedly in the last decade; in fact, the recent availability of new and more sensitive instruments has revolutionized chemical research. Chemists are now able to make direct observations on ephemeral molecular fragments which have been the subject of speculation for years.

One of the most common, and elusive, intermediates in organic reactions is the carbonium ion. This is a fragment of an organic molecule which bears a positive electrical charge on one or more carbon atoms. It can be formed either by breaking off a part of a larger molecule, during which process an excess electron accompanies the leaving group, or by adding a positively charged fragment (such as a hydrogen ion) to a neutral molecule. In the past few years considerable controversy has developed about the carbonium ion. The major question comes down to this: Must the effective positive charge remain localized at a single carbon atom, or can it be spread out over several nearby carbon atoms?

A Foundation grantee, William LeNoble of the State University of New York at Stony Brook, has applied a somewhat neglected but powerful technique to this problem. By determining the changes in the volume of a solution while a reaction involving a carbonium ion intermediate is in process, he was able to show that the charge can be shared. This technique makes use of the fact that molecules in solution occupy a definite amount of space; when molecules react with each other the volume they occupy changes in a predictable way. Thus, when a molecule splits apart, it takes up more space as the chemical bonds holding the constituent atoms together are loosened. On the other hand, if electrical charges are developed during the splitting process, molecules of the solvent are attracted to the charged centers and the volume of the solution is decreased; the more localized the charge, the greater the decrease.

Reactions accompanied by a volume increase occur at a slower rate as externally applied pressure increases. LeNoble's experimental method of determining volume changes in reacting solutions makes use of this principle. From the observed changes in the reaction rate, it is possible to calculate the actual volume of activation and infer the nature of the intermediate chemical species. Dr. LeNoble has applied this approach to several problems with considerable success; in some cases his results have refuted conclusions which have been generally accepted.

Of course, an alternative approach to the study of unstable compounds is to try to find means of stabilizing them so that they can be observed by direct methods which require more time. An exciting advance of this kind was made in 1962 by George Olah of the Dow Chemical Co., who found that a variety of carbonium ions could be prepared and kept for relatively long periods of time in an antimony pentafluoride solution. Dr. Olah, now at Western Reserve University, has continued his work and, in collaboration with Paul Schleyer of Princeton University and Martin Saunders of Yale University, has used modern instrumental techniques to learn a great deal about the properties of the ions. Crystals of the carbonium ion salts with antimony pentafluoride can also be isolated; Norman Baenziger, at the University of Iowa, is determining the detailed structure of some of the most interesting of these salts by X-ray diffraction. With the clue provided by Dr. Olah, other investigators have made simple, stable carbonium ions in a variety of highly acid solvents, such as the fuming sulfuric acid used by Norman Deno of Pennsylvania State University. These and other studies supported by the Foundation have already produced some surprising results, as well as a deeper understanding of important chemical intermediates in many chemical reactions.

Spectroscopic Studies of Energy Transfer in Molecules

The energy of a molecule is describable in terms of its external bodily motions (rotation and translation) and the internal motions of its atoms and electrons with respect to one another (vibration and electronic motion). The transfer of energy from one to another of these four types of motion can determine the course of important chemical processes. This is the case, for example, in the science of photochemistry which is concerned with the effects of light, particularly ultraviolet radiation, on materials. Absorption of light can increase the electronic energy content of a molecule to such an extent that it will decompose, unless alternate and competing processes occur. For example, through energy transfer, the electronic energy is converted into the other forms of motion and, ultimately, is lost as heat.

Spectroscopy presents a unique, and possibly the most powerful, tool for the study of energy transfer processes. This advantage is based on the fact that, in accordance with the laws of quantum mechanics, the electronic, vibrational, and rotational energies can only assume certain discrete values. Similarly, the radiant energy which is absorbed or emitted by a molecule is quantized in an amount which is inversely proportional to the wave length of the radiations, and consequently subject to precise measurement. Because of this fact, it is possible to determine, from quantitative measurements of the absorption and emission of radiation by the molecules of a specimen which is being studied, a great deal about the energy levels it possesses, and the rates at which they are accepting energy from or releasing it to their environment. By inference one can also determine the manner and rate at which energy is being transferred internally from one form of molecular motion to another.

Further information can be obtained if observations are made while the specimen is observed at different temperatures and pressures. Since such changes affect the energies with which the molecules collide with one another and the mean distance between them, the forces that the molecules exert on each other are altered. Consequently, the rate at which energy is transferred between them varies, and the observed variation in the rate of collisional energy transfer with temperature and pressure can be used to obtain information on the forces which molecules exert on each other.

Encouraging progress on the spectroscopic study of energy transfer has been made recently by D. Bradley Moore, an NSF grantee at the University of California, Berkeley. Moore and his coworkers observed the emission spectrum from hydrogen deuteride molecules which had been raised to a single excited electronic energy state by monochromatic ultraviolet radiation (1066 Å). The observed emission spectrum was generated by transitions from the single excited state to various vibrational levels of a lower electronic state, thereby providing information on the relaxation of the vibrational excitations through the collision process, and on the nature of the intermolecular forces.

This same group of researchers has observed the time it takes for a molecule of methane to effect an internal redistribution of the energy it receives from an incoming quantum (the relaxation time). Radiation from a helium-neon gas laser, operating at a wavelength of 3.34 microns, was used to preferentially increase the vibrational energy associated with the stretching of the carbon-hydrogen bonds of the methane molecules. The relaxation time was measured by observing the emission of infrared radiation caused by a decrease in the vibrational energy of the bending vibration, which falls in the 6.7-micron region of the spectrum. This observation is the first direct proof that higher frequency vibrations can transfer their energy first to lower frequency vibrations, which energy in turn is converted to rotational and translational energy.

Although these advances are still preliminary in nature, they provide invaluable guidelines for future, more detailed, studies which should lead to a better understanding of chemical kinetics and collisional mechanisms. The availability of such basic knowledge could very well lead to important technological advances in such areas as the improvement of radiation-resistant materials, the generation of power by magnetohydrodynamic methods, the development of chemical lasers, and methods of photochemical synthesis.

Fixation of Atmospheric Nitrogen

Since the chemical element nitrogen is one of the essential ingredients of plant tissue, the problem of supplying it in adequate quantities for agricultural purposes is a matter of major economic concern. Central to this problem is the fact that plants are only able to absorb nitrogen when it is made available to them in the form of chemical compounds (except possibly in the case of leguminous plants). Such compounds, when they are added artificially to the soil, are called fertilizers.

The principal source of the nitrogen which is used as a raw material in the manufacture of fertilizer is ordinary air, which contains 75 percent pure molecular nitrogen by weight. The chemical inertness of this substance is such, however, that the most successful commercial process now in use for the fixation of atmospheric nitrogen into a chemical fertilizer requires the use of a catalyst and the employment of high temperatures (450°–600° C.) and pressures (200–600 atmospheres). These severe manufacturing conditions are, of course, reflected in the price of the product. One such product is chemical ammonia which is used extensively not only as a fertilizer, but also as a precursor for many other important industrial chemicals. According to information from the U.S. Department of Agriculture as summarized in *Chemical and Engineering News* 44, August 15, 1966, the U.S. output of ammonia has been growing at an annual rate of more than 10 percent over the past 15 years. In the year ended June 30, 1966, production climbed 22 percent to an estimated 9.7 million tons. Between 70 and 75 percent of all ammonia produced is used in agriculture.

The development of more efficient catalysts for the fixation of nitrogen under less extreme manufacturing conditions would result in substantial financial and agricultural benefits. One approach that appears to offer the greatest promise of lower cost production of ammonia in the near future involves the search for a catalytic compound that could adsorb and activate atmospheric nitrogen; the activated nitrogen could then combine with hydrogen to form ammonia (and concurrently regenerate the original catalyst) at lower temperatures and pressures. Until recently the systematic development of such catalysts was hampered by the fact that no compounds capable of chemically adsorbing molecular nitrogen were known. Within the last year, however, compounds of this type have been reported by one American and two foreign investigators, all working independently. The American investigator, James P. Collman of the University of North Carolina, with Foundation support of his research, has discovered two compounds in which molecular nitrogen is bound to a metal ion derived from the element iridium. Although the nitrogen in these compounds was introduced in an indirect manner by a series of rather complex chemical reactions not involving the use of atmospheric nitrogen, the results of these investigations are nevertheless very encouraging forward steps. One may even hope that eventually catalysts will be found which, when added to the soil, will adsorb nitrogen from the air continuously and release it in a form that can be utilized by plants in a process similar to the nitrogen-fixing reactions which occur in leguminous plants.

Energy Levels of Organic Molecules

The study of energy transfer and charge transfer in organic molecules has been of interest for many years, since many life processes, such as photosynthesis, cannot be understood without a detailed knowledge of these mechanisms. The structure and electronic properties of relatively simple organic crystals have been the subject of numerous investigations—first, because the regular arrangement of molecules making up the crystal facilitates certain measurements, and second, because the simpler chemical systems are more amenable to theoretical interpretation.

In the past one of the methods used for observing photon-induced processes in crystals has been to irradiate the crystal with a beam of light containing photons of a known energy, and to measure the current generated in the crystal by means of electrodes attached to it. A major drawback of this method has been that the juxtaposition of the electrodes to the crystal introduces unknown and variable disturbing potentials which invalidate the measurements.

Recently M. Pope of New York University, an NSF grantee, developed a new method which makes the use of attached electrodes unnecessary. He suspends tiny fragments of the crystal which become electrically charged by friction. They are introduced into the apparatus in a vertical external electric field having enough strength to produce an upward force which counterbalances the force of gravity. The fragment is then irradiated with photons of gradually increasing energy (frequency) until photoemission occurs. The more highly charged fragment then accelerates upward in the electric field. The electric field strength is then adjusted until the particle is again suspended motionless, and from the amount of the adjustment the charge alteration can be determined. By using measurements of this kind, and employing other rather sophisticated experimental and theoretical techniques, Pope has been able to determine almost all the energy levels of both anthracene and tetracene.

The results thus obtained not only have established a minimum for the conduction band energy (which is twice the value previously derived from data plagued by electrode problems), but have also established for the first time, experimentally, the existence of an energy state known as the charge transfer exciton.

A Unique Facility for Nuclear Structure Physics Research

Studies of the arrangement of the particles which compose an atomic nucleus and the forces which bind them together are usually made by bombarding nuclei with energetic particles (such as protons) and observing with great precision the directions and energies of the physical entities emitted from these collisions. This experimental procedure requires, however, that the energies imparted to the bombarding particles by the particle accelerator also be very precise. Until recently this has been done principally by means of electrostatic accelerators, which are limited in existing designs to maximum energies of the order of 20 million electron volts (MeV). Some work has also been done at higher energies by using a small portion of the beam from a circular accelerator (i.e., that part having the desired energy). Because of the small number of particles in a partial beam, however, the experiments which employ them are very long and tedious, and frequently have led to inconclusive results.

Recently construction of a new type of particle accelerator, called a variable-energy sector-focused cyclotron, was completed at Michigan State University with NSF support. The new machine will allow precision measurements to be carried out at bombarding energies up to 55 MeV. Tests with it indicate that an ultimate precision of 0.01 percent in the energy imparted to protons will be possible in an energy range from 14 to 55 MeV. At the same time that this precision is being achieved, the intensity of the accelerated beam is about 100 times that of a partial beam of equal precision obtainable from older machines.

The unique features of the new machine result from the fact that prior to its construction the essential design and operating parameters of the machine were calculated in precise detail with the aid of computing machines. Also contributing to the very high resolution and intensity of the particle beam is the use of a slit system near the center of the machine which selects the desired particles while they still have a very low energy. As a result a very high proportion of the selected beam reaches the target, and only a small part strikes the interior of the machine and generates undesired radioactivity.

New 10-Billion-Volt Electron Synchrotron

The Atomic Energy Commission has been, and continues to be, the Federal agency which provides the major very high energy accelerators which are essential tools for research in elementary particle physics in the United States. (The name "elementary particle" is given to the fundamental units from which atoms are constructed, and to other tiny physical entities which are generated and destroyed when these particles interact with one another.) Recognizing this fact, the Foundation has not provided facilities of comparable size for this area of research. It has, instead, generally allocated relatively limited funds to support the research of a number of university-based high-energy physicists (and their students) who perform their research as visitors at AEC-supported, high-energy accelerator facilities.

The major exception to this policy was the decision in fiscal year 1965 to provide funds to Cornell University for the construction of a 10 billion volt electron synchroton. The high duty cycle (fraction of the time the particle beam is on) of this accelerator, which permits the study of certain types of multiparticle reactions to be carried out much more economically than is possible with any other U.S. electron accelerator of this energy, constitutes the principal scientific justification for the new facility. Further incentive for initiating the project was the fact that it could be carried out by a single major university physics department, thus involving the faculty and students intimately and imaginatively in the design and use of the machine. When completed, a substantial portion of the operating time of the accelerator will be available for use by scientists throughout the country.

Although completion of the facility is not expected until fiscal year 1968, in view of the anticipated cost of the project (about $12 million) it is appropriate to report here briefly on progress to date.

Construction of this accelerator was begun in fiscal year 1966. The accelerator tunnel has been completed and installation of utilities almost completed. More than two-thirds of the accelerator magnets have been fabricated, and more than one-half of the magnets and their associated power supply components, vacuum components and control units have been placed in the tunnel. Construction of the laboratory building, including the experimental area, was begun in March 1966. Because of some construction difficulties, the building schedule has been delayed 2 months and the initial part was occupied in December 1966. This delay will not affect the overall time schedule for completion of the accelerator.

In order to minimize costs, a decision was made to build the alternating current components of the magnet power supplies at Cornell; this decision has permitted Cornell to utilize the latest developments in solid state technology in the design of the high-power rectifiers and inverters. A prototype unit of the accelerating structure has been successfully tested at full power, and no delays are anticipated in the completion of the remaining components of the radio-frequency accelerating system. The first section of a linear accelerator which is to be used as an injector has been tested and found satisfactory, and delivery of the components for the remaining sections is nearly complete. Using the first section of the linear accelerator as a temporary beam injector, tests of one-third of the magnet ring were begun in late October 1966, and a good electron beam over this portion of the magnet ring was achieved almost immediately.

Completion of the magnet ring is expected in March 1967, and low power tests of the electron beam around the completed ring will begin shortly thereafter. Salaries, components, and construction items representing more than 80 percent of the anticipated total costs of the facility have either been paid for or are under fixed-price contract. Completion of the project on schedule and within the contract funds is expected.

The Radius of the Pi-Meson

The pi-meson, or pion, is known to play a central role in determining the structure and properties of nuclei and nuclear matter. It therefore is considered to be one of the most important of the elementary particles. Many of its characteristics (e.g., mass, lifetime, and spin) have been well established for some time. The physical "size" of the pion, however, has been extremely difficult to measure because of its short lifetime and its strong interaction with nucleons. Until recently, only an inadequate upper limit for the pion radius (several times larger than the radius of the proton) was known.

During the past year an NSF grantee, K. Berkleman, measured the rate of production of pions when protons were bombarded by electrons accelerated by the Cornell 2BeV electron synchrotron. Using previous theoretical studies of Fubini, Nambu, and Wataghin the observed production rate can be related to the "size" of the pion.

Berkleman's work indicates that the electric charge of the pion is distributed over a region of approximate radius 7×10^{-14} cm. which, within the accuracy of experiment, is the same as the proton radius.

The Relation of Partial Differential Equations to the Global Properties of Topological Manifolds

A system of partial differential equations is a set of mathematical expressions which describes the behavior of a particular type of mathematical function in terms of its behavior as one changes the values of the independent variables by infinitesimal amounts. The solutions of such differential equations are functions which exhibit the prescribed behavior. Another (seemingly quite different) field of mathematics called topology is concerned with the behavior of a function as one makes major changes in the values of the independent variables—such as, in the case of a function y of one variable x plotted in the x,y plane, does the curve representing the function form a loop and close back on itself? A fundamental connection between these two conceptually rather dissimilar areas of mathematics has been discovered by M. Atiyah and I. Singer. They have obtained an "index theorem," which gives a computable formula for a numerical index describing properties of a system of partial differential equations of a given type. It turns out that the same index can be computed as a function of purely topological properties of another system of *algebraic* equations with coefficients obtained from the system of partial differential equations.

The result is particularly interesting for two reasons. On the one hand, the proof of the theorem involves a recently developed part of topology, called K-theory, and there is a surprisingly intimate relation between K-theory, a branch of topology, and elliptic equations, a branch of partial differential equations. On the other hand, the theorem can be applied to manifold theory in which are found many natural elliptic operators. The formula extends and contains a number of well-known theorems: namely, the Riemann-Roch theorem, the Hirzebruch index theorem, Chern's generalized Gauss-Bonnet theorem, and the A-genus integrality theorem.

Partly in recognition of this outstanding work Dr. Atiyah was one of the four recipients of the Fields Medal at the International Congress of Mathematics in August 1966. He is on the faculty at Oxford University and has received only occasional support from the Foundation during visits to the United States. Dr. Singer, an NSF grantee, is at the Massachusetts Institute of Technology.

Environmental Sciences

Man has so carelessly treated the surroundings in which he lives that he may be endangering his survival. As the population of the earth increases, wise and cautious use of the earth becomes imperative. The major environmental problems faced by man today, such as the pollution of the earth's air and water resources and the depletion of its soils and minerals, can only be solved through the application of the scientific knowledge and methods of chemistry, physics, biology, and mathematics. Through scientific investigations of his environment, many interdisciplinary in nature, man should be able to gain the knowledge necessary for adapting himself to his environment and for adapting the environment to his need. Fortunately, advances in related scientific and engineering fields have opened up new opportunities for productive study of our environment.

Some of the unsolved problems being attacked by scientists concerned with the environmental sciences programs are those of the physical and chemical properties of the oceans, the details of ocean currents, the circulation of the upper and lower atmosphere, and the actual physical and chemical makeup of the earth itself. Scientists are also seeking to discover the basic mechanisms that generate hurricanes and earthquakes. Others are performing research on the impact of pollutants on the earth's resources.

Recognition of the increased importance placed on the environmental sciences by the Foundation is evidenced by the establishment in fiscal year 1966 of a Division of Environmental Sciences, which includes atmospheric sciences, the solid earth sciences, and oceanography. Also under the jurisdiction of this division are a number of national research programs (see page 45)—U.S. Antarctic Research Program, Weather Modification, and the recently completed International Years of the Quiet Sun, and the International Indian Ocean Expedition.

Illustrative of the range of environmental sciences being supported by the Foundation are the following examples of recent research findings.

Global Atmospheric Circulation

It has long been recognized that continuous meteorological observations over the entire earth are needed for weather prediction purposes. This is true not only because storms tend to move in on the western side of continents from oceanic areas where observations are sparse, but more fundamentally because the large-scale motion of the atmosphere governs many localized phenomena. For example, readjustments of stratospheric wind patterns in the Arctic may influence the position of the jet stream over central United States, and the position of the jet stream is the

Figure 4.—*Scientists prepare to attach solar-powered transmitter to GHOST balloon to be launched from Christchurch, New Zealand. The 6-foot balloons, designed to float at fixed altitudes up to 40,000 feet, are providing the first direct information on the flow of air around the world in the Southern Hemisphere.*

most important determining factor in the large-scale aspects of weather in the lower levels of the atmosphere.

"GHOST" Balloon Project—The Foundation, through its National Center for Atmospheric Research, is supporting a group of scientists who this past year began testing a *G*lobal *HO*rizontal *S*ounding *T*echnique (GHOST) balloon system designed to gather basic meteorological data on a worldwide scale.

The GHOST project represents a joint effort by NCAR, the Environmental Science Services Administration, and the New Zealand Weather Service. It is based on the concept of a fleet of 10,000 or more free-floating balloons, each equipped with weather instruments and a radio transmitter, drifting for months at predetermined levels over all the earth's surface. An operational GHOST system would include at least two relay satellites, which would interrogate each GHOST transmitter in turn and would automatically relay the weather data and the balloon location back to a ground station.

Through the 31st of October 1966, approximately 50 experimental balloon flights have been launched from Christchurch, New Zealand, to test the general concept of using long-lived balloons. Tracking of these flights, which are designed primarily as technological tests of balloon performance, is accomplished by determining position in relation to the sun. Each balloon carries a miniature (about 3 ounces) solar-cell powered transmitter, and a device that measures the sun's elevation. The signals are broadcast continuously and are monitored by several tracking stations in the Southern Hemisphere. Under good radio propagation conditions the signals, which have a power of less than 1 watt, can be heard halfway round the world. The simple electronic system has proven reliable and has provided some important temperature and environmental information that is useful to the design of the more complex system that will be required in an operation system to communicate with a satellite.

These flights have confirmed the possibility of long lifetimes, and hence favorable economic considerations, at the higher levels—40,000 feet. Several balloons stayed aloft for periods of 50 to 100 days. Three balloons have exceeded 100 days—balloon X in its seventh month has achieved over 14 orbits of the earth, and the other two are at 158 and 140 days as of the end of October. Global circuit times range from about 10 days to 15 days.

Computer Model of Atmospheric Flow—NCAR has participated in the development of mathematical models of the general circulation which heve been run successfully on a computer in simulation of large-scale flow patterns. As higher speed computers become available, the models can be extended. In fact, work is now in progress on the development of computers with greatly expanded storage and processing capabilities to cope with the complexity of atmospheric circulation on a global scale.

These various research efforts are expected to be completed at about the same time so that data gathered by the GHOST balloons will be fed into this newer advanced computer, which has been programed with the general circulation model. Success in these activities will provide a method for improving weather prediction over the entire earth.

Origin and Evolution of the Pacific Ocean Basin

How old are the oceans? Have they existed since the early days of earth's history? How have they changed? Are they still changing? These and many more questions perplex geologists and oceanographers today. In their search for the answers to these questions concerning the history of the earth, geologists and oceanographers are now probing the depths of the oceans and are drilling into the islands that break the surface of the seas.

Until recently, most of the answers were sought from the 21 percent of the earth's surface that constitutes land. Earth scientists now realize that many of the secrets of the earth's origin and its subsequent evolution may be discovered in the depths of the oceans or in the seamounts which rise above the ocean floor.

Although clues to the solutions of these problems are being discovered in all of the oceans, during the past year two significant finds were made in the largest of all ocean basins, the Pacific. Seventy-five million years was added to the known age of the Pacific, and new light was thrown on the manner in which the ocean basin has changed through recent geologic time.

Age of the Pacific Ocean Basin—Until recently, the oldest rocks collected from the ocean basins were of late Cretaceous age, about 100 million years old. However, on land the geologic record shows sedimentary rocks at least 2 billion years old. But these rocks, although they are of undoubted marine origin, were deposited in comparatively shallow water, such as that presently covering the continental shelf or under the shallow seas that once covered interior areas of the continents.

Does this mean that the present ocean basins are only about 100 million years old? Were there deep sea basins throughout the history of the earth or were the earlier seas all shallow? These questions may be answered by the continuing search for older sedimentary rocks in the deep oceans.

During the 21st cruise of the *Vema,* scientists from the Lamont Geological Observatory of Columbia University found evidence that pushes the age of the Pacific Ocean back at least to 175 million years.

A core collected from the Shatsky Rise (31°51′ N. 157°20′ E.) between the Emperor Seamount chain and the Japan Trench is of early Cretaceous age, 106 to 110 million years old—the oldest sediment thus far recovered from the ocean basins. By using a seismic profiler (a device similar to an echo sounder that probes for reflecting layers in sediments), it was found that these old sediments, that have been uplifted and exposed at the core locality, dip down and are covered in adjacent basins. Moreover, the profiler records indicate that at least 200 meters (650 feet) of older sediments lie between the lower Cretaceous beds and the harder basement rocks.

Deep-sea sediments of the type found in the core accumulate at a rate of about 0.1 inch per thousand years. At this rate 200 meters represent some 60 to 80 million years of deposits, giving a minimum age of about 175 million years for the Pacific Ocean basin. It may even be much older, for the inferred "basement" may in fact be harder consolidated sedimentary rocks.

This new evidence has important bearing on ideas of the age and origin of ocean basins in general. The relatively thin layers of sediments above the harder basement in the deep seas are only about 0.5 kilometer (1,640 feet) thick in the Pacific, and but slightly thicker in the Atlantic Ocean basin. Assuming that the rate of oceanic sedimentation has held fairly constant, all of this sediment could have accumulated in the last 100 million years. If the Pacific is at least 175 million years old, either the assumptions about rates of sedimentation must be altered or older sediments that may go back much farther into geologic time are buried in the recesses of the deep. The Foundation-supported Deep Ocean Sediment Coring Program may throw light on this question.

Geological History of Midway Atoll—The Hawaiian Islands are part of a northwest-southeast seamount chain extending some 1,600 miles. Volcanic activity is thought to have started at the northwest end and to have progressed southeastward to the island of Hawaii, where is persists today. As lavas erupted to build individual islands, the load of volcanic rock depressed the crust of the earth and the islands slowly subsided. Meanwhile, corals and other reef-building organisms maintained some of the islands as coral atolls.

Midway Atoll, near the northwest end of the Hawaiian chain, is one of the oldest of the Hawaiian group, and preliminary geophysical surveys indicated that it might contain a thicker and older sedimentary record than the younger islands to the southeast.

From August to October 1965 a project to drill through the coral of the atoll and into the underlying volcanics was carried out under the auspices of the Hawaii Institute of Geophysics of the University of Hawaii, supported by the National Science Foundation. Collaborating on the project were the U.S. Geological Survey and the Office of Naval Research. The drilling was planned and directed by H. S. Ladd of the U.S. Geological Survey, with G. P. Woollard and G. A. Macdonald of the University of Hawaii as coinvestigators. Scientists from other institutions also participated.

Chief objective of the drilling was to obtain samples of the coralline limestone and volcanics that would reveal the early history of the Midway Islands and, by inference, the history of other parts of the Hawaiian group. The core samples are still being studied, but the results to date have provided a good outline of Midway's history.

Midway started as a volcanic island in the Tertiary Period, some 30 to 40 million years ago. For several million years this island persisted, its volcanoes spitting forth lava intermittently, much as Mauna Loa and Kilauea do today. During this time, Midway was rimmed by a zone of shallow water in which thrived a great variety of plant and animal life. About 25 million years ago, its volcanic vents long since quiescent, Midway was partly planed off by marine erosion and slowly sank beneath the waves. As the volcanic island subsided, marine plants and animals,

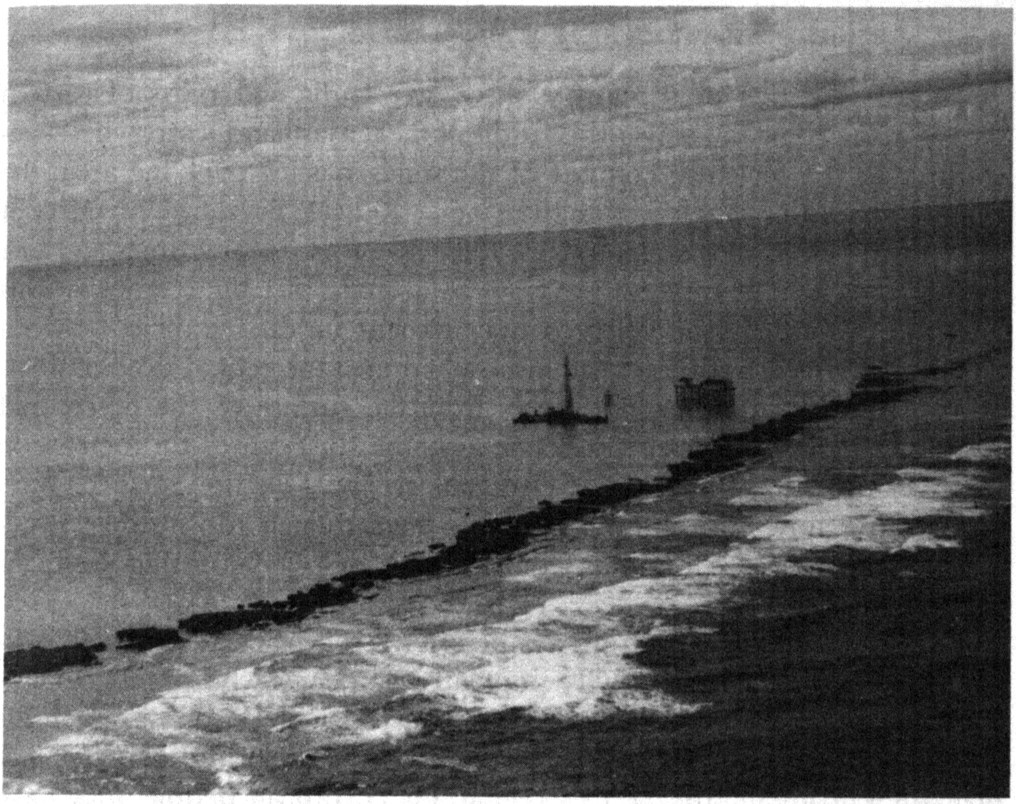

Figure 5.—*Rock cores obtained near Midway Atoll in the Pacific Ocean indicate that the Midway Islands have undergone a complicated history related to volcanic activity, ice ages, biological activity, and marine erosion extending some 30–40 million years into the past.*

notably the corals, were able to build the reef and keep it at or near sea level, until finally about 1,200 feet of reef limestone capped the now submerged lavas.

At some later time, perhaps 5 to 10 million years ago, the island emerged or sea level dropped, and the upper part of the limestone was exposed to leaching and alteration by the atmosphere and fresh waters. The island, standing several hundred feet above sea level, persisted long enough to be inhabited by land snails such as are found today on the higher islands of the Hawaiian chain. After this period, the island was again submerged.

In the Pleistocene glacial epoch (starting about 1 million years ago) the island emerged several times as a result of the worldwide lowerings of sea level during the great glacial eras. Finally, in very recent time (10,000 to 20,000 years ago), the island again sank entirely beneath the sea and the existing reefs were built around the rim of the platform. The relentless attack of the waves reduced dead parts of the reef to a lagoon-filling sand, and storm waves built some of this sand into the two Midway Islands that rise today above the lagoon on the southern part of the atoll.

An investigation of the atmosphere over India and parts of eastern Asia is attempting to answer the riddle of the Rajasthan Desert where, according to the moisture content of the winds passing over the area, the climate should be much wetter than it is. Reid A. Bryson, University of Wisconsin meteorologist, noted in 1962 that dust is sometimes so thick in this area that it reduces visibility to as little as 1 or 2 miles. This quantity of dust, Bryson believes, may account for discrepancies between the known characteristics of the atmosphere and theoretical explanations. It appears that the dust originates from the surface of the desert and is carried aloft by the winds. The airborne dust causes an increase in the cooling rate of the air. The cool air sinks to the surface, thus, suppressing any rain shower activity, even though moisture is available. The desert is maintained then by a self-perpetuating feedback mechanism.

The Rajasthan was not always desert. Archeological evidence indicates it was once rather heavily populated by people who practiced agriculture and kept domestic animals. University of Wisconsin scientists David A. Baerreis and Harvey Nichols are now exploring the possibility that ancient inhabitants of this region, the Harappan people, may have inadevertently created the desert. As the Harappans expanded fields and pasture lands, they may have broken the protective cover of vegetation over a sufficiently wide area to permit winds to pick up enough dust to trigger the desert conditions.

In theory, the present-day monsoon circulation in the area is perpetuated by the curious conditions over the Rajasthan Desert. Changes in the desert conditions should bring rains to the Rajasthan, just as they occur over the rest of India during the monsoon season. A strong possibility exists that broad-scale dust control by surface manipulation in the Rajasthan might once again allow the monsoons to sweep into the desert, reestablishing the area as an arable region.

Since the Rajasthan lies near the Punjab and the Indian State of Uttar Pradesh, an area of enormous population, expansion of the arable land would be of tremendous benefit.

Engineering

In engineering as in other areas, the Foundation supports fundamental research projects. These engineering projects deal with such varied subjects as the separation and purification of chemicals, fluid turbulance, soil mechanics, design of earthquake-resistant structures, metallurgy, energy transfer (e.g., plasmas, lasers, thermoelectrical devices), materials processing, bioengineering, information theory, and operations research. The nature of engineering, however, differs from that of other disciplines in that research engineers commonly deal with the application of scientific knowledge to the solution of technological problems. Indeed, many successful engineering research projects have led to economically feasible results, either in the form of improved existing technology, or through entirely new approaches to the solution of existing problems.

An engineer thus finds that the specific research problems facing him may be microcosms of larger problems of an economic or technological nature facing an industry, society, or the Nation as a whole. Conversely, these larger problems pose many a challenge for research engineers. In the first two projects discussed below, research engineers working with fundamental engineering concepts developed, in each case, technological advances of potentially great economic importance. The third project describes the development of a new machine for simulating earthquakes to permit testing of scaled-down models of building structures for their resistance to earthquakes.

3–D Color Photographs Through Holography

George Stroke and Antoine Labeyrie of the University of Michigan have developed a new technique for reconstructing three-dimensional holographic images with white light instead of a laser beam. Working with Keith Pennington and Lawrence Lin of the Bell Telephone Laboratories, they have produced multicolored 3–D images.

In holography, unlike the ordinary photographic process, the image of an object is not recorded directly on the film. Part of the coherent light from a laser beam illuminates the subject and is reflected onto the front of the film. The other part of the light from the laser beam (the reference beam) is aimed by mirrors directly at the front of the same film, where it interferes with the reflected beam from the subject. An interference pattern resembling a moiré pattern is recorded on the film as disturbances in the photographic emulsion set up by the interfering wavefront.

By reversing the technique, that is, transmitting a laser beam through the film, a visual image can be produced from the film. Just as perspective changes when a person changes his position, the resulting picture can be modified by changing the position of the light source, the film, or the viewer. In other words, a three-dimensional image is produced exhibiting parallax and perspective just as a solid object would.

Stroke has developed a reflection technique differing from the conventional one just described, in that the reference beam strikes the back rather than the front of the film. The subject beam, however, falls on the front of the film. The two sets of waves travel in opposite directions through the photographic emulsion. Thus, standing waves are created and stored in the emulsion along the direction of propagation of the two sets of waves, or perpendicular to the surface of the plate. A series of stratifications are formed in the thick emulsion parallel to the plate's surface, rather than at right angles as in the conventional technique.

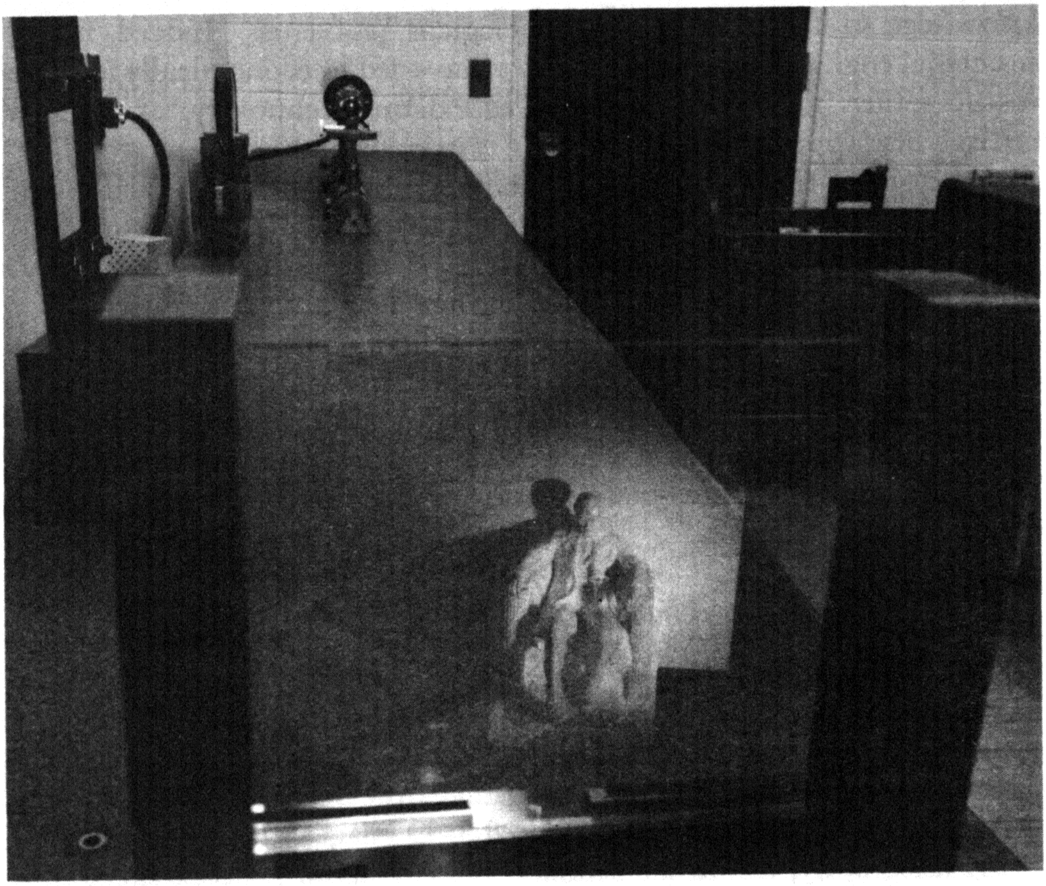

Figure 6.—***Holography is a lensless photographic process that produces three-dimensional images using a laser beam as a source of coherent light. Objects can be seen that would normally be hidden if the viewer were restricted to the single perspective of ordinary photography. Holography has now advanced to the stage where three-dimensional multicolor images can be produced.***

The stratifications act as a color filter similar to the antireflection coating on a camera lens. When ordinary white light illuminates the plate, these stratifications filter all colors other than the one with which the holographic image has recorded.

Teaming up with Keith Pennington and Lawrence Lin, the two researchers from the Bell Telephone Laboratories, Stroke and Labeyrie are using their reflection technique for colored holograms. Two gas lasers—one emitting in the blue and the other in the red—have been used to produce multicolor holograms with white light. In this case, the reference beams from both lasers are made to impinge on the back of the photographic plate, and the same color-filter stratifications are set up in the emulsion.

Further Developments—Another NSF grant awarded this year to Thomas E. Everhart and Steven E. Schwarz at the University of California, Berkeley, is aimed at extending further the uses of holography by developing an electron interferometer which can also be used to produce electron holograms rather than visible light holograms. An electron microscope will be modified to incorporate a coherent electron source and a Mollenstedt biprism. The advantage of this proposed technique is that the image can be magnified by electron optics before it is recorded photographically.

Advances in Technology of Sheet Steel Rolling

More than 20 million tons of cold-rolled, low-carbon, strip steel are produced annually in the United States. Products made from this material range from automobile and refrigerator bodies to barn roofs and food containers. Due to the size and output of steel mills, improvements in the basic process technology are apt to result in multimillion dollar economies. Consequently, any basic improvements in the processing of sheet metal could result in large savings.

The bulk of low-carbon strip is produced in a dead-soft, annealed state to obtain maximum ductility in forming operations. In this condition the steel is inherently prone to form irregular and unsightly surface patterns during stamping, or sharp creases when bent, resulting in rejects and disrupting production. Existing preventive measures for dealing with these defects, known as Luders bands, are costly and often inconsistent in their effect.

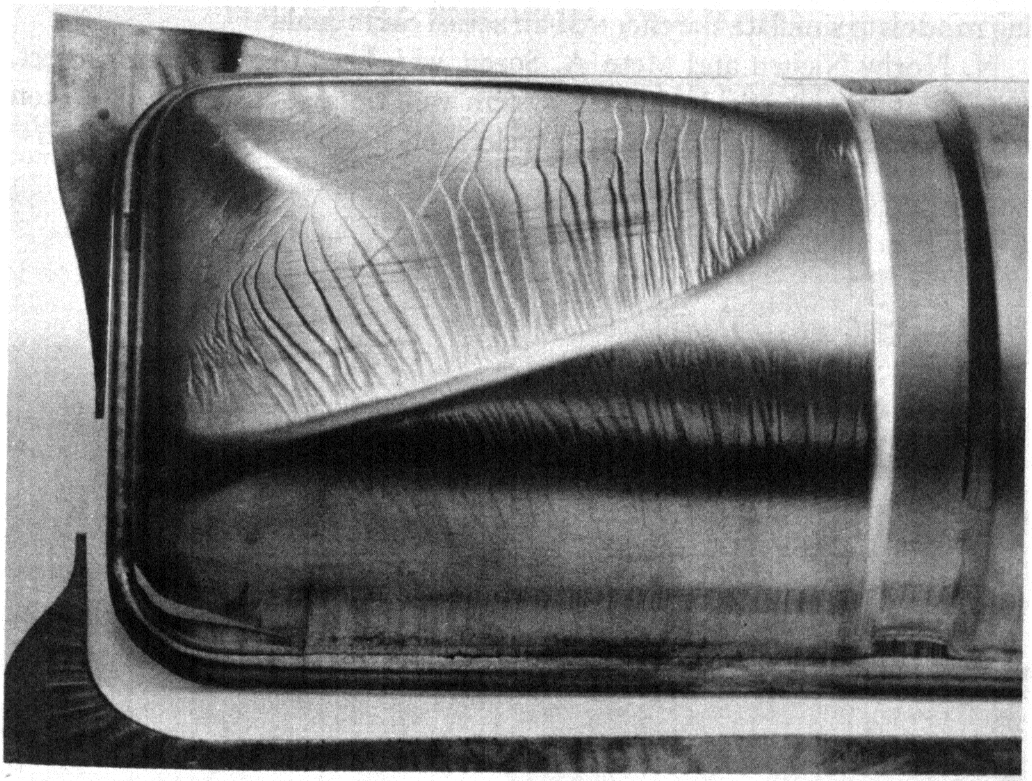

Figure 7.—*Gross strain defects are clearly visible on this pressed automobile part. For years, such defects in rolled metal strip have caused production difficulties and resulted in rejected materials. Under an NSF research grant, an Illinois Institute of Technology engineer has found a method of rolling sheet metal that may eliminate the strain that contributes to such defects.*

In the course of an investigation of mechanical processing of metal strip, N. H. Polakowski, of the Illinois Institute of Technology, explored the effect of tension leveling on the yielding behavior of mild steel. In this process, the strip is pulled along a sinuous path between a series of staggered rollers. Although the strip thus treated develops numerous, light, visible, and equidistant Luders bands running across the sheet, the metal develops no undesirable strains in subsequent forming processes.

From his study, Polakowski concluded and proved that the parallel Luders bands can be refined and their spacing reduced by using leveler rolls of much smaller diameter than now used and, at the same time, increasing the speed of the mill. The resulting Luders bands are nearly invisible.

Among the practical advantages of this technique for reducing the effect of Luders bands is that the appearance of the strip is not affected by roll wear since the surface texture is intrinsically generated in the strip rather than being imprinted on it by the rollers.

Earthquake Simulation Machine

An "earthquake machine" that can be electronically programed to the sequence of an actual quake is nearing completion at the University of Illinois. The machine's fury will be unleashed on scaled-down building models to simulate the effect of an actual earthquake.

N. Norby Nielsen and Mete A. Sozen, who head the research project, state that the electric hydraulic system will be able to move a 10-ton test structure up to 1 inch at an acceleration 3 times gravity and reverse

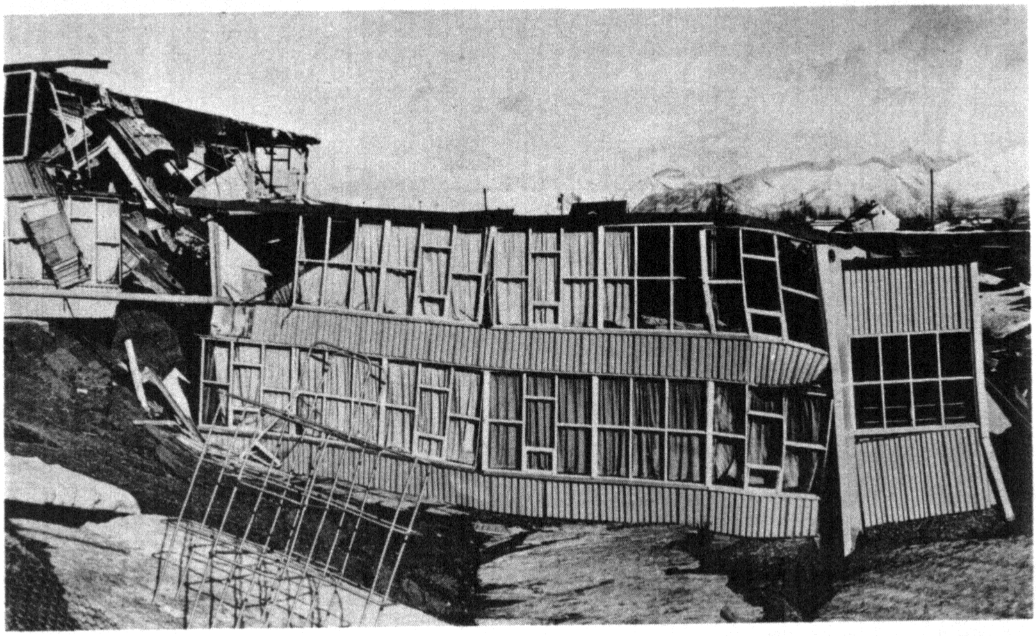

Figure 8.—*An earthquake machine now being completed at the University of Illinois will simulate, on scaled-down buildings, the effect of tremendously destructive forces such as those that destroyed this building during the Alaskan earthquake of 1964.*

the movement within one one-hundred-twentieth of a second, or at an acceleration 7.5 times gravity reversing 60 times a second. Scale models will be on a quake table 12 feet long and 5 feet wide. The machine will also be able to produce steady vibrations at any frequency. This will enable the Illinois engineers to reproduce on a model of a five-story reenforced concrete building tests that have been made on the actual building with vibration machines. Comparing data from the model tests with those from the full-size tests will provide correlation for interpreting results when the model is later subjected to intense artificial earthquake effects.

From the point of view of earthquake engineering research, the occurrence of an actual earthquake can be viewed as a full-scale prooftest of great significance to the engineering profession in promoting public safety and welfare. The Foundation has, therefore, provided support to the National Academy of Engineering to arrange for immediate onsite investigation of damage following destructive earthquakes before rehabilitation and damage clearance have destroyed the evidence. The inspection team project is directed by George Housner of the California Institute of Technology and Nathan Newmark of the University of Illinois.

NATIONAL RESEARCH PROGRAMS

The Foundation is responsible for a number of widely varied research programs of national significance, which ordinarily are so large or so complex as to require coordinated planning and funding on a national basis. In the case of each, NSF has been assigned the management or coordinating responsibility by the President, the Congress, or as a result of agreement within the Executive Branch. As with other NSF activities, most of the funding of national research programs is in the form of grants to colleges and universities.

U.S. Antarctic Research Program

The scientific activities of the United States in Antarctica are funded and organized through the National Science Foundation, with the Department of Defense providing logistic support through the U.S. Naval Support Force, Antarctica. In keeping with Antarctic Treaty principles, the United States maintains a high level of international cooperation through exchanges of personnel, data and publications, joint research programs, and cooperative logistic arrangements with other treaty signatories—Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, South Africa, the United Kingdom, and the U.S.S.R.

Research Stations

The establishment in January 1966 of Plateau Station at a 12,000-foot elevation in the central part of East Antarctica, the major ice sheet of the

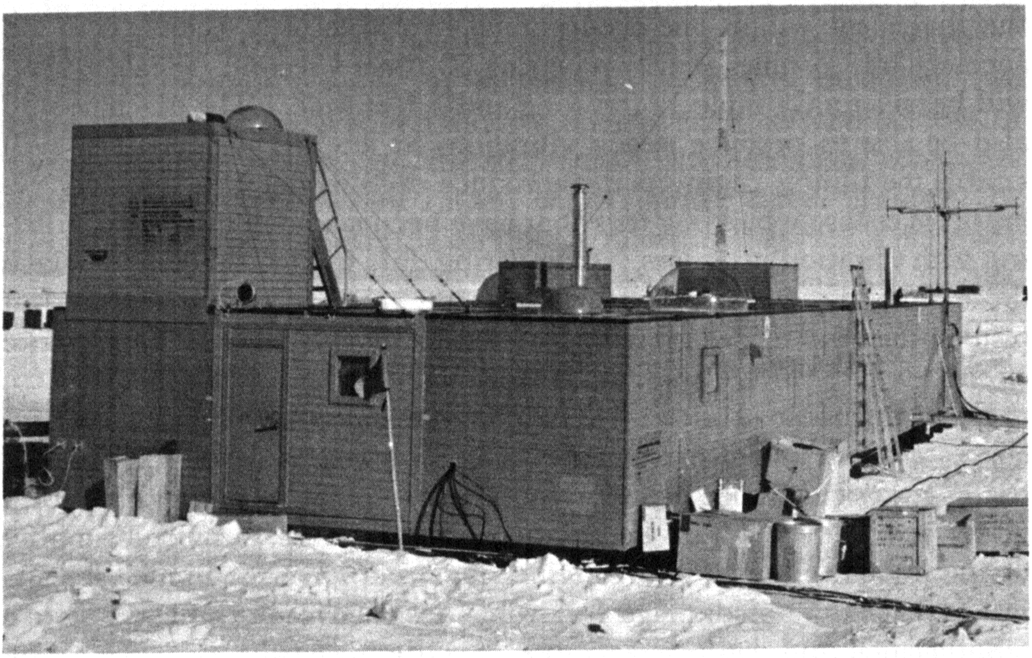

Figure 9.—*Plateau Station, a small eight-man scientific outpost, located high on the continental plateau 630 miles from the South Pole, was established in January 1966. Four U.S. Antarctic Research Program scientists conducted research in upper atmosphere physics at the station during the past year.*

continent, opened an uninvestigated area to scientific research. This small station, probably the most isolated inhabited site in the world, was occupied by four scientists and four support personnel through the past austral winter.

The construction is a major achievement in the design and fabrication of a compact installation. It is of modular construction and was transported by air in preconstructed units. Special programs in meteorology, glaciology, geomagnetism, aurora, and very low frequency propagation will continue until the closing of the station in January 1968.

In West Antarctica, Eights Station was closed in December 1965 after nearly 3 years of continual operation in conjunction with the research activities of the International Years of the Quiet Sun. Byrd, Pole, McMurdo, and Palmer Stations continued as permanent U.S. installations, while Hallett Station was reopened for the summer in cooperation with New Zealand.

Operations on Land

With the support of U.S. Army turbine helicopters, the exploration of the vast Pensacola Mountain system, first discovered by a U.S. Navy reconnaissance flight in 1956, was completed and the area mapped.

This year geologists, geophysicists, biologists, and topographic engineers coordinated their programs in an activity involving at one time 40 persons, about equally divided between scientific investigators and logistic support personnel, at the remote base camp. What may be the largest mass of layered gabbro in the world was located by the geologists. Layered gabbro, which occurs in very few places on the earth, is a valuable source material for studying the processes of emplacement and crystallization of igneous rock. The rock mass is a minimum of 6,600 feet thick, and aeromagnetic profiles indicated that the gabbro body extends over an area of at least 3,000 square miles.

Fossils located in the Pensacola Mountains indicate sedimentary rocks that range in age from Precambrian through Paleozoic. They are among the richest fossil beds yet found in Antarctica.

The 15th major U.S. oversnow traverse, the second of a series of four designed to explore the area between the South Pole and Queen Maud Land, covered 714 miles. Starting at the Pole of Inaccessibility, where

Figure 10.—***Samples from this deep snow pit at Byrd Station, Antarctica, are being analyzed to determine the concentration of common lead precipitated from the atmosphere during the last 60 years.***

last year's traverse terminated, the 11 scientists and engineers with their 3 Sno-Cat vehicles traveled northwest for about 435 miles, then northeast to Plateau Station where the journey ended. Their scientific equipment included a radio sounder to measure ice thickness, used for the first time on the oversnow traverses. They crossed an unexpected under-ice ridge, rising more than 4,000 feet over a horizontal distance of less than 5.5 miles, at the western part of the area, getting its depth profile accurately by the continuous records of the sounder.

Research on the ionosphere, using the 21-mile antenna near the Byrd Station, was enhanced by the construction of a small substation and the installation of a 10-mile antenna at right angles to the original unit. These antennas are presently being used in the 3- to 30-kilocycles-per-second range to investigate the height variation and ion densities of the *D* region of the ionosphere. Signals transmitted to a receiver near Seattle, Wash., will permit analysis of the electron density.

One of the most promising advances for the exploration of the Antarctic ice sheet occurred not in Antarctica but in Greenland. Sponsored by the Foundation, engineers from the U.S. Army Cold Regions Research and Engineering Laboratories completed a drill hole through the 4,500-foot thick Greenland ice cap and penetrated 13 feet into the morainal material beneath the ice. The ice-moraine interface was well below freezing, with a temperature of 9° F. (−13° C.) and in the last 50 feet of ice much dirt material was found.

This achievement, which involved first a thermal drill and finally an electromechanical drill, will greatly advance our knowledge of the mechanism of movement of the vast ice sheets of Greenland and Antarctica. The study of the ice cores obtained should give a continuous record of late Pleistocene climate (about 10,000 years ago).

The drill and accessories are now in Antarctica for a similar program at Byrd Station.

Shipboard Operations

The research vessel *Eltanin* made five cruises during fiscal year 1966, Cruises 19 through 23. Three of the cruises crossed the Pacific Ocean between Chile and New Zealand, one was in the southeastern Pacific Ocean, and one was in the Scotia Sea. In all, 35,795 nautical miles were covered in 284 days at sea. A wide variety of programs, about equally divided between the physical sciences and the biological sciences, was continued on all cruises. The introduction during the past year of paleomagnetic studies of the sediment cores, using known times of paleomagnetic reversals as an absolute age datum, will help significantly in establishing dates of sediment core deposition and rates of sedimentation.

Eight programs were carried out on the *Eastwind* during a 10-week cruise from Marguerite Bay to the South Orkney Islands in the Antarctic Peninsula area. These programs included hydrographic stations and studies of marine fungi, phytoplankton, bacteria, and sea-bottom fauna in the channels and fjords, and ornithological and entomological collections at land sites.

During fiscal year 1966, through an arrangement with the U.S. Maritime Administration, a contract was let for the construction of a 125-foot wooden vessel designed especially for use in the Pensinsula area.

Administration

The bimonthly publication, *Antarctic Journal of the United States,* was issued for the first time in January 1966. It replaces both the *Bulletin of the Antarctic Projects Officer* of the Deparment of Defense and the *Antarctic Report* of the Foundation, and should contribute materially to the dissemination of information on the Antarctic activities of the United States.

During fiscal year 1966, a total of 135 grants and contracts were awarded at a cost of $8.4 million for Antarctic research activities. The number of participants in Antarctic fieldwork, exclusive of the supporting military personnel, was 167 during the summer months and 38 during the winter. The scientific and technical complement on the *Eltanin* was about 38 on each cruise.

Weather Modification

During fiscal year 1966, the science of weather modification assumed an increasingly important role in the national planning for water resources. For example, existing cloud-seeding techniques are considered of sufficient value to make possible the production of increased snowpack in the mountains of the West, which will lead to increased water supplies "downhill." This possibility brings with it, however, the problem of developing an engineering system that will yield enough additional snow to make the effort economically feasible.

Unfortunately, the atmosphere is not always cooperative, and it is necessary carefully to select for seeding those clouds which contain the proper structure and water content to respond gainfully to modification efforts. The proper choice of the clouds to be seeded depends not only on an understanding of the critical factors involved, but also on the ability to quickly and accurately evaluate the suitability of the clouds for seeding as they move into the target area.

This has placed additional emphasis on the need for further basic research to produce the desired knowledge in the shortest possible time.

Special Weather Modification Reports

The urgency for increased activity in the field of weather modification research was highlighted by the publication of two reports during the past year. One was prepared by the National Academy of Sciences'

Panel on Weather and Climate Modification; the other, by the National Science Foundation's Special Commission on Weather Modification.

The NAS Panel report states that "The field of weather modification cannot progress independently of basic understanding leading to more refined predictability of the state of the atmosphere. The immediate scientific and engineering steps toward this composite goal are clear. They amount to a new research and development program for weather and climate modification of a kind and scale very different from that which exists today."

The NSF Special Commission report recognizes the human dimension aspects of weather modification, and explores the social, economic, legal, biological, and international facets of the problem, as well as those of the physical sciences. It concludes that these problems are of great immediate urgency because "weather and climate modification is becoming a reality. The daily activities of man influence the atmosphere in a number of ways, and his ability to induce deliberate changes in measurable magnitude by artificial means is progressing."

New NSF Approaches

In accordance with the national need for increased effort in all aspects of research in weather modification, the Foundation has remained committed to the continuation of a vigorous and expanding role in this field. Indicative of this commitment was the expenditure of almost half of the fiscal year 1966 weather modification allocation of $2 million for new and imaginative approaches to the subject under the guidelines provided by the two authoritative reports. These approaches included the formation of three new university groups for the study of hail suppression, the establishment of a Task Group on Human Dimensions, the initiation of a broad program of research in the basic principles of weather modification by the Rand Corp., the provision of support to a number of commercial weather modification operators to permit them to obtain scientifically useful information from their commercially sponsored operations, and the expansion of university research effort in the electrical aspects of cloud formation and precipitation phenomena.

During September 1965, a working conference on hail suppression was convened at Dillon, Colo., by the National Center for Atmospheric Research under Foundation auspices, to establish the framework for the preparation of a plan for a National Hail Suppression Research Project. This conference was called in accordance with the request to the Foundation for the preparation of such a plan by the Federal Council on Science and Technology's Interdepartmental Committee on Atmospheric Sciences. A steering committee under the chairmanship of Verner Suomi of the University of Wisconsin was charged with the responsibility for preparation of the planning document.

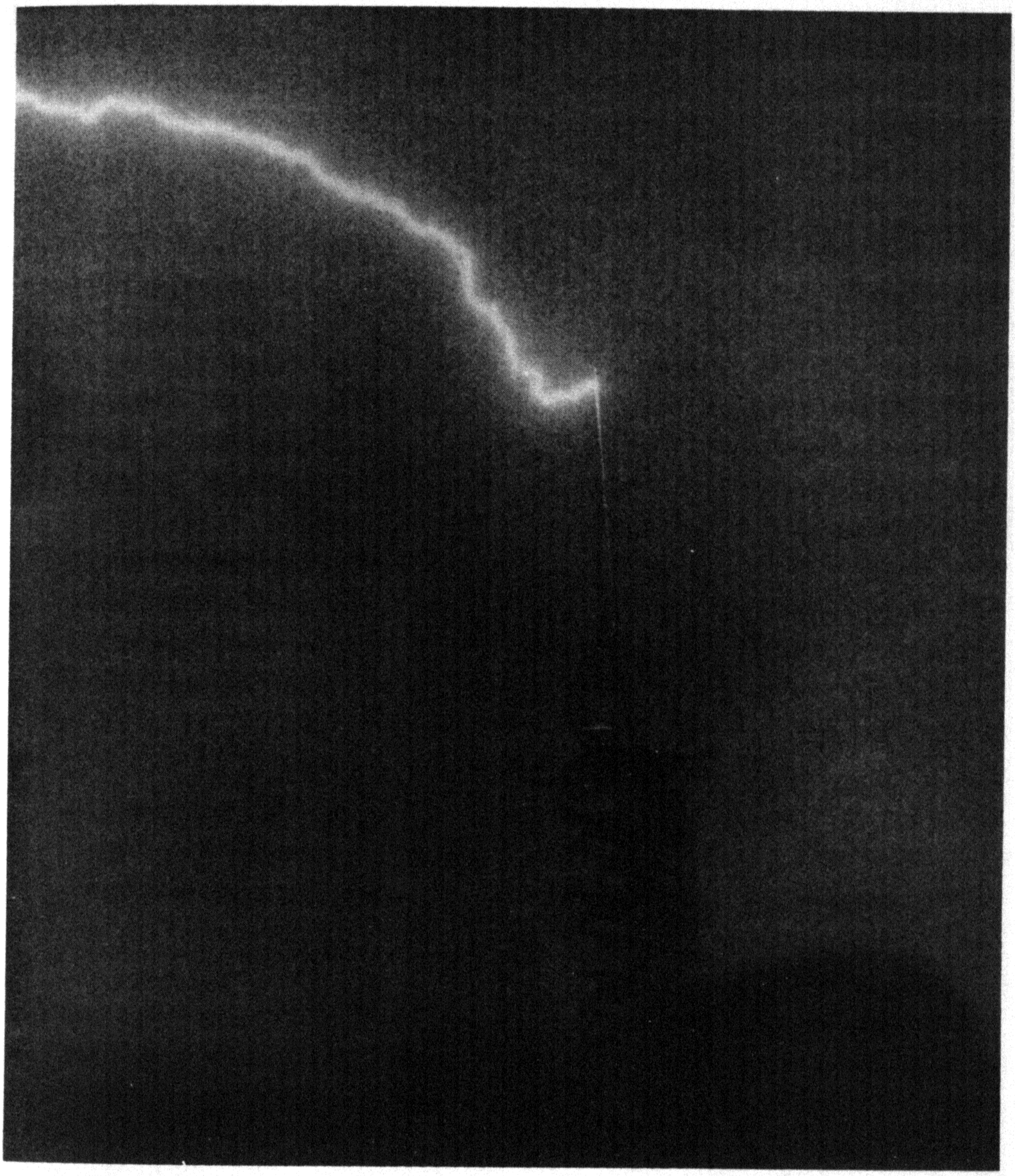

Figure 11.—*University of Arizona scientists record lightning stroke on a tower during a study aimed at reducing the severity of lightning discharges. The investigation includes study of the structure of thunder storms, location of charge centers, and the amount of charge generated.*

As part of this plan, the Dillon Conference sparked the interest of the scientific community in the possibility of a cooperative hail research project during the summer of 1966 in which some 23 separate research teams pooled their facilities and talents to concentrate on the same hailstorms in the Great Plains area. The South Dakota School of Mines and Technology in Rapid City was selected as the host university. Twelve representative hailstorms were studied under Project Hailswath, between June 10 and July 10, 1966, in the area ranging from North Dakota to Colorado. This project was a unique experiment to determine whether a community effort of scientists could be successfully organized and carried to completion. Approximately 12 aircraft and 81 technical and scientific personnel demonstrated the feasibility of assembling a critical mass of manpower and facilities to study a large storm system of considerable complexity and extent.

The National Center for Atmospheric Research, in keeping with its responsibility as a national laboratory, contributed facilities and equipment. These consisted of an aircraft, radar sets, a high-gain antenna, and other items of support equipment. NCAR also made time available for computer analysis of the data obtained. In addition, seven NCAR scientists participated in the field experiments.

Weather Modification Research Accomplishments

Under Project Hailswath, a new technique for the continuous monitoring of ice nuclei from an aircraft and from a roving ground vehicle was tested for the first time, and provided a means for accurately tracing the silver iodide plumes from ground and airborne generators. It was interesting to note that the chimney discharge from a local cement plant provided approximately the same nuclei count as the silver iodide from one of the ground generators.

Project Whitetop of the University of Chicago completed a second successful summer at Bemidji, Minn., by studying the role of ice nuclei in the formation of precipitation from large air mass types of storms in the Minnesota area. It was found that precipitation from these storms was heavily influenced by natural seeding from ice-crystal showers originating in high-level cloud decks above the relatively low-lying stratoform clouds.

Research on the mechanism of nucleation by materials such as silver iodide continues at the University of Arizona, Colorado State University, and Lehigh University. The importance of trace impurities and crystal surface defects in ice nucleation capability is leading to a better understanding of the mechanism of operation of artificial nucleation materials, and may lead eventually to a cheaper and more effective substitute for silver iodide.

The adaptation of mathematical models for studying possible modification techniques of global circulation patterns continues at the University of California at Los Angeles. The hurricane model at New York University shows promise of pointing out possible modification techniques for treating these severe tropical storms, and the tornado model at the University of Oklahoma is providing increased knowledge of the mechanics of tornado formation. Much remains to be learned, but high-speed electronic computers are bringing closer the solutions to such important national weather problems as drought, floods, hurricanes, and tornado control.

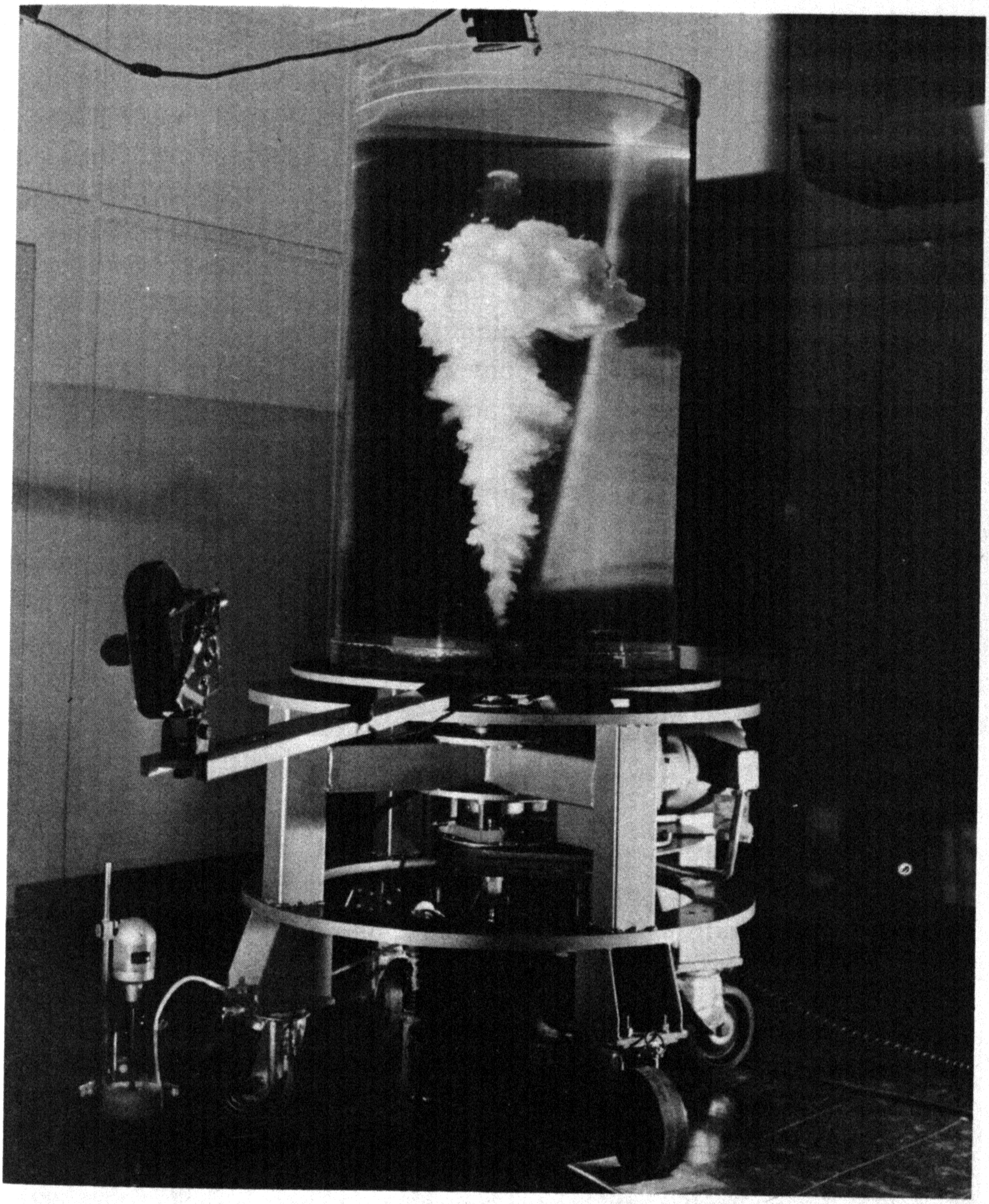

Figure 12.—*This "tornado in a tank" system was developed by University of Oklahoma scientists and is now providing increased knowledge of the mechanics of tornado formation.*

Advance Notice of Field Operations

In accordance with its reporting responsibilities under Public Law 85–510, the Foundation published a regulation, which became effective on January 1, 1966, requiring notification of intent to modify the atmosphere at least 30 days prior to actual field operations, submission of quarterly activity reports, and retention for 5 years of logs of field activity subject to examination upon request. As of June 30, 1966, notification of 92 projects had been filed with the NSF.

United States-Japan Cooperative Science Program

This program, now ending 5 years of operation, has proven to be a successful experiment in binational scientific exchange. Originally designed to foster a closer collaboration in scientific investigations of mutal interest to the two participating nations, the program has succeeded in utilizing talent and special devices developed in both countries to bring about valuable scientific discoveries that are of mutual benefit. In many instances the equipment and techniques so brought together are unique and promise exciting future developments.

Operationally, the program is guided by a joint committee consisting of distinguished scientists from both countries. This group annually reviews and evaluates projects underway, with the aim of determining new areas that are of mutual scientific interest and thus should be investigated cooperatively. The NSF, as the implementing agency for the United States, has benefited from this guidance.

Much of the success of the program lies in the insistence upon shared support; each country funds the activities of its citizens. During the past year there has been some effort to support more U.S. scientists of Japanese ancestry, on a short-term basis, to enable them to work in Japan.

Three types of activities can be identified under the program: cooperative research projects, visits by scientists of one country to the other for research or factfinding in a specific field, and scientific seminars, conferences, and planning meetings. During fiscal year 1966, 310 United States and 335 Japanese scientists participated. Thirty new cooperative research projects were initiated during the year and 28 meetings were sponsored, mostly in Japan.

Broad areas of cooperative work include: exchange of scholars, exchange of scientific and technological information and materials, earth sciences of the Pacific area, atmospheric sciences of the Pacific area, biology of the Pacific area, medical sciences, education in the sciences, hurricanes and typhoon research, and pesticide research.

Perhaps a major result of the program has been the stimulation of greater interest by Americans in Japanese science; historically, Japanese scientists have closely followed progress in American science. A common reaction from an American scientist following visits to Japanese laboratories is one of amazement at the scope of the work and the progress of the Japanese scientists. The realization has come that the United States has as much to gain as the Japanese in a cooperative venture of this type.

During fiscal year 1966, program expenditures for the U.S. portion of this venture totaled $701,700.

Figure 13.—*A University of California scientist, working with Japanese colleagues at Tohoku University, examines specimens in an electron microscope during an investigation of limestone. The study is one of several being conducted under the United States-Japan Cooperative Science Program.*

International Years of the Quiet Sun (IQSY)

The IQSY covered the period from January 1964 to December 1965, and provided for cooperative observations of the sun and its effects upon the earth during the low activity period of the solar storm cycle. It supplemented the observations made during the International Geophysical Year (IGY) from July 1957 to December 1958—a period of high activity in the sun's 11-year cycle.

Since the conclusion of the observational period of IQSY on December 31, 1965, efforts have been devoted to reducing and analyzing the large amount of data collected around the world by individual investigators and made available to all through the World Data Centers. From these studies should come new insights into solar processes and their relationship to the solar and terrestrial atmospheres, and into the interaction between these two atmospheres.

Results of the Program

The academies of science of the participating countries are now preparing for the IQSY Final Assembly to be held in July 1967, when the results of this international interdisciplinary research effort will be presented. Publications of consolidated scientific results will appear in 1968 and 1969 so that the new knowledge of solar effects on the earth's environment will become widely available.

Many discussions of results by individual investigators have already appeared in the journals of research.

During the IQSY, significant new information concerning outbursts of energy from the sun was achieved through the combined use of optical flare patrols, solar radio and radar telescopes, ultraviolet measurements using rockets, and infrared observations from balloons. These measurements have shown that flare activity on the unseen portion of the sun can be detected by observing the reaction in the outer part of the corona not hidden by the solar disc. This technique gives warning of solar flares up to 1 to 2 days ahead of their effect on earth.

The concept that the solar corona exists as an outward-flowing solar atmosphere to well beyond the earth's orbit has been confirmed.

The recent knowledge concerning the characteristics of the "solar wind" and its effect on twisting and distorting the geomagnetic field have come from satellite observations, and from the analysis of audiofrequency waves called "whistlers" generated by lightning impulses. The whistler waves propagate from one hemisphere of the earth, along the geomagnetic field lines to distances up to several earth radii, and then to the other hemisphere at a conjugate point. It is possible, through subtle interpretation of the complex up-and-down frequency change with time characteristics of "whistlers", to learn about the electron density distribution in the space through which the whistler has traveled.

The IQSY program has revealed a new feature of the electron density distribution in the magnetosphere about the earth. A study of very low frequency radio noises disclosed that the electron density distribution through the ion layers is not always uniform. It varies with time and the amount of solar activity. This may be a very significant observation because it is a possible method by which energy is coupled into the atmosphere. This phenomenon was not predicted by theory, and thus a new and more complicated model of the magnetosphere and the plasma must be developed.

Energetic particles emitted from the sun during a flare, with a wide spectrum of energy levels and confined as a moving plasma by electric and magnetic field reactions, have been observed to intersect the geomagnetic field. By comparing the results obtained from the IQSY program with those from the IGY program, it was possible to determine that the number of protons per unit volume emitted by the sun appears to vary by a factor of five between active and quiet sun conditions.

Extensive studies were made of the reaction on the terrestrial magnetic field and the resulting selection and guidance of the particles along the field lines and their precipitation in the earth's atmosphere to form aurora and airglow. Ground-based cameras and television systems were used to obtain the form distribution and spectrum in the optical wavelengths. Radio wave techniques were used to measure electron density. Chemical species formed by the particles and the energy spectrum of the incoming particles were obtained by balloon, rocket, and satellite measurements. By these techniques, significant contributions were made to the knowledge of the specific energy levels of the electrons and protons spiraling in along given magnetic field lines.

It is now known that the aurora and airglow phenomena resulting from the particle bombardment are tied directly to the still mysterious mechanisms by which these particles are injected from the solar wind into the terrestrial magnetic field and atmosphere.

Particle interactions at polar latitudes resulting in blackouts of communication systems were also investigated by a number of methods.

New techniques employing electromagnetic waves interacting in a nonlinear medium, have been used to investigate electron and ion characteristics in the lowest part of the ionosphere. These characteristics are especially important to understanding the interaction between the lower and upper atmosphere.

Because the terrestrial and solar phenomena cannot be measured in the laboratory or even in space without disturbing effects, subtle analytical techniques are required to derive fundamental information from the gamut of solar-terrestrial interactions. This basic research will eventually allow an understanding of solar processes, of conditions of interplanetary space, and of the variations in solar effects on the terrestrial atmosphere that affect man in many ways. A full understanding of these complex interactions is not yet possible, but the IGY–IQSY programs have added greatly to the understanding of many of the fundamental processes involved.

Administration and Funding

The program was supported by more than 60 nations. Overall coordination of this vast program has been through the IQSY Committee of the International Council of Scientific Unions, and in the United States by the U.S. Committee for the IQSY of the Geophysics Research Board of the National Academy of Sciences. The U.S. research effort involved scientists from both the universities and the Federal agencies.

NSF coordinated participation by Federal agencies and provided all special funding. From fiscal year 1963 through fiscal year 1966 the Foundation supported 143 IQSY projects at a total cost of approximately $10 million.

International Indian Ocean Expedition

The international effort to explore scientifically the Indian Ocean, probably the least known of the world's large bodies of water, was completed by the end of 1965. This brought to a conclusion an international effort initiated in 1959, with U.S. participation beginning in late 1960 when scientific responsibility was assigned to the National Academy of Sciences Committee on Oceanography, and the National Science Foundation was directed to plan and coordinate Federal support for U.S. participation.

The United States had 13 ships participating in the program; in all there were 41 vessels from 13 nations, manned by scientists from 28 nations. The U.S. institutions participating extensively in the expedition included Woods Hole Oceanographic Institution, the Universities of Rhode Island, Michigan, and Hawaii, Stanford University, Lamont Geological Observatory (Columbia University), and Scripps Institution of Oceanography (University of California). In addition, scientists from more than 40 other American universities, private research institutions, and government organizations took part in various phases of the program.

The support for U.S. participation derived principally from NSF with some assistance provided by the Navy, the Bureau of Commercial Fisheries, the Weather Bureau, and the Coast and Geodetic Survey. NSF support for the entire period (fiscal years 1961–66) amounted to $15.5 million; the total U.S. effort cost about $20.3 million.

The U.S. scientific programs followed the general outline of aims set forth in the original objectives of the Expedition; namely, (1) geophysical and geological examination of the Indian Ocean basin, (2) chemical and physical description of the waters of the Indian Ocean and their motions, (3) study of plant and animal populations of the ocean, and (4) analysis of the interaction between the ocean and the atmosphere. The meteorological studies included land-based as well as shipboard activities and entailed the use of research aircraft.

Data Collection

Responsibility for collecting and publishing the results of this massive international scientific activity rests with the International Oceanographic Commission. To date, 2 volumes of collected reprints of individual articles have been published containing a total of 129 articles. This, of course, represents only a small portion of the scientific output which is anticipated.

Several atlases—meteorological (United States), physical and chemical (United States), geological (U.S.S.R.), and biological (Germany)— are under preparation. A physiographic diagram has already been published by the Lamont Geological Observatory.

Sorting centers at Cochin, India, and the Smithsonian Institution in Washington, D.C., are processing and identifying vast collections of biological materials taken during the expedition. The Smithsonian Center, for instance, received about 5,400 unsorted samples. To date, about 1,200,000 specimens have been sorted and 375,000 sent for identification and description to about 50 systematic specialists. Those figures include about one-fifth of the plankton and one-fourth of the benthic and midwater trawl specimens.

Expedition Results

Final assessment of the Expedition is still several years off but a number of discoveries and developments have occurred that are worthy of special comment.

Discovery of the East Indian Ocean Ridge—The existence of a major ridge running south from the Bay of Bengal approximately 3,600 miles has been confirmed from echo-sounding records of some 20 ships. It is generally about 8,000 feet in height and has been named the East Indian Ocean Ridge. Records of other ridge systems in the Indian Ocean show their connection with the Mid-Atlantic and East Pacific Ridges, and their topographic features suggest that they were formed by similar processes.

Numerous other bottom features have been delineated in this once little-known ocean, including a series of canyons in sediment drainage planes and what may be the steepest continental slope in the world (more than 45 degrees).

Ocean Currents, Upwellings, and Monsoons—Nearly all participating countries studied the various currents of the Indian Ocean. Of particular interest were data on the subsurface countercurrent and certain areas of upwelling. The equatorial countercurrent was shown to be similar to those in the Atlantic and Pacific, though not as well developed.

Figure 14.—*Scientists and technicians of the Smithsonian Oceanographic Sorting Center process and identify hundreds of thousands of biological specimens taken during the International Indian Ocean Expedition. Later detailed identification and description by specialists will provide new knowledge of life forms in this vast body of water.*

Studies of areas of marked upwelling, particularly off the Arabian and Somaliland coasts, indicate that they are related to the monsoon patterns and that they have a distinct bearing on the biological productivity of the area.

The U.S. vessel *Anton Bruun* reported extraordinary seafood catches in this upwelling area, where previously a Russian vessel had reported a sea of dead fish (the result most likely of an oxygen deficiency in the water). It may be that the monsoon winds in that region are responsible for dramatic cyclic changes in the water composition and, therefore, its biological content.

These same upwelling observations have also clarified longstanding questions concerning the temperatures in the northeast corner of Africa. The typically lower temperatures are now thought to be related to the strong upwelling of deep ocean waters.

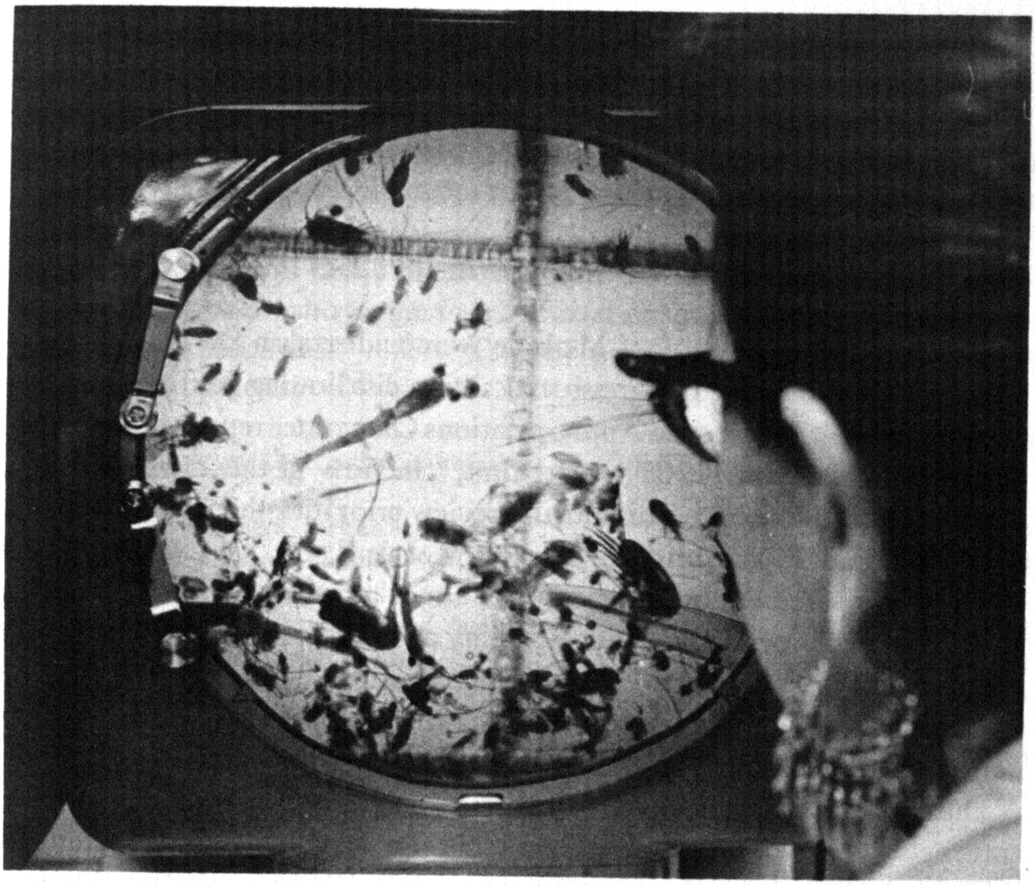

Figure 15.—***Smithsonian Oceanographic Sorting Center technicians identify small sea-dwelling creatures, some of them previously unknown, magnified many times by this instrument.***

Establishment of the Indian National Institute of Oceanography—Discoveries of potential fisheries may eventually assist in the alleviation of food shortages in this overpopulated region of the world. Another more immediately demonstrable benefit of the IIOE to India itself has been the development of centers for environment-related studies and observations out of which has come the establishment of a National Institute of Oceanography. U.S. scientists played a major role in assisting India with these endeavors (notably the Marine Biological Sorting Center at Cochin and the Tropical Meteorology Center at Poona). As a result of the IIOE programs India has taken a long step forward in applying research in the environmental sciences to the solution of economic problems.

Typical of the cooperation received by IIOE participants from local laboratories was the arrangement between the Centre d'Oceanographie et des Pêches at Nossi Be, Madagascar, and the U.S. Program in Biology. Some 28 scientists from the U.S. program utilized the facilities of this installation over a period of 17 months during 1963 and 1964. At the conclusion of the activity, the laboratory was given all the IIOE equipment and supplies in exchange for services received.

In addition to the many direct benefits deriving from the expedition, and the excellent example it set for future cooperative international scientific endeavors, IIOE undoubtedly served to highlight the importance of ocean-related scientific and technological efforts and provided an incentive for expanding worldwide oceanographic research activities.

Deep Crustal Studies of the Earth (Project Mohole)

Steps to terminate Project Mohole were undertaken by NSF in September 1966 following congressional action disallowing further funding of the project. The House Appropriations Committee report on the NSF budget for fiscal year 1967 stated that, "In view of the current world situation and the need to continually review priorities, the committee has not allowed additional funds for Project Mohole."

This unique research program was aimed at penetrating the earth's crust in order to permit scientific scrutiny and analysis of the mantle. It was to involve drilling in the deep ocean basins to a depth of about 35,000 feet below sea level from a stable, dynamically positioned and self-propelled floating platform.

During fiscal year 1966, a number of major system and component contracts were awarded. The largest of these was the subcontract for the drilling platform which was awarded October 6, 1965, to the low bidder, National Steel & Shipbuilding Co. of San Diego, Calif., for approximately $30 million.

At the time the project was discontinued, most of the research and development work had been completed, but construction of the drilling platform and fabrication of certain other equipment were in their very early stages.

A number of signficant contributions in the field of engineering had already resulted from the work completed. These will undoubtedly have a considerable impact on the drilling industry, and on the possible development of stable platforms for heavy work at sea. Among these contributions are the design and model-testing of the unique Mohole drilling platform and of the platform positioning system; the design, fabrication, and testing of a coring turbodrill and the design and fabrication of the prototype of a revolutionary retractable diamond coring bit; the design and fabrication of a deep-ocean untended digital data acquisition system; and the design of a method of sonar hole reentry.

From March 1962, when Project Mohole was initiated, through the end of fiscal year 1966, approximately $54.5 million had been obligated. Of this amount, $19.3 million was expended. It is estimated that an additional $10 to $15 million will be required to close out contracts and properly preserve the technical information developed.

SPECIALIZED UNIVERSITY RESEARCH FACILITIES AND EQUIPMENT

Ever more sophisticated facilities and equipment are required to keep pace with scientific progress. The Foundation provides limited support for the acquisition of specialized facilities and equipment essential for the advancement of basic research.

The table below shows the number and amount of grants in this program during fiscal year 1966. Two of particular interest are then discussed in some detail.

	Number	*Amount*
Biological and medical sciences research facilities and equipment	31	$4,042,396
University atmospheric research facilities	19	799,776
Social science research facilities	7	771,200
University computing facilities	30	8,899,100
Oceanographic research vessels and facilities	7	2,370,718
University nuclear research facilities	23	6,495,768
Chemistry research instruments	45	2,360,003
Engineering research facilities	45	1,175,000
University astronomy research facilities	7	1,362,750
Total	214	$28,276,711

Support for science facilities and equipment is also available through other NSF programs:

1. The University Science Development Program. In fiscal year 1966, about 59 percent of the $36.4 million obligated was for facilities and equipment. (See page 115.)

2. The Graduate Science Facilities Program which allows up to 15 percent of the grants to be used for general-purpose laboratory apparatus. Of the $16.2 million awarded in fiscal year 1966, about $3 million was for laboratory apparatus. (See page 117.)

Alpha Helix—Early in 1966, the Scripps Institution of Oceanography dedicated the *Alpha Helix,* the first U.S. vessel devoted to marine physiological investigations.

Until this vessel was built, scientists who were interested in the study of plants and animals in their natural environment in remote areas of the world were severely handicapped by the lack of adequate research facilities and equipment. Under the direction of Per F. Scholander of Scripps, a plan was developed for a floating laboratory that could be used anywhere. She was to be fully air conditioned to withstand tropical climates, and she was to have a reinforced hull to protect against polar ice floes. She was to be fully equipped with machine tools and the electronic gear necessary for the fabrication of sophisticated apparatus as needed.

A grant from the National Science Foundation made possible the construction of this floating laboratory, the *Alpha Helix.* It took 5 years for the design and construction. The 133-foot ship has a 31-foot beam and weighs 300 gross tons. A controllable-pitch propeller gives her a continuous speed control from zero to a normal cruising speed of 11 to 12 knots. She berths a scientific party of 10 and a crew of 12, 4 of whom may be students to assist the scientific party when the ship is not in transit.

As befits her design criteria, the heart of the ship is in her laboratories. One large main deck area, 24 by 26 feet, houses the analytical laboratory and a "wet" laboratory that can be maintained at any temperature down to 41° F. (5° C.). Below deck is an electrophysiological and optical laboratory with adjacent photographic darkroom. Next to these are a −4° F. (−20° C.) freeze laboratory and a special machine shop, completely equipped.

During this first year of operation, the *Alpha Helix* is located off the northwest coast of Australia in the fabulously rich biological areas of the Great Barrier Reef. During 1967, its second year, an extensive program is planned in the vast basin of the Amazon River. The third year will develop around an expedition to northern latitudes, most likely the Bering Sea region.

Figure 16.—***Designed for marine physiological investigations, the 133-foot floating laboratory,*** **Alpha Helix,** ***was constructed under an NSF Specialized Science Facility grant. The vessel provides seaborne scientists with complete facilities and equipment for studying plants and animals in their natural environment.***

In general, each expedition is subdivided into scientific programs which require field operations of at least 3 months. The scientific parties are flown to and from the ship. As a rule, there will be at least three major programs each year and each program is to be headed by a senior scientist on the ship. Usually the shipboard scientific party can be augmented by an independent shore camp centered around a prefabricated shore laboratory.

Because this vessel is considered a national research facility, an advisory board has been established, composed of distinguished physiologists. This board oversees the entire program. Members include: T. H. Bullock (Chairman), and R. O. Peterson, University of California, San Diego; E. G. Ball, Harvard University; L. R. Blinks, Stanford University; W. O. Fenn, University of Rochester; K. Schmidt-Nielsen, Duke University; and H. B. Steinbach, University of Chicago.

The cost of construction of the *Alpha Helix* was approximately $1,540,000 which included funds for the design, construction, and requirements for instrumentation, outfitting, and equipment. The first year's operational costs amounted to $437,000.

Research Triangle Computer—The modern digital computer, capable of performing automatically a preselected sequence of arithmetic operations, was first developed in the middle 1940's. Since that time the speed, capacity, and general utility of computers has been so increased that by January 1965 the cumulative value of installed computers in the United States was about $7 billion and the annual growth rate was about 25 percent. A corresponding growth in the use of computers for research and education in universities has occurred, and many educators now feel that every college student should have some contact with a computer as a part of his general education.

It may eventually be necessary for universities to spend as much annually for the support of their computer facilities as they do for their libraries. In the case of many institutions, particularly smaller ones which do not have the staff and financial resources to permit them to operate computer facilities of their own, it appears that the institutions can best meet their needs by sharing a single, large, central facility with a group of neighboring institutions. Each institution would have a number of operating stations on its own premises which would be connected to the central facility by public or private communication links.

A very large facility should be able to provide essentially simultaneous service to as many as 200 remote operating stations.

To help explore such possibilities, the Foundation this past year granted $1.5 million in support of the Triangle Universities Computation Center (TUCC). Chartered by the State of North Carolina, TUCC is a consortium of the University of North Carolina, North Carolina State University, and Duke University. The central computer is an IBM system 360/75 capable of storing half a million characters (letters or digits) in

Figure 17.—***A chemical enigneer at Clemson University operates a hybrid computer used in graduate and research programs in chemical engineering. Purchase of the computer was made possible, in part, through an NSF grant for specialized research equipment for engineering.***

its fast memory and up to 400 million characters in its slowest memory. On each of the campuses of the parent universities a smaller system 360/30 has been provided which solves the simpler problems and refers the more difficult ones to the main unit.

Additionally, the North Carolina State Board of Higher Education has initiated a campus orientation project centered about TUCC's facilities. All North Carolina institutions of higher education, through the use of local operating stations connected to the TUCC facility by telephone lines, will be afforded the opportunity to explore the uses of the digital computer in the educational process. These remote terminals will have no computational capability of their own but will operate entirely through TUCC's main facility.

NATIONAL RESEARCH CENTERS

Four "National Research Centers" essential to the basic research effort of the Nation in astronomy and the atmospheric sciences are funded by and under the control and supervision of the Foundation. Such centers are established when the need for large and specialized facilities to serve the entire academic community or for large-scale concerted attacks on special problems create requirements that go beyond those that logically can be met by single academic institutions. The centers are open to all qualified scientists regardless of their institutional affiliations, subject to priorities based on scientific merit and feasibility.

The centers, which are operated under contract by independent, nonprofit corporations composed of universities, are as follows: National Radio Astronomy Observatory (Green Bank, W. Va.), operated by Associated Universities, Inc.; Kitt Peak National Observatory (Tucson, Ariz.), and Cerro Tololo Inter-American Observatory (Chile), both of which are optical astronomy observatories operated by Associated Universities for Research in Astronomy, Inc.; National Center for Atmospheric Research (Boulder, Colo.), operated by the University Corporation for Atmospheric Research, Inc.

The astronomical observatories were established primarily to provide large and costly telescopes and associated equipment for use by the scientific community at large. They are staffed by a limited number of outstanding resident astronomers and by the requisite number of engineers, technicians, and service personnel. The resident astronomers give continuity and cohesiveness to the program, do advance planning for new facilities, etc., as well as contributing to the research itself. However, a majority of the time available on the telescopes is assigned to visiting astronomers and graduate students, the selection being based on the scientific promise of the work that they propose to do.

The National Center for Atmospheric Research (NCAR) serves several important functions. It is a laboratory at which a sizable staff of highly qualified scientists from many disciplines investigate the atmosphere in all of its phases, working especially on problems of a complex nature that require broad, concerted attacks. Significant parts of the work are done by visiting scientists primarily from academic institutions, who thus have opportunity to utilize special equipment or to take part in projects of broader scope than would be possible at their home institutions. NCAR also organizes and coordinates major programs participated in by other institutions, especially universities. In addition to participation in NCAR's own research program, scientists from other institutions are provided special facilities, such as aircraft, a balloon-launching facility, and a large computing center, for the conduct of their own experiments.

NATIONAL RADIO ASTRONOMY OBSERVATORY

The National Radio Astronomy Observatory (NRAO) was established at Green Bank, W. Va., in 1956 to provide large radio telescopes for radio astronomers from all institutions. The NRAO has three sites: Charlottesville, Va., where the headquarters, the computer division, and some administrative offices are located, and where the research staff works when not using the telescopes; Green Bank, W. Va., the main site where the majority of the radio telescopes are located; and Kitt Peak, Ariz., where a 36-foot radio telescope is located at the Kitt Peak National Observatory. NRAO is managed by Associated Universities, Inc. (AUI), under contract with the NSF.

Facilities and Instrumentation

The major NRAO Green Bank facilities include a 300-foot radio telescope movable in a north-south direction, the new 140-foot fully steerable radio telescope which can be used down to a 1-cm. wavelength, two 85-foot radio telescopes operating as a variable baseline interferometer,[1] and a variety of radiometers that operate at wavelengths from 1.5 meters down to 3 millimeters. A 36-foot radio telescope operating at millimeter wavelengths is under construction on Kitt Peak and is expected to be available for visitors in 1967.

Auxiliary technical facilities at Green Bank include machine shops, an electronics division responsible for the design, construction, and maintenance of receivers; a telescope operations division responsible for running and servicing the telescopes; and a small library, photographic, and reproduction section. A larger library and an IBM 360/50 computer are located in Charlottesville.

New radiometers operating at wavelengths between 2 and 21 centimeters were developed during the year; other radiometers operating at 3.5- and 9.5-mm. wavelengths have been completed for use on the 36-foot radio telescope. Detailed design of a 416-channel digital

[1] An interferometer uses wave interference phenomena to increase the resolving power of the combination of telescopes above that of either telescope alone.

auto-correlation receiver for spectral line observation is complete and construction has begun. In addition, NRAO is concentrating effort on producing receivers which will be quickly operational for short, repetitious programs, such as the investigation of lunar occultations (when the moon passes in front of celestial objects) and the fluctuations of the intensity of radio sources as observed over various time intervals. A third 85-foot antenna will shortly be added to the interferometer to provide data at close antenna spacings, and a 42-foot portable antenna is being added to the interferometer system to make possible the acquisition of data at baselines up to 27 miles.

The equipment for a very long baseline interferometer experiment is under construction for use at 610 megacycles per second (a wavelength of 49 centimeters) and operable between any two radio telescopes capable of working at that frequency. Initial operation is expected between the Arecibo 1,000-foot telescope in Puerto Rico and the NRAO 140-foot telescope early in 1967. The effective baseline between these two sites (about 1,500 miles) will be 5.2 million of these wavelengths, making it possible to discriminate between radio sources separated by a few hundredths of a second of arc (a few millionths of a degree).

Very Large Antenna Array (VLA) Project—Development of an engineering plan for the VLA is being undertaken by a group comprised of scientists from the NRAO staff, universities, and industry. The VLA would produce angular resolutions of 3 seconds of arc (about one-thousandth of a degree) in its initial phase.

Largest Feasible Steerable Telescope (LFST) Project—A small engineering group is investigating various design concepts for a large, steerable telescope, of parabolic or equivalent type. A number of these designs are presently available including: (1) a feasibility study of an air-supported floating sphere inside of which the structure of the reflector could be built, (2) a similar concrete shell, floatable on water, (3) a large, fixed-focal-point telescope, and (4) a "homology" telescope whose surface would deform from one paraboloid of revolution into another when the telescope is tilted in elevation angle.

Research Programs

K. I. Kellermann and I. I. K. Pauliny-Toth have made a large number of observations of sources at various times at 2, 6, and 11 cm. with the 140-foot telescope. Significant variations in intensity were found for a number of these sources. The quasi-stellar source 3C 273, which had been increasing at a rate of 10 percent per year as observed at a 2-cm. wavelength, was found to have changed its rate of increase to about 50 percent per year near the end of 1965. Several sources were found to have anomalously high intensities at short wavelengths, while others were found to have maximum radio intensity at longer wave-

Figure 18.—***The Great Nebula in Andromeda, the nearest spiral galaxy to our own Milky Way, as photographed through an optical telescope . . . . .***

lengths in the region between 20 and 60 centimeters. These two scientists confirmed the discovery of radio radiation from the planet Uranus (found earlier by Kellermann in Australia) and observed for the first time radio radiation from Neptune.

The evolution of radio source spectra has been investigated by Kellermann, who has concluded that the observed variety of source spectra can be understood if high velocity electrons are injected in a series of recurring bursts. In a separate study made at the NRAO a visitor, H. Van der Laan, of the University of Western Ontario, has advanced a theory that predicts the evolutionary history of a variable radio source.

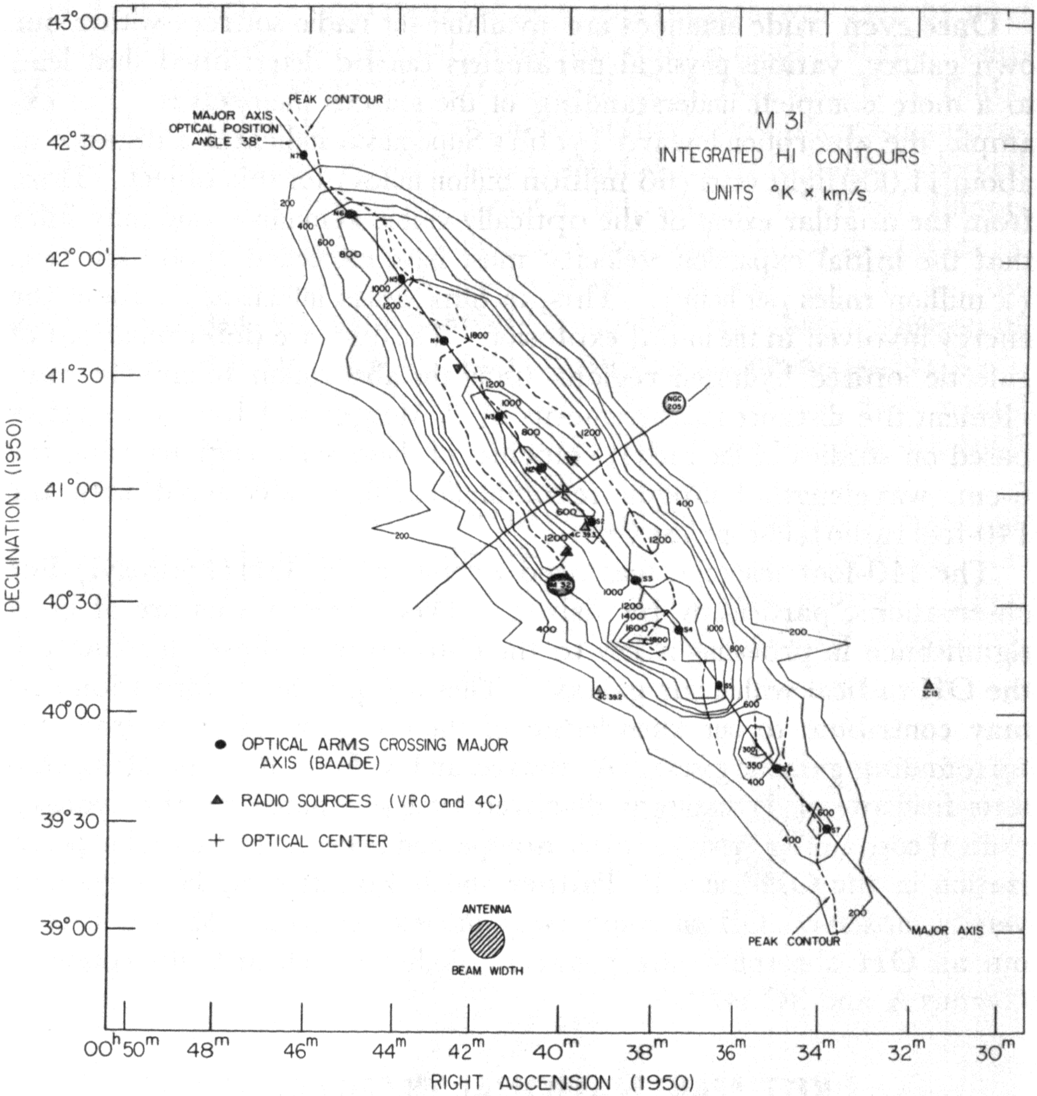

Figure 19.— . . . . ***The same galaxy as resolved by the 300-foot radio telescope at the National Radio Astronomy Observatory. This map shows the amount of neutral hydrogen in the galaxy with the greatest concentration near the center.***

G. Westerhout, University of Maryland, is determining the pattern of the distribution of neutral hydrogen within our own Milky Way Galaxy. This is based on over a million individual observations of the 21-cm. neutral hydrogen wavelength. When completed, this work will be of exceptional value in high resolution studies of spiral arm structure and galactic rotation.

Another hydrogen-line program was pursued by T. K. Menon and D. Williams, University of California, Berkeley, who studied absorption in neutral hydrogen clouds lying in front of discrete radio sources. The amount of absorption is indicative of the mass of absorbing cloud, while the velocity of the cloud often yields distance limits within which the source itself is located.

Once even crude distances are available for radio sources within our own galaxy, various physical parameters can be determined that lead to a more complete understanding of the sources themselves. For example, the absorption toward Tycho's Supernova indicates a distance of about 11,000 light years (66 million billion miles) for this object. Thus, from the angular extent of the optically visible remnants one may infer that the initial expansion velocity must have exceeded 9,000 km./sec. (2 million miles per hour). This, in turn, yields information about the energy involved in the initial explosion. The distance determinations of galectic ionized hydrogen regions using the absorption technique complement the distance measurements by P. Mezger and his collaborators based on studies of the radial velocities of these same regions using the 6-cm. wavelength hydrogen recombination line discovered with the 140-foot radio telescope last year.

The 140-foot telescope was used extensively for OH(hydroxyl) line observations, particularly by visitors. These observations are of great significance in providing a key to the distribution of these elements and the OH radical within our galaxy. They also provide information that may contribute to our knowledge of the evolution of stars from the surrounding galactic gases. A. Barrett and A. E. E. Rogers, Massachusetts Institute of Technology, discovered a line emitted by the hydroxyl radical containing the oxygen-18 isotope, and investigated circular polarization in the OH line. P. Palmer and B. Zuckerman, Harvard University, observed OH emission near discrete sources. Menon carried out an OH absorption line program, finding significant absorption in Cygnus A and 3C 147.1.

KITT PEAK NATIONAL OBSERVATORY

The Kitt Peak National Observatory (KPNO) provides optical astronomers with modern telescopes in a very fine viewing location. The observatory is located 45 miles southwest of Tucson, Ariz., on 6,875-foot-high Kitt Peak. Administrative headquarters are located in Tucson. KPNO is managed for the Foundation by the Association of Universities for Research in Astronomy, Inc. (AURA).

Instrumentation and Associated Research Programs

Stellar Division

The 84-inch reflector is the largest stellar telescope in operation at Kitt Peak. Significant additions to its complement of auxiliary instruments and control apparatus include an efficient new spectrograph with an electronic image-tube system, additional cameras for the large fixed spectrograph, and a new digitally controlled torque motor to drive the main 8-foot worm gear more precisely over a wide range of angular rates.

In its first year of operation, the new spectrograph was used by nine visiting astronomers, six graduate students, and the resident staff. Representative visitors' programs were those of G. A. Dulk and J. A. Eddy, University of Colorado, who investigated Jupiter's atmosphere for aurora-like hydrogen emission which may accompany the radio bursts observed at predictable locations on the planet's disk; and of T. Owen, Illinois Institute of Technology, who found new molecular bands in spectra of Uranus and Neptune. Staff spectrographic research by H. A. Abt included a search for companions of "magnetic" stars, determination of their rotational speeds, a search for companions among 91 sunlike stars, and abundance analyses of magnetic or "peculiar A-type" stars whose atmospheres contain relatively large amounts of common metals, such as iron, magnesium, and calcium, and of rare earths.

C. R. Lynds and his collaborators have continued their development of image-tube techniques, using the 84-inch telescope primarily for the systematic spectroscopic investigations of quasi-stellar sources. They have independently observed a large fraction of the objects for which very large red-shift velocities are now known.

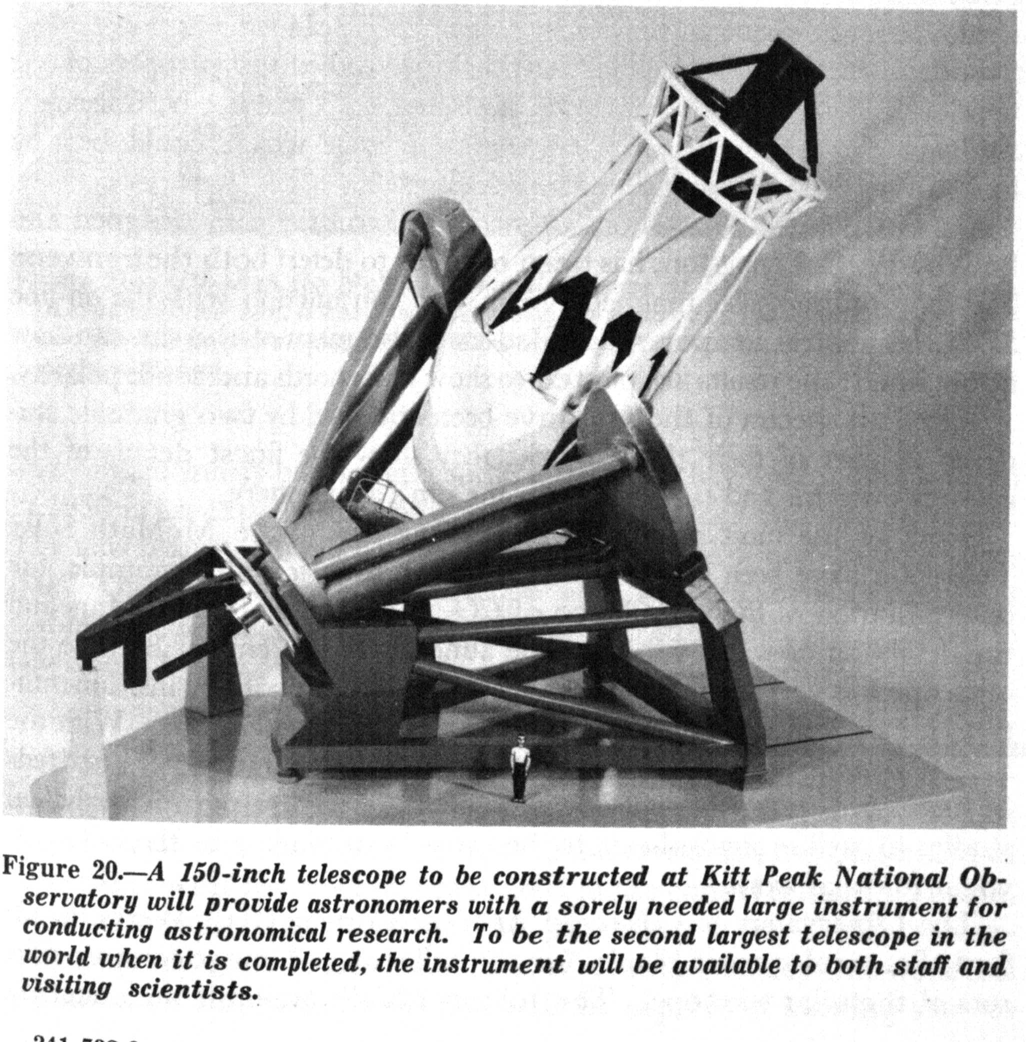

Figure 20.—*A 150-inch telescope to be constructed at Kitt Peak National Observatory will provide astronomers with a sorely needed large instrument for conducting astronomical research. To be the second largest telescope in the world when it is completed, the instrument will be available to both staff and visiting scientists.*

D. L. Crawford and his associates have continued the development of photoelectric measuring instruments for the 84-, 36-, and 16-inch telescopes, with emphasis on multichannel and automatic data readout capabilities. This equipment will be used for basic investigations of stellar ages and composition, and for galactic structure researches.

Work continued on the 150-inch telescope project, under the direction of D. L. Crawford and W. W. Baustian, on a schedule planned to permit use of this instrument by visitors in the spring of 1972. Optical Shop modifications for work on the primary mirror blank were completed at the Tucson headquarters, and the General Electric Co. plant at Cleveland, Ohio, has made satisfactory progress in producing the fused quartz blank. Contracts presently in force will produce final design and specifications of the telescope mounting, building, and dome. Construction should begin in 1967.

Solar Division

The McMath Solar Telescope, the world's largest, has been used on a wide range of problems—solar, planetary, and stellar. Dr. Roddier from Meudon, France, spent a year at the Observatory studying the mean lifetime and velocity of the turbulent elements on the sun's surface. He used a new technique employing a magnetically scanned resonance spectrometer. Other visiting solar astronomers studied the sunspots of the new cycle, which should reach its peak in 2 or 3 years. N. Sheeley is studying those characteristics of the solar cycle which could best be looked for in a search for similar cycles in stars.

An instrument to measure magnetic fields on the sun, designed and built by W. C. Livingston, has been modified to detect both the transverse and longitudinal solar magnetic fields. In conjunction with the on-line SDS 910 control computer, detailed magnetic maps of the sun can now be obtained; the results are plotted to show both north and south polarity.

Excellent spectra of the sun have been obtained by two graduate students as part of their thesis work; they show the finest details of the gaseous currents and turbulence in the sun's atmosphere.

Some of the most exciting and exacting uses of the McMath Solar Telescope have been in the study of planets and stars; for example, the determination of the abundance of CO_2 in the atmosphere of Mars and the detection of water vapor in the atmosphere of Venus. Because the telescope has very high dispersion spectrographs as auxiliary instrumentation, it can provide very detailed spectra of the brighter stars. With the SDS 910 computer used as integrator to store and add together hundreds of successive scans, high-quality records result. These permit analytical studies of stellar atmospheres to be carried out, similar to those long in vogue for solar work.

The Observatory has received from the Corning Glass Works, Bradford, Pa., replacement blanks for the heliostat and image-forming mirrors of the solar telescope. The mirrors initially available are undersize

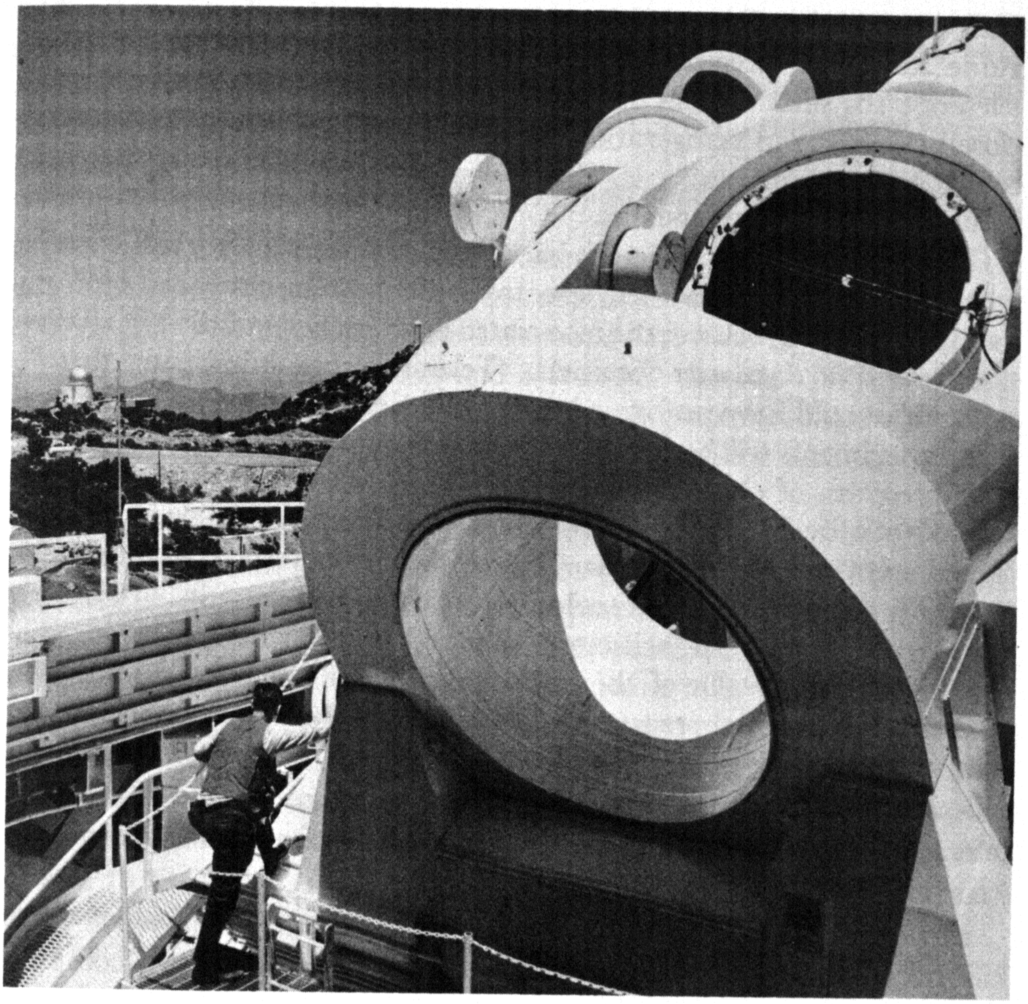

Figure 21.—***Although the McMath Solar Telescope at Kitt Peak is used mainly in studying the sun, it has also been used to determine the abundance of carbon dioxide in the atmosphere of Mars and to detect water vapor in the atmosphere of Venus.***

and contain many bubbles and surface defects; they were manufactured in 1930 in an experimental program for the 200-inch Palomar telescope. The new blanks, 82 and 63 inches in diameter, are of first-quality material. They will provide the telescope with its permanent optics, after completion of the grinding and polishing operations that are expected to take about 1 year.

Space Division

A concentrated effort was made to bring the 50-inch, remotely controlled telescope into test operation for astronomical programs. So far, the telescope, operated by an on-line digital computer, has performed in accordance with test programs generated at the control center in Tucson, 50 miles away. The prototype FM photoelectric star finder successfully acquired stars to the design limit of 8th magnitude, and work has begun on an improved model that will be capable of locating stars to

12th magnitude. Fainter objects can be acquired by offset from brighter guide stars. A three-channel photometer was built and used with the telescope for simultaneous observations of stellar U, B, and V colors. A closed-cycle Freon refrigeration system for cooling the photomultiplier cells has been built, and a 10-channel grating photometer and spectrum scanner is under development.

The Observatory's Space Division launched Aerobee rockets carrying astronomical telescopes with spectroscopic instrumentation. Unfortunately, either the rocket or the associated pointing system failed in all three flights, and no data were obtained. Telemetry records indicated that the payloads would have performed as intended, if the rockets had permitted. The experiments will be flown again as soon as possible.

A program of observations of the planets Mars and Venus has been carried out by M. J. S. Belton and D. M. Hunten. Spectra were obtained with the McMath Solar Telescope and its vertical vacuum spectrograph by means of a photoelectric scanning attachment. Data were recorded in a way that facilitated later processing in the computer. The first result was a value of the carbon dioxide abundance on Mars, corresponding to partial pressure of 5 millibars, or $\frac{1}{5000}$ that of the Earth's atmosphere. This number can be combined with other measurements to give a value for the total atmospheric pressure of around 6 millibars, which agrees closely with the results obtained from the Mariner IV spacecraft.

More recently, the presence of water vapor in the atmosphere of Venus has been confirmed. Full use was made of the telescope's computer to correct for the contaminating light from the day sky and for the strong absorption lines due to the Earth's atmosphere.

The Space Division also carries out on Kitt Peak a program of observations of the twilight airglow, both for its own interest and for the possible bearing on the atmospheres of other planets. A. L. Broadfoot has studied the light scattered by N_2^+ ions, of special interest because nitrogen cannot be detected by absorption spectra of planets. He has also found sporadic emission from calcium ions; this observation appears to provide a new and very sensitive method of observing meteor trails.

The space astronomy effort is supported by a considerable program of theoretical studies. M. B. McElroy and J. W. Chamberlain have conducted a radiative transfer analysis of a planetary atmosphere whose properties vary with depth. Also, they have studied the thermal structure of the Martian upper atmosphere, and have tried to reconcile their results with the data provided by Mariner IV. J. C. Brandt and M. J. Belton have published a catalog of comet-tail orientations to derive data concerning the solar wind, which is a continuous but varying stream of particles emitted by the sun. The result of this study indicates that the solar wind does indeed control the orientations of certain comet tails.

R. Goody, a visiting scientist from Harvard University, worked with Belton on the problem of the implications of a large carbon dioxide content in the structure and circulation of the Martian atmosphere.

Visitors, Students, and Staff

During this fiscal year, 41 visiting astronomers, including 4 from outside the United States, and 16 graduate students made use of the stellar telescopes. The McMath Solar Telescope was used by 16 visitors, of whom 5 were graduate students and 3 foreign scientists. The resources of the Space Division were used by five visiting scientists, including one for whom an Aerobee rocket system was provided and a payload integrated.

In addition to receiving advanced graduate students who use telescope observing time to obtain material for Ph. D. theses, the Observatory has conducted each summer during the past 5 years a summer research assistant program. These assistants are primarily first- and second-year carefully selected graduate students who work with the resident staff. These students and staff members have found the experience to be mutually beneficial. The students gain experience in actual research work, both observational and theoretical, and the staff gets stimulating help in their programs and acquaintance with the most promising young persons in the field. In the 5 years of operation of this program, 44 students from 26 universities participated, 16 this past summer.

As of June 30, 1966, the Observatory staff consisted of 227 full-time employees, of whom 46 were scientists or engineers.

CERRO TOLOLO INTER-AMERICAN OBSERVATORY

The Cerro Tololo Inter-American Observatory is located on a 7,200-foot mountain in the foothills of the Andes Mountains about 300 miles north of Santiago, Chile. The administrative headquarters building is in the coastal city of La Serena, about 60 miles from the telescopes. The creation of this Observatory, which may be considered as a southern counterpart of KPNO, grew out of the desire of astronomers to observe the southern part of the heavens which is inaccessible from northern latitudes. Here are found some of the most interesting celestial objects, such as the Magellanic Clouds (the nearest external galaxies) and some of the largest and nearest star clusters. Also, the center of our own galaxy, the Milky Way, passes nearly overhead at the latitude of Cerro Tololo, 30° S.

The three telescopes of apertures from 60 to 74 inches heretofore available in the Southern Hemisphere are not modern instruments, not located in astronomically favorable climates, and not regularly available to U.S. astronomers. To rectify this condition, a 3-year survey was conducted in Chile with the cooperation of the Chilean Government to

Figure 22.—*Cerro Tololo Inter-American Observatory, located on a 7,200-foot mountain in the Andes in Chile, enables astronomers to study the southern heavens inaccessible to observatories in northern latitudes. New telescopes planned for Cerro Tololo will permit scientists to study such objects as the center of our Milky Way galaxy and the nearest outside galaxies.*

find a site for a new observatory. Cerro Tololo was selected and construction began in 1963. At present, two 16-inch telescopes are in full operation with most of the observing time being used by visiting astronomers.

During the fiscal year 1966, the construction of the most important permanent buildings on Tololo began; by the end of the year the buildings for the 36- and 60-inch telescopes were completed except for their rotating domes. The water and power distribution systems were finished, and preparation of the sites for workers' cottages, dining hall-dormitory, and administration-office buildings was well underway. Road repair was required during the year because of unprecendented storms that devastated many areas of north-central Chile in August 1965.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

The National Center for Atmospheric Research (NCAR) was created by the Foundation in 1960 as part of an increased national research effort in the atmospheric sciences. The ultimate goal of this effort is to achieve a detailed understanding of the large-scale behavior of the earth's atmosphere. Such understanding will make possible increased accuracy and leadtime for weather prediction and will also provide a sound foundation for assessing the potential of weather and climate modification.

NCAR is operated, under contract with the National Science Foundation, by the nonprofit University Corp. for Atmospheric Research (UCAR), representing 23 universities with graduate programs in the atmospheric sciences.

Research Programs

Research programs at NCAR are centered in the Laboratory of Atmospheric Sciences (LAS) and the High Altitude Observatory (HAO).

Laboratory of Atmospheric Sciences

The LAS program emphasizes three main overlapping areas of research: the general circulation and motions of the atmosphere; the life cycles of trace gases and aerosols in the atmosphere; and the physics of clouds and precipitation, including the dynamics of cumulus convection and studies of turbulence. Highlights of the year's activities include:

1. A cooperative study of the chemistry of the tropical atmosphere currently underway with the U.S. Army Tropic Test Center in Panama. Preliminary results of field studies indicate that a number of preconceptions about the sources and amounts of trace chemicals in the tropical atmosphere were in error and will have to be revised.

2. Studies of freezing nuclei, which play an important role in the formation of precipitation from supercooled clouds. Progress was made in identifying natural source areas, and laboratory studies of a wide range of organic substances have clarified their roles as freezing nuclei.

3. The acquisition of detailed information on the composition and distribution of gases and aerosols in the troposphere and the lower stratosphere, through the use of aircraft and balloons.

4. An investigation of the scattering of solar ultraviolet and visible radiation in a nonhomogeneous atmosphere (one which includes dust and other pollutants), taking secondary scattering and absorption into account—a major theoretical problem that has been attacked with some success. This study is important because radiation scattering affects the energy balance of the atmosphere and the portion of the solar radiation that reaches the surface of the earth. NCAR tables of scattered ultraviolet radiation in the ozone absorption bands at selected levels were published in 1966 as an American Meteorological Society Monograph.

5. Field testing of the dropsonde, a recording instrument which is dropped through thunderstorms from aircraft to determine motions within the storms.

6. Laboratory studies on radio emission by droplets colliding in an electric field which have led to a quantitative estimate of the radio emis-

sion spectrum under a given set of conditions in a cloud. This work has implications for the use of radio techniques for studying terrestrial cloud processes and may inspire a new examination of the microwave emission from cloud-covered Venus.

High Altitude Observatory

The HAO program is concerned with the sun, the solar atmosphere, and the region between the sun and the earth. Accomplishments during fiscal year 1966 include:

1. Analysis of the combined results of three sets of solar measurements made by (*a*) a NASA aircraft over the Pacific during the eclipse of May 30, 1965; (*b*) the HAO balloon-borne Coronascope II on flights made June 3 and July 1, 1965; and (*c*) the HAO K-coronameter in daily observations in Hawaii. This analysis has enabled HAO to define the shape of a coronal streamer from the sun and to determine the velocity and distribution of electrons in the streamer. Thus, it is now possible to determine the distance from the sun to which the solar magnetic field governs streamer shape and the point at which the electrons break free of the sun's magnetic field.
2. A survey of the magnetic fields in 50 solar prominences, using the new magnetograph at Climax, Colo. As a result, the range of fields that can occur in prominences has been determined, as well as the manner in which the geometry of the field related to the geometry of the prominence.
3. A detailed analysis of the earth's magnetic field variations which showed that ionospheric currents change in phase with the solar cycle. However, the currents were larger than could be accounted for solely on the basis of increased solar activity as reflected in increased conductivity of the ionosphere. The hypothesis that solar activity also affects the winds of the ionosphere is being subjected to continuing investigation.

Facilities

The NCAR Facilities Laboratory operates facilities in ballooning, aviation, computing, and field observing, which include sites, equipment, and technical staffs to assist visiting scientists. The plans and performance of each facility are reviewed by an advisory panel, which includes non-NCAR scientists, to assure its continuing response to the developing needs of the entire scientific community.

Scientific Ballooning Facility

During the year the Scientific Ballooning Facility successfully tested a *G*lobal *HO*rizontal *S*ounding *T*echnique (GHOST) balloon system in the Southern Hemisphere. These continuing tests represent a significant step in the developments of a global system for collecting meteorological data from several levels of the earth's atmosphere. These data are gathered by superpressure constant-volume balloons that float at predetermined densities in the atmosphere. They do not float at a constant altitude because the density varies with the temperature. Each balloon carries a very lightweight package consisting of a solar navigation sensor, solar cell power source, coder circuitry, transmitter, and other sensors. (For further discussion of the GHOST project see page 35.)

The crew of the NCAR Scientific Balloon Flight Station, at Palestine, Tex., launched approximately 90 balloon flights from Palestine and from the Naval Air Facility, Litchfield Park, Ariz., during the year.

Research Aviation Facility

The Research Aviation Facility now operates three Beechcraft Queen Airs. The third plane was leased in May 1966, to accommodate increasing requirements for research support. During the fiscal year, 305 flights were made in support of 12 NCAR and 9 university research projects in such fields as air motions, cloud physics, atmospheric radiation, and trace gas and aerosol studies. The facility also conducted sensor and research equipment development programs.

A summer work-study program designed to acquaint graduate students with the capabilities and limitations of aircraft as tools in atmospheric research, was established in the Research Aviation Facility in June 1966, with eight students from seven universities in attendance.

Other Facilities

The Computing Facility acquired a Control Data Corp. 6600 system early in January. The 6600 was formally accepted in May and is presently operating 21 hours a day, 7 days a week. The Field Observing Facility supports research projects which require special observations not available through the regular synoptic networks.

Program on Applications Analysis

A new Program on Applications Analysis was established during the year to help bring the results of basic research in the atmospheric sciences to bear on certain practical problems. The applications group is sponsoring a study of human factors in weather modification, and is also investigating the astronomical "seeing" problem.

National and International Programs

In addition to conducting its own research programs and supporting university research projects, NCAR participates in a number of atmospheric research efforts conducted by Government agencies, university scientists, and other research groups on a national or international scale. Two of these efforts that will continue to absorb much of NCAR's energies and resources are weather modification research and large-scale meteorological experiments.

National Effort in Weather Modification

The national effort will involve rapidly increasing activity, by NCAR as well as by Government and independent research groups, during the next few years. Many of NCAR's basic research programs, particularly those in the physics of clouds and precipitation, concern atmospheric processes which must be understood in greater detail before the weather can be deliberately modified on a systematic and predictable basis. NCAR's work in computer simulation of general circulation is also relevant to weather modification, as is any other effort to improve man's ability to predict atmospheric behavior. The evaluation of the results of weather modification experiments is difficult without knowing with reasonable certainty what would have happened if no attempt at modification had been made.

NCAR is also interested in the effects of inadvertent atmospheric modification, resulting from human activities, which can seriously affect weather and climate. Examples of such inadvertent modification include the triggering of cirrus cloud formation by jet aircraft contrails and the alteration of the radiative balance by the "greenhouse effect" of large quantities of carbon dioxide produced by the combustion of fossil fuels.

NCAR's participation in national programs concerned with deliberate weather modification during 1966 included:

1. Furnishing equipment and technical assistance to contractors of the Bureau of Reclamation in field research and pilot cloud-seeding operations in the Colorado Rockies.

2. Cosponsoring with the National Science Foundation, a national conference on hail modification at Dillon, Colo., held in the fall of 1965. (For further details see page 50.)

3. Establishing the Program on Applications Analysis (PAA) in the Facilities Laboratory. One task of this group will be to undertake analyses of potential weather modification techniques and the problems that will be involved. Such analyses will usually be done at the request, and with the support, of the agency which is interested in applying the techniques.

Large-Scale Meteorological Experiments

Now in progress or in the planning stage are large-scale meteorological experiments which should culminate in a Global Atmospheric Research Project (GARP) around 1972. GARP will be an international undertaking comparable to the International Geophysical Year.

In addition to the Southern Hemisphere GHOST experiment, NCAR's contributions to large-scale meteorological research included acting as host, in May 1966, to a planning meeting for an experiment known as TROMEX (Tropical Meteorological Experiment). Although planning for TROMEX is still in the preliminary stages, it is envisioned as an intensive observing program to obtain much needed knowledge about tropical meteorology. The tropics are the regions where the energy falling on the earth in the form of sunlight is transferred to the atmosphere; the processes responsible for this are fundamental to the whole terrestrial heat balance. TROMEX planners include scientists from NCAR, Environmental Science Services Administration, NSF, the Department of Defense, and the universities.

Other NCAR efforts which eventually will contribute to large-scale meteorological experiments are development of a realistic mathematical model of the general circulation and specification of requirements for a supercomputer to handle global atmospheric data. NCAR is one of many groups, including ESSA, the Massachusetts Institute of Technology, the University of California at Los Angeles, and the Lawrence Radiation Laboratory of the University of California, which are working on these or closely related efforts.

Visitors, Students, and Staff

The Advanced Study Program (ASP) promotes and fosters the broad view of the atmospheric sciences essential to the solution of many basic problems, and helps define specific problems that are of first priority urgency for the general progress of the atmospheric sciences.

Starting in late spring of 1966, ASP conducted a 6-week colloquium on certain aspects of thermal convection as it relates to problems of heat transfer in various atmospheres. This topic is highly relevant to many problems of tropical meteorology.

The UCAR Fellowship Program, administered by ASP, is in its third year. The fellowships provide for a year of graduate study at any university that offers the doctoral degree in atmospheric sciences or in any closely related fundamental discipline, and include summer research appointments at NCAR. Two graduate students were selected in fiscal year 1966 to participate in this program.

Five 1-year postdoctoral appointments at NCAR were awarded for the academic year. The postdoctoral program provides a thorough exposure to various problems in the atmospheric sciences. This program is open to recent graduates as well as to teachers in liberal arts colleges.

During fiscal year 1965, NCAR began an affiliate professorship program which allows members of the NCAR research staff to establish formal ties with universities to visit, teach, and take part in other academic activities. Six NCAR scientists accepted affiliate professorships during fiscal year 1966.

Calculated on a full-time equivalent basis, and including visitors at NCAR for 4 months or more, the NCAR staff reached 418 at the end of June 1966, including 86 at the Ph. D. level. In addition, some 300 scientists, from colleges, universities, and private or government laboratories in the United States and abroad, visited NCAR during the year (some briefly and some for extended periods) to discuss scientific problems with the NCAR staff and with each other, and to pursue research projects on their own or within NCAR research programs.

NCAR, formerly housed in buildings leased from the University of Colorado, moved into its permanent laboratories in the fall of 1966.

SCIENCE EDUCATION

The continuing viability of the scientific enterprise depends upon an ever-increasing supply of well-trained people—the scientists, technicians, and teachers of the future. This, in turn, is dependent upon high-quality instruction provided at academic institutions.

In determining specific aims for science education improvement, the Foundation, with the advice of scientists from universities, colleges, and research establishments, has set up important goals centered around clearly identified needs. The goals have been modified as other educational needs have emerged. In a few instances the goals have been broadened in scope, while in others the support effort for particular goals has been shifted to accommodate new or expanded activities or to discontinue activities that have fulfilled their purpose.

Primary goals of science education programs are to—

- Further the scientific training of high-quality graduate students and scientists.
- Improve the subject-matter competence of teachers of science, mathematics, or engineering at all academic levels.
- Provide modern materials of instruction and courses of study.
- Increase the scientific knowledge and experience of talented high school students and undergraduate college students.
- Improve science instruction at the undergraduate level by assisting institutions in acquiring modern instructional scientific equipment.
- Improve the American public's understanding of science.

Foundation support for education in the sciences was originally restricted to the graduate level through the award of fellowships to high-ability graduate students and advanced scholars. From 1952 to the end of fiscal year 1966, the Foundation invested more than $210 million in such fellowships and traineeships. This represents a total of 42,850 fellowship awards offered to the most highly qualified individuals identified from among 151,625 applicants, and 8,197 traineeships for award by the 193 institutions receiving grants.

It was early recognized, however, that the techniques the Foundation had been using to support research at the frontiers of knowledge and the education of students at the graduate level were not adequately strengthening the base of science education, and the Foundation accordingly sought new approaches to more comprehensive support for science education. It was determined that the greatest contribution could be made in this connection by supporting those efforts where creative scientists could improve and stimulate science education at all levels. The cardinal plan adopted by the Foundation envisaged placing support at those points which would have the greatest influence on the system as a whole. Instead, therefore, of channeling support below the graduate level to the direct science education process, early emphasis was placed on such efforts as updating and increasing the subject-matter competence of teachers and making modern instructional equipment available.

To provide sorely needed supplementary teacher training in the sciences and mathematics, the Foundation has supported teacher institutes since 1953. Such institutes are organized and conducted by the colleges and universities with Foundation support. In 1966, some 21,000 high school teachers of science and mathematics attended summer institutes devoted to their respective fields; some 1,600 teachers were enrolled in full-time institutes covering the entire academic year, and 13,000 more attended in-service institutes while continuing to teach in their schools.

Improvement of courses of study in science and mathematics and of the devices required to teach such courses effectively represents a major Foundation educational effort. Its success lies primarily in the involvement of experts in science and mathematics subject matter working cooperatively with expert teachers. Such groups have developed high quality courses, textbooks, and other teaching materials, from the viewpoint of both subject matter and methodology of teaching, that could not have been produced or tested by individuals working alone.

Large-scale projects concerned with physics, mathematics, chemistry, and biology courses for secondary school students have contributed significantly to modernized science instruction in the Nation's classrooms.

Approximately 1,200,000 students, representing almost every State, are now using biology courses developed by the Biological Sciences Curriculum Study. An estimated 410,000 students are using chemistry courses developed by either the Chemical Bond Approach Project or Chemical Education Material Study. The commercial version of the high school physics text developed by the Physical Science Study Committee, published in 1960, is now estimated to have been used by 230,000 high school students.

Major emphasis of Foundation support for education below the graduate level was directed primarily at precollege education, in part, because the inadequacies were felt to be greatest there and the need for immediate remedial action was strongly evident.

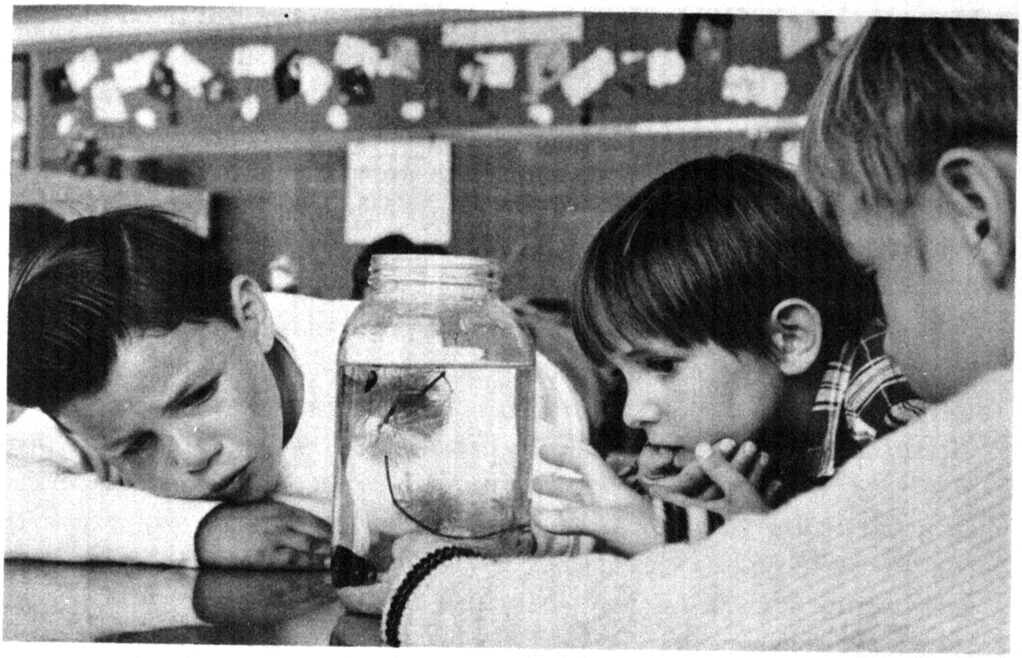

Figure 23.—***The mystery of green growing things captures the interest of children . . . . With the support of the NSF, the Elementary Science Study seeks to improve science course content.***

In considerable measure the somewhat more recent programs of support for undergraduate education have been of a similar nature. Curriculum studies and institutes for college teachers have been important components, and to these have been added fellowships for college teachers, programs of visiting scientists, etc. NSF has supported many of these programs through professional societies, some of which have set up special commissions to study the problems and carry out certain aspects of the programs.

The conditions that formed the basis of current Foundation activities in science education are changing rapidly, making necessary certain changes in the direction of future efforts. Thus, the Foundation is assessing all aspects of its educational policies and programs in order to find ways of providing more effective assistance for contemporary needs.

While no drastic or abrupt changes in support programs are contemplated, some reorientation appears necessary and, indeed, shifts in the direction of some efforts have already begun. More attention is being directed to the problem of increasing academic strength of school systems and institutions of higher education. Greater discretion is being accorded institutional authorities in the development of programs for upgrading their curricula, facilities, faculty and students. Increased attention is being given to the preservice training of teachers, whereas past efforts have focused on the retraining of in-service teachers. New authority to the Office of Education is permitting some reductions by the Foundation beginning in fiscal year 1967 in undergraduate student and equipment programs.

Nevertheless, in looking ahead, the Foundation sees the need for substantially increased attention and institutionally based support for science education at the undergraduate level. It is clear that only comparatively few undergraduate institutions have benefited from the Foundation's research and education grants designed to strengthen undergraduate academic science. To assist more of such institutions the Foundation during the year planned, and in its fiscal year 1967 budget requested funds, for the College Science Improvement Program. (This program was announced in October 1966.) Main purposes of this program are to accelerate the development of the science capabilities of predominantly undergraduate institutions and to enhance their capacity for self-renewal.

An attempt will also be made to broaden support in appropriate programs that will benefit the predominantly undergraduate institutions, with a particular view toward producing science teachers who are competent to teach modern-day science.

In the next decade, if past trends in requirements for scientists and engineers can be considered a reliable guide for the future, the Nation will be faced with a number of problems. These include meeting growing requirements for scientific and engineering personnel, providing for the growing numbers of students soon to be in the pipeline, and providing maximum education for those yet to enter high school and college. Being cognizant of these problems, the Foundation is presently engaged, through its various programs, in supporting the development of a broad base of institutions capable of providing advanced training in science at a level of quality commensurate with national needs.

GRADUATE EDUCATION IN SCIENCE

Educational activities at the graduate level represent a key effort of the National Science Foundation. Indeed, science education and scientific research at the graduate level are so closely intertwined that it is difficult to separate the two in a meaningful way.

Significantly, the leading educational institutions that have emerged in the Nation during the past several decades are at the same time outstanding centers of academic research.

The nature of this association can best be illustrated by examining the process by which a graduate student advances toward his doctoral degree. He normally begins his graduate education with a series of formal courses that provide, for the most part, the same broad coverage of his major field as his undergraduate courses, but in a much more detailed and fundamental way. In good graduate departments these courses are reshaped each year by addition of the most recent results of on-going research.

Near the conclusion of this period of course work, the graduate student faces his most critical decision. Up to this point, his education has established a rather broad base of knowledge. He must now select his research

Figure 24.—*For high school students field work is often the most interesting part of science. These students collect marine specimens during a Summer Institute in Oceanography at Humboldt State College, Calif.*

specialty and faculty adviser, and undertake his first original research problems.

This initial research experience serves a dual educational purpose. First of all, it provides the student with basic experience in the practical experimental or theoretical techniques of his specialty. And, as original research, it acquaints the student with the current problems in his field, allowing him to begin to discern for himself the areas of current and future concern. The success of this first direct research experience enables the graduate student to select the topic for his dissertation research and, hopefully, to carry it to a successful conclusion.

This close relationship between education and research is even more apparent in the case of the various postdoctoral fellowships; they nearly always involve research programs, and the merit of the proposed research is an integral part of the evaluation of a fellowship application.

On the other hand, substantial portions of research project grant funds go directly to support educationally valuable research activities of graduate students. It is estimated that from $15 to $20 million of the Foundation's annual obligations for research provides for salaries of graduate research assistants (an estimated 5,100 of these assistants participated in NSF-supported research projects during fiscal year 1966). Such Foundation support of graduate-level research is necessarily a contribution to graduate education, further demonstrating the inseparable nature of the two elements.

In fiscal year 1966, the Foundation supported 8 fellowship and traineeship programs which provided opportunities for 8,580 individuals to obtain training at the graduate and postgraduate level. Table 3 summarizes data on applicants, awardees, and expenditures.

Table 3.—*NSF Fellowship and Traineeship Programs, Fiscal Year 1966*

Program	Applicants	Awardees	Amount
Graduate fellowships	9,656	2,500	$12,180,550
Cooperative graduate fellowships	275	275	1,471,390
Summer fellowships for graduate teaching assistants	2,915	910	990,000
Graduate traineeships	15,386	4,193	22,347,909
Postdoctoral fellowships	1,070	230	1,580,000
Senior postdoctoral fellowships	397	95	1,082,550
Science faculty fellowships	1,078	326	4,160,000
Senior foreign scientist fellowships	61	51	672,550
Total	30,838	8,580	44,484,949

Graduate Fellowships and Traineeships

Fellowship support for graduate students began in the Foundation's first year of operation and has continued as an important program over the past 15 years. Predoctoral fellowships are awarded in national competition on the basis of the candidate's merit and ability, without assignment of quotas by scientific field or discipline.

In case of substantially equal merit, consideration is given to factors of geography and—to a lesser extent—field of science in making selections.

The principal objective of the Graduate Traineeship Program is to bring about an increase in the number of qualified individuals who undertake and complete advanced study leading to master's and doctoral degrees in the fields covered. Emphasis is placed on making grants to institutions where existing facilities and staff can accommodate additional first-year graduate students in programs of high quality, or whose students can, through traineeships, make faster progress toward an advanced degree.

Graduate trainees to be supported in this program are selected by the institutions themselves; the term traineeship is used to distinguish support of such individuals from traditional fellowships awarded directly by NSF to individual applicants.

As in previous years, the largest number of fellowship and traineeship awards were made to predoctoral students. In the four programs (Graduate Fellowships, Cooperative Graduate Fellowships, Summer Fellowships for Graduate Teaching Assistants, and Graduate Traineeships) a total of 7,878 awards (3,685 fellowships and 4,193 traineeships) were offered—up from the 6,838 offered in fiscal year 1965. The total number of applicants in these programs increased from 26,295 in fiscal year 1965 to 28,232 in fiscal year 1966.

After carefully studying the program of Summer Fellowships for Graduate Teaching Assistants, the Foundation concluded that the support of a reasonable number of graduate teaching assistants in the summer

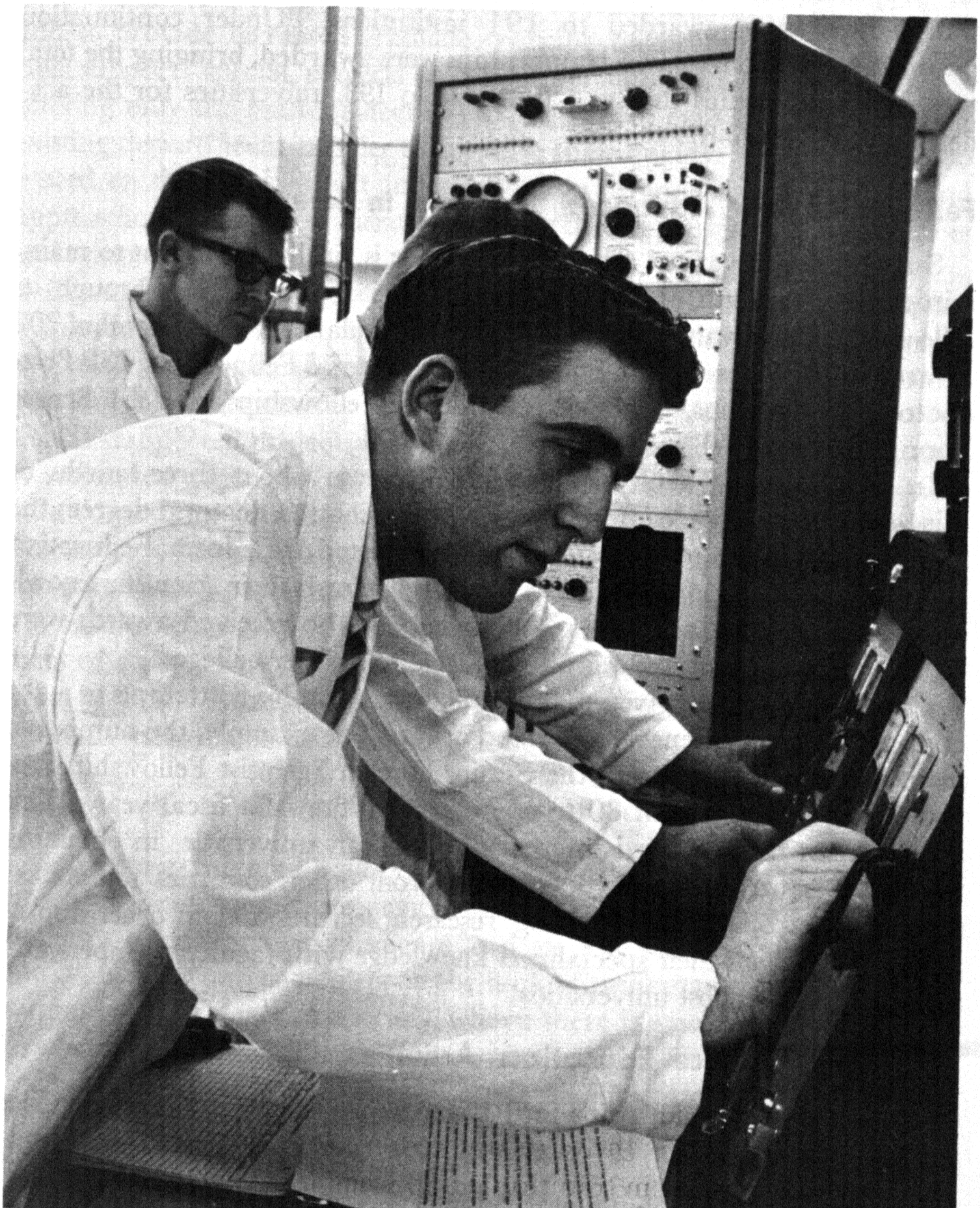

Figure 25.—*Working under an NSF-supported graduate traineeship, this University of Washington student is participating in nuclear engineering research.*

months should be continued. However, effective in fiscal year 1967, this will be done by means of traineeships rather than fellowships. The universities will then have sole responsibility for selecting the graduate teaching assistants to receive summer traineeships.

The Foundation's Graduate Traineeship Program has now been in existence for 3 years. This year, for the first time, the Graduate Traineeship Program covered all the fields of science supported by the National Science Foundation. Of an estimated 200 institutions eligible to apply for these traineeships, 196 schools submitted a total of 2,269 departmental proposals for new traineeships. Grants providing for 2,149 new traineeships were awarded to 191 institutions. Under continuation grants, an additional 2,044 traineeships were awarded, bringing the total to 4,193 traineeships that are available to 193 universities for the academic year 1966–67.

Fellowships for Advanced Scholars in Science

Support for advanced scholars in science is vitally important to maintaining the strength of the Nation's scientific potential. Through its fellowships for advanced-level study, the Foundation made a total of 702 awards in fiscal year 1966: 95 Senior Postdoctoral Fellowships, 230 Postdoctoral Fellowships, 326 Science Faculty Fellowships, and 51 Senior Foreign Scientist Fellowships.

In the Science Faculty Fellowship Program about three-fourths of this year's awards were offered to teachers wtihout a doctoral degree; the remainder went to teachers who had completed their formal education and desired an opportunity to extend and refresh their scientific knowledge. Most of the science faculty members who received awards were those teaching at an undergraduate level at smaller colleges.

Careful attention is given to these programs, and NSF attempts to make changes in them whenever the need arises. For example, the number of institutions participating in the Senior Foreign Scientist Fellowship Program will increase from 80 to about 200 in the next fiscal year. This results from the increased interest of American universities in obtaining the services of distinguished scientists from other countries to conduct seminars, participate in on-going research, lecture, and in other appropriate ways share their specialized knowledge with faculty members and students in U.S. host universities.

Advanced Science Education Activities

In addition to fellowships and traineeships, the Foundation provides support for a number of other graduate education activities. Funds available for these activities totaled $3.5 million in fiscal year 1966. These activities allow for maximum flexibility and adaptability in assisting the academic community to adjust to the rapidly shifting volume and change in the educational demands being made at the graduate level.

Advanced Science Seminars

A total of 38 of these seminars were supported in fiscal 1966, to supplement graduate school curricula and enable participants to pursue science subjects in depth. Many were highly innovative. For example, the Systems Ecology Sequence Project at the University of Tennessee stressed the application of mathematical techniques to many environmental problems, through the use of computers.

Special Projects in Graduate Education

In an effort to maintain educational excellence at the graduate level and to provide increased graduate training opportunities, the Foundation supports special projects at a number of graduate schools—some offering only the master's degree—to help them expand and alter their existing departments in order to upgrade their quality. Emphasis is also placed on the development and application of promising new ideas and approaches in advanced science education through support of conferences and symposia.

Examples of such conferences in fiscal year 1966 were those dealing with graduate education in applied mathematics and in social psychology, and with master of science programs in chemistry at non-doctorate-granting institutions.

NSF-supported projects that may develop into pilot programs for new or reoriented graduate curricula include (1) the interdisciplinary graduate curriculum in colloid and surface science at Clarkson College of Technology, (2) programed training in social research (to develop a set of computer-based problems to teach research methodology to students in the social sciences) at Johns Hopkins University, and (3) the development of a program of graduate education in tropical studies at field stations in Costa Rica, under the Organization of Tropical Studies, an interuniversity cooperative organization.

Public Understanding of Science

Activities in this area have been devoted largely to exploratory projects aimed at identifying those devices or techniques that can increase the layman's understanding of science and its role in today's world. Primarily, NSF's concern centers on the lack of understanding of science at various levels of American society, where there is a need to reach specific groups of the nonscientific public.

Examples of such projects will serve to illustrate the Foundation's objectives and accomplishments in trying to improve the public's understanding of science. Seminars and conferences held by colleges and universities for science writers, editors, and others connected with the mass media of communication have received NSF support for a number of years. The total attendance at these programs, which are designed primarily to increase the scientific knowledge of the newsmen, is estimated to be about 2,000.

Support has also been provided for science film series—one, for example, has been presented on 47 educational TV stations.

The most recent attempt to improve the quantity and quality of science writing has been through the support of two graduate-degree programs designed to produce science communicators. Open to persons with undergraduate degrees in science, these programs will provide training in communication techniques as well as advanced training in science.

UNDERGRADUATE EDUCATION IN SCIENCE

Undergraduate institutions trying to provide high-quality science education commonly find that their most critical problems are recruiting and retaining well-trained teachers, modernizing courses and equipment, and providing especially challenging courses for youths of unusually high aptitude. It is in the national interest for the Government to provide assistance in this area because national requirements for scientists and engineers are on the increase. Today there are nearly 3 million people employed in science and technology (scientists, engineers, technicians, and teachers); by 1970 it is estimated that 4 million people will be required.

Obtaining adequately trained teachers for the instruction of the future scientists and technologists is perhaps the most difficult problem. Compounding it, however, has been the discovery that many curricula considered adequate only 10 years ago are now hopelessly outdated. Not only do the colleges find each year that they must present more scientific material of ever greater complexity, but they also find that their undergraduates, nurtured in the new high school science and mathematics curricula, are ready to deal with sophisticated concepts formerly reserved for graduate courses.

Defining the Need

As the first step in the area of course content and curriculum improvement, national and regional curriculum conferences have been held in which experts examine current practices in undergraduate science education and define major areas of need. These conferences bring together knowledgeable people who, because of diverse interests, usually do not associate with one another professionally, including research scientists who previously may have been inclined to leave teaching problems to the teachers. Conference subjects have ranged from the role of design in engineering education to the coordination of junior college and university physics curricula.

To investigate the basis of frequent appeals from undergraduate institutions for assistance in obtaining modern instructional equipment, the

Foundation as long ago as 1960 commissioned a number of scientific societies to survey the equipment needs of undergraduate departments in their respective disciplines. A sampling of some 300 institutions provided data which, in sum, showed that instructional equipment needs in the 1961–70 decade would outstrip locally available funds by a ratio of 4:1. The initiation of the Foundation's Instructional Scientific Equipment program was a direct outgrowth of this "Krauss-Mills Report."

The report has subsequently been cited separately by the U.S. Atomic Energy Commission in support of the Nuclear Education Assistance Program and by the U.S. Office of Education in support of its Title VI: Equipment Program of the Higher Education Act of 1965.

During fiscal year 1966 several inquiries were made into undergraduate science education needs. For example, a proposed "College Science Improvement Program" was the subject of intensive discussion at eleven regional meetings attended by representatives of 408 colleges and universities. These science teachers and administrators were fully briefed on the Foundation's plans, and then invited to comment, criticize, and advise as to how this program could be made more responsive to existing needs. Many of their comments and suggestions have been incorporated into the new program's guidelines, which were announced in October 1966, with a budget of $10 million for fiscal year 1967. That more changes were not suggested points to the fact that many provisions of the program arose from earlier informal discussions between college science faculty and Foundation staff.

This continuing dialog between staff and teaching scientists remains one of the Foundation's most effective mechanisms for monitoring academic science needs.

The second step in meeting a need is to initiate a program experimentally, and test it to see if it fulfills the purposes intended. In the area of undergraduate science education, NSF has emphasized innovative programs that pioneer new training techniques and upgrade old ones in science education. These have served as educational research and development efforts for the examination, development, testing, and evaluation of novel ideas.

This kind of effort frequently produces valuable dividends. A number of the Foundation's current programs—teacher-training institutes, research participation, and course content improvement, among others—had their genesis in small experimental projects of this nature.

The third step is to bring into full operation those experimental programs that have proven successful. Such NSF activities in support of undergraduate education in science include programs that assist college students with high ability in science, programs that provide supplementary training for college teachers, and programs that help undergraduate institutions improve their courses and acquire modern tools of instruction. Fiscal year 1966 activities in each of these areas are described below.

Undergraduate Research Participation

NSF-supported projects for high-ability undergraduate students provide them with opportunities to do essentially independent research under the guidance of a competent research adviser—and, as a byproduct, to prepare themselves for a smooth transition, later on, to graduate work. These students may participate as junior colleagues in research projects conducted by experienced scientific investigators, or they may engage in independent study activities oriented toward the theoretical aspects of mathematics, physics, physical chemistry, astronomy, and other subjects.

The rising interest of the academic community in this activity is reflected in the fact that 1,623 requests seeking 31,836 student research opportunities were received in fiscal year 1966, an increase of 42 percent over the number received in the preceding year and by far the greatest number in the program's history. A total of 710 grants amounting to $6.6 million were made to 592 institutions to provide research experience to 6,584 students.

Research participation projects afford benefits to faculty and curriculum as well as to students. Summer projects provide opportunities

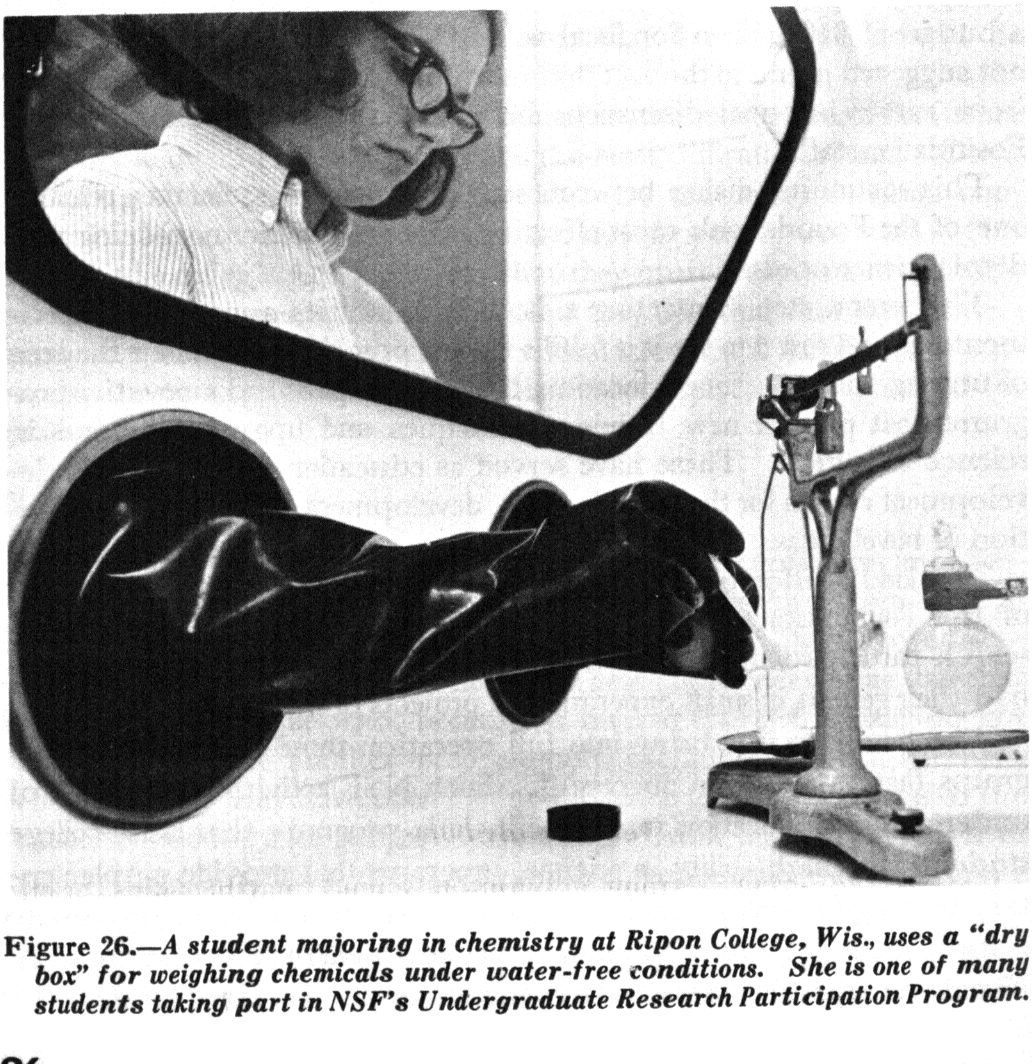

Figure 26.—***A student majoring in chemistry at Ripon College, Wis., uses a "dry box" for weighing chemicals under water-free conditions. She is one of many students taking part in NSF's Undergraduate Research Participation Program.***

for professors—often promising young teachers with vital research interests but little research support—to remain in their laboratories and carry forward their own scientific investigations while supervising their undergraduate research participants. Science departments that have for years sent students only to medical and dental schools suddenly find their graduates entering Ph. D. programs.

During its 8 years of operation the Undergraduate Research Participation Program has provided more than 43,000 opportunities for student research experience. Project directors report that a high proportion of the student-participants go on to graduate school, many being the recipients of awards and fellowships.

College Teacher Programs

Faculty-centered activities supported by the Foundation are directed toward three major groups: college science teachers whose initial preparation was once adequate, but whose teaching effectiveness has been eroded by years of classroom work unrelieved by adequate refresher training; those who were never adequately prepared for their present duties; and those whose preparation for their major duties is adequate, but who are assigned collateral teaching in subspecialties in which they are not fully qualified. Table 4 summarizes College Teacher Program support for fiscal year 1966.

Table 4.—*NSF College Teacher Programs, Fiscal Year 1966*

Program	Proposals Received			Grants Awarded		
	Number	Participants	Amount	Number	Participants	Amount
College teacher institutes..	207	6, 624	$9, 672, 274	108	3, 135	$3, 896, 237
Academic year institutes...........	18	467	3, 161, 513	11	145	771, 391
Summer institutes.....	115	3, 692	4, 986, 518	64	2, 003	2, 542, 262
In-service seminars....	3	96	66, 547	3	71	52, 060
Conferences..........	71	2, 369	1, 462, 696	30	916	530, 524
Research participation....	369	893	2, 347, 544	250	586	1, 381, 023
Total.............	576	7, 517	12, 019, 818	358	3, 721	5, 277, 260

Teacher Institutes

Institutes are group-training activities in science, mathematics, or engineering, offering instruction especially designed for teachers. They have proven to be a very effective mechanism for updating the teacher's knowledge of science.

Most institutes have been conducted at an advanced level, but a shift is now under way toward emphasis on instruction in basic subject matter. This is in response to serious and growing imbalance in the supply of men and women with adequate training to teach undergraduate science.

Academic Year Institutes offer full-time, subject-matter programs to college teachers on leave from their home campuses, and give the teacher a chance to become fully involved with new materials in his field of science. Since its initiation, this program has provided training for 781 college teachers. Fiscal year 1966 grants are supporting 145 teachers at 14 institutions.

Summer institutes are conducted at a time when college faculty members are free to work at self-improvement, and when graduate facilities are not overtaxed by regular enrollments. These institutes have assisted more college teachers than any other individual program; about 16,000 training opportunities have been provided to college teachers during the program's existence. Fiscal year 1966 summer institutes supported a total of 1,989 participants at 45 institutions.

In-service seminars provide part-time training while participants teach full time in their home institutions. Usually meeting once each week for 2 hours or more, in-service seminars are most appropriate in large metropolitan areas where there is a cluster of colleges within commuting distance. During its 3-year existence, the In-Service Seminar (formerly called In-Service Institute) Program has provided training opportunities to 266 college teachers.

Because of its potential as a program of moderate cost with immediate benefit to the college classroom, plans call for an increase in this activity.

In addition to the college teacher programs discussed here, a Science Faculty Fellowships Program provides support for further training of college faculty. (See page 92.) The fellowships make an especially valuable contribution to improved college and university science instruction, particularly at institutions where the primary emphasis is on undergraduate instruction. In fiscal year 1966, for example, 82 percent of the individuals who were offered awards were teachers from the smaller schools.

Conferences

Designed for college teachers with good general backgrounds who need only an intensive and specialized program, conferences ordinarily are of 1 to 4 weeks' duration and focus on specialized topics or recent advances in a given area of science. Most follow traditional disciplinary lines, though some are multidisciplinary or interdisciplinary.

Representative of conferences supported in fiscal year 1966 were a Water Resources Conference at New Mexico State University, conferences on Electronics for Scientists at the University of Illinois and Oregon State University, and a Conference on Applications of Systems and Communications Models in Political Science at Virginia Polytechnic Institute.

The grants made in fiscal year 1966 in this program supported 916 participants in conferences held at 30 institutions, and totaled $616,800.

Research Participation

The Foundation provides opportunities for college teachers to utilize summer recesses for full-time research as associates of experienced investigators at institutions that conduct major research programs. Some of the participants perform research for the first time; others resume an interest long frustrated by heavy teaching schedules. Given this research opportunity, many teachers demonstrate considerable promise and develop a continuing interest in research.

Additional support through "academic year extensions" during the succeeding year is provided so that some of the teachers may go on with their projects—with continuing guidance from their research mentors—after returning to their home institutions. Experience with the first 2 years of such academic year extensions has demonstrated that some of these teachers show sufficient promise in research to justify a second extension of support. A few of these, indeed, have enhanced their competence to the point where they can, and have, successfully competed with established investigators for research funds.

Research participation projects for the summer of 1966 supported 159 predoctoral and 236 postdoctoral science faculty members.

Instructional Improvement

Several Foundation activities are designed primarily to help colleges improve their undergraduate instructional programs. These involve identifying problem areas in undergraduate science education, recruiting leading research workers and outstanding teachers to create model courses and instructional materials, and bringing about curriculum improvements in the institutions themselves.

Science Curriculum Improvement

Under this program, the Foundation encourages and supports innovation and experimentation aimed at improving undergraduate instruction in the sciences on a nationwide basis. One of the most important achievements of the Foundation's programs in science education has been the development of a cadre of scientists who are willing to devote substantial effort to helping solve the educational problems of their disciplines.

At the forefront of this effort have been the national college commissions in biology, chemistry, physics, geology, engineering, mathematics, geography, and agriculture. A comparable organization, the Union of Social Science Teaching, was organized in 1966 to upgrade instruction in that area. These groups of scientists develop course outlines and other teaching materials (films, laboratory apparatus, etc.) that are highly current and are based on a thorough understanding of concepts important on the modern scientific scene. Examples of significant developments supported in fiscal year 1966 are:

- Completion of a film on superconductivity by the Michigan State University, continued production of college physics films by Educational Services Inc., and the making of two films on symmetry by the Polytechnic Institute of Brooklyn.
- Development of films and textual materials in mathematics under the auspices of the Mathematical Association of America.
- Development of new course outlines for introductory geography by the Commission on College Geography.
- Production of films on electrical engineering and on fluid dynamics by Educational Services Inc., continuation of engineering case studies by Stanford University, and development and dissemination of a new, simplified computer language for introductory instruction at Cornell University.
- Two major interdisciplinary writing efforts—one to produce textual materials on contemporary natural science for nonscience majors (University of California, Berkeley), the other on physical science for the nonscientist (Rensselaer Polytechnic Institute).

In fiscal year 1966 the Foundation's grants for College Science Curriculum Improvement projects amounted to approximately $6 million. Most of the funds were in support of 6 major projects, while 31 small projects also received support.

Instructional Scientific Equipment

Closely related to course content improvement is the NSF effort to assist colleges and universities in the purchase of modern instructional scientific equipment. Through matching grants for up-to-date laboratory equipment, the Foundation has fostered the updating and improving of individual courses, laboratory exercises, and instructional methods at the undergraduate level.

Priority is given to proposals based on informed and effective planning for undergraduate instructional improvement, and support is granted to those judged to offer the greatest promise of relative improvement of instruction.

Since 1962, when the Foundation's first grants for instructional scientific equipment were made, some $37 million has been awarded to a total of 957 institutions for the purchase of instructional equipment. Through the stimulus provided by the requirement for matching, recipient institutions have invested a more than equal sum. A total of 970 grants were made during fiscal year 1966 at a cost of $7.7 million. This provided 31

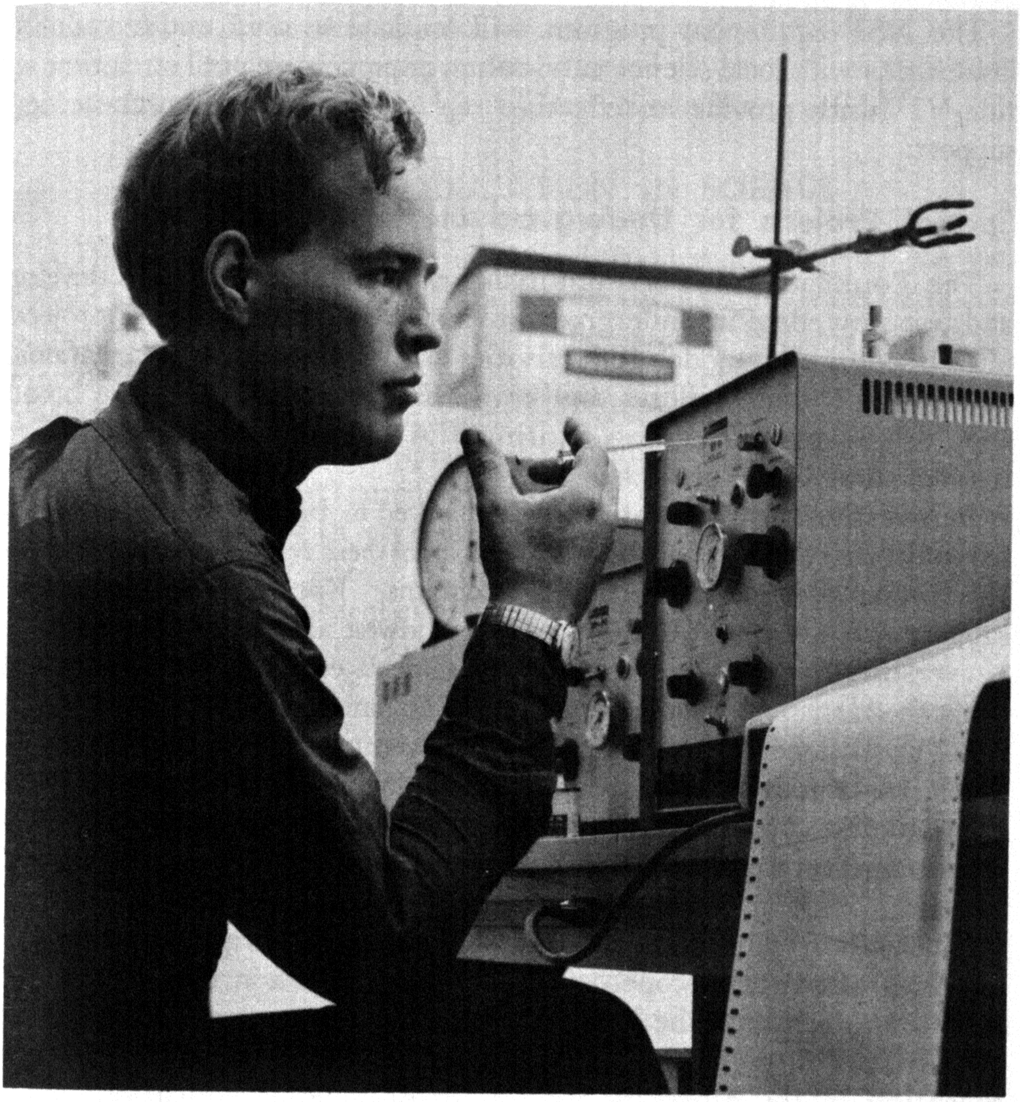

Figure 27.—***A senior at Knox College, Ill., participating in the Undergraduate Research Program, uses a gas chromatograph to separate and identify a mixture of organic compounds. The instrument was purchased through a Foundation equipment grant to the college.***

percent of the funds requested and accommodated 43 percent of the proposals received. Of the 546 institutions receiving grants, 82 were receiving them for the first time.

The future role of the NSF Instructional Scientific Equipment Program is being considered in the light of the provisions of title VI of the Higher Education Act of 1965, administered by the U.S. Office of Education. Title VI offers support through matching-fund grants to institutions for the purchase of equipment to improve the quality of classroom instruction. It is important to point out that while title VI directs that consideration be given to enrollment pressures and the financial needs of the proposing institution, such pressures are not sufficient justification for an award under the NSF Instructional Scientific Equipment Program.

The NSF equipment program will continue to assist undergraduate institutions with local science curriculum improvement until such time as title VI funds provide an effective replacement for the much-needed support.

Special Projects for Undergraduate Education

The Foundation supports promising experimental projects to develop and test new ideas in undergraduate science education. Such projects often become pilot models for activities that will enhance the educational programs of many colleges and universities when applied on a broad scale. NSF made 27 grants totaling $1.4 million in fiscal year 1966 to support these varied projects.

Interinstitutional associations have proved to be effective instruments for enabling colleges and universities to pool their resources and thus provide more effective instructional programs. For example, with NSF support the Associated Colleges of the Midwest and the Wisconsin State Universities System are offering their students extensive field study and research participation opportunities. The junior colleges of the State of New York, together with the State University of New York at Stony Brook, have undertaken a program of continuing conferences to improve the teaching of physics in the 2-year institutions and to develop new courses and curriculum materials in physics for the 2-year college terminal student.

Curriculum conferences range from 1-day State or regional sessions to meetings of national scope. Of particular interest in fiscal year 1966 were a conference at the University of Chicago to assess undergraduate preparation for the study of medicine, a study of industrial engineering education by the American Society for Engineering Education, and a series of workshops and information sessions sponsored by the Commission on Engineering Education and the University of Michigan on the use of computers in teaching engineering design.

Detailed reports of all conferences are widely distributed and frequently have a pronounced impact upon undergraduate instruction.

Visiting scientist projects represent an important component of the Foundation's efforts to provide sources of guidance to departments that wish advice as to helpful directions for change. Professional societies arrange for outstanding scientists to visit colleges, where they consult with faculty members on local problems relating to course and curricular improvement, deliver lectures on their specialities, and assist undergraduate students in making educational plans. The experience and counsel of a senior faculty member from a major institution can be of enormous value to professors in a small department who are seeking to update and upgrade their science program.

Other imaginative projects receiving support in fiscal year 1966 include a seminar at Tufts University (supported jointly with the U.S. Office of

Education) to devise new ideas for educational experimentation, and an experimental program in computer-moderated programed instruction in statistics at the System Development Corp., Santa Monica, Calif.

PRE-COLLEGE EDUCATION IN SCIENCE

A child's experiences with science and mathematics during the pre-college period largely determine whether he becomes motivated and adequately prepared to undertake a scientific career. For this reason the Foundation seeks to support programs that make available the best possible instructional materials, the skilled teaching needed to put these materials in effective use, and the special opportunities that permit students to achieve their maximum learning potential.

Nationwide interest in increasing the quality of science instruction has been sparked by the success of early NSF-supported, teacher-training institutes and course content improvement projects. Nevertheless, much remains to be accomplished; promising new ideas must be developed and tested. The Foundation, therefore, hopes to continue to provide prototypes that can be implemented on a larger scale throughout the Nation with funds that are available from other Federal agencies and from non-Federal sources.

Improvement of Instructional Materials

In today's classrooms good science instruction is heavily dependent upon the use of modern instructional materials. To provide for the development of such materials, the Foundation encourages the active collaboration of leading scientists and teachers, specialists in education, and other experts in carrying out course content improvement efforts.

The fruits of their labor, begun in 1954, are indeed impressive and are having an increasing impact on the quality of science teaching in the Nation's elementary and high schools. While the early efforts were centered on the development of materials at the high school level, a number of major projects at the elementary and junior high school level are now well under way.

By the end of fiscal year 1966, more than 275 definitive editions of textbooks and other printed materials—many now available through commercial publishers—had been developed by these NSF-supported groups. In addition, 511 separate scientific topics have been presented in 16- and 8-mm. films for classroom use in precollege education in science.

Obviously the Nation's teachers and school systems have a wide variety of up-to-date instructional materials from which to choose. A few examples of the on-going projects will exemplify the progress that is being made.

The Chemical Education Material Study (CHEM Study) group, sponsored by the University of California at Berkeley, is completing its

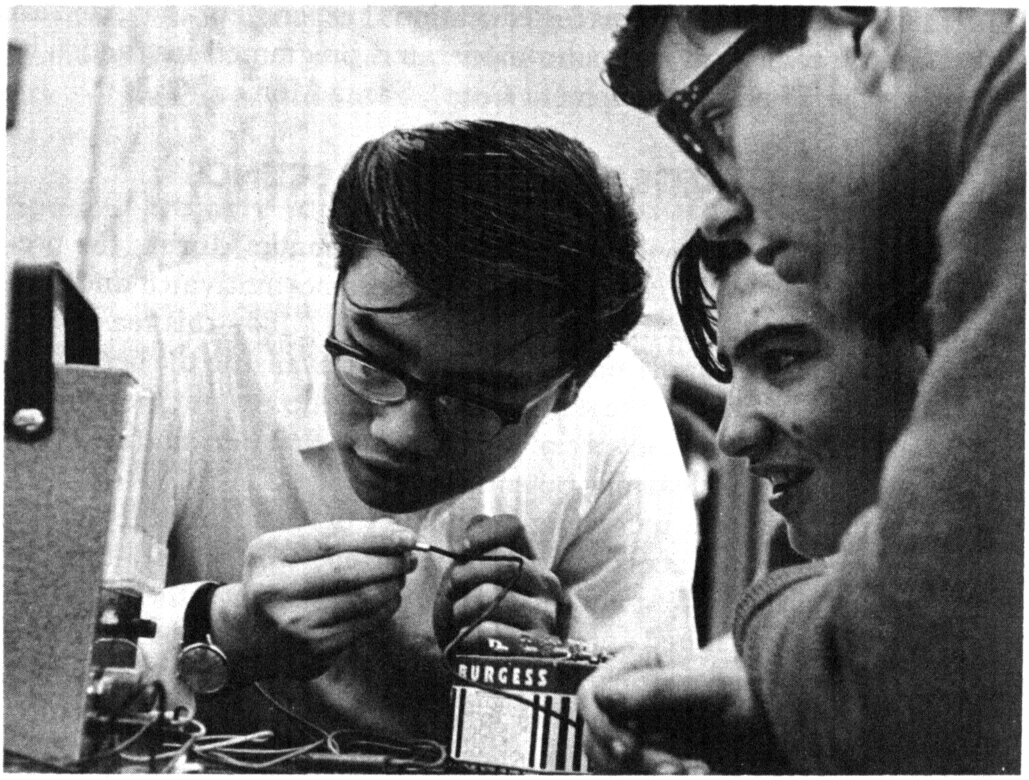

Figure 28.—*Deeply engrossed students at Brooklyn Technical High School experiment with laboratory equipment in "The Man-Made World," a new course on technology being developed with NSF support by the Commission on Engineering Education.*

task of producing instructional materials (textbook, laboratory guide, teacher's guide, achievement examinations, programed pamphlets, wall charts, and some 30 films) for a high school course in chemistry. Arrangements have been made to sell revision rights to three commercial publishers. The revised versions will replace the first edition of the CHEM Study materials.

In response to school requests for suitable materials for teaching in the earth sciences, the American Geological Institute organized a major Earth Science Curriculum Project which is now working with its final revision of materials (textbook, laboratory guide, teacher's guide, new apparatus, and a variety of reference and supplementary materials). The final version is expected to be published in 1967.

Two major activities in mathematics have been emphasized by the School Mathematics Study Group (SMSG) during the past year: (1) the National Longitudinal Study of Mathematical Abilities, and (2) the planning of a comprehensive mathematics program for grades 7 through 12.

The former is a long-range study of mathematical abilities that follows the progress of students taking conventional and newer types of mathematics curricula over a 5-year period, with beginning points in the 4th, 7th, and 10th grades. Its goal is to answer fundamental questions in mathematics education and provide a basis for future reform.

The latter activity will take full advantage of the last 10 years of mathematics curriculum development and particularly of the information developed by the National Longitudinal Study of Mathematical Abilities. It is expected that the program will include a full year of calculus, together with some of the basic notions of probability and numerical analysis. The sequence of topics will probably differ considerably from the present grade placement of these topics, with the relationship between mathematics and science playing an integral part.

A new course in high school physics, jointly supported by the National Science Foundation and the U.S. Office of Education, is being developed at Harvard University. This project is at the halfway mark in its development of a basic physics course, plus complementary instructional materials for variations to suit the needs of individual schools.

Current work on a High School Geography Project, carried on by the American Association of Geographers, is concentrated on the development of a 10th-grade course in geography concerned with the study of selection of sites for towns and cities and a study of how they grow. The project aims to make finished course materials in this subject and a variety of other topics available for widespread use in the 1969–70 school year. A total of 26 projects, mostly of a continuing nature, were supported in 1966 at a cost of $9.9 million.

Cooperation in School System Improvement

Curricular reform must ultimately be carried out in the classroom. Vastly improved materials, whether supported by NSF or other sources, are of vital importance. How well they are used, however, depends primarily on the local school system. Responsibility for the education of students rests with local school boards and school superintendents, and their understanding of the requirements imposed by improved curricula and the competence of their teachers governs the successful adoption of the new materials.

The Cooperative College-School Science Program provides a means for NSF assistance in the complex task faced by a school system when adopting improved materials and in other ways improving its instructional program. This activity encourages collaborative efforts between school systems and neighboring colleges or universities, including consultation with experts who are well-versed in modern course content in science and mathematics.

Grants are made only to the cooperating colleges or universities, but the active participation of the school system is required for such activities as designating the schools and teachers who will be using such materials, sharing some of the costs, and arranging for teachers to undertake necessary retraining.

Each project supported under this program can be individually tailored to the needs of the school system benefiting from the activity. Thus, detailed planning may culminate in intensive training sessions for teachers, followed by a flexible arrangement for additional help in adapting the new materials after the teacher returns to the classroom.

Until 1966 the program had been directed primarily toward the secondary school level but it has now been expanded to include some elementary school science and mathematics. A total of 2,016 secondary school teachers, 2,465 elementary school teachers, and 1,544 secondary school students participated in 57 projects at 50 institutions. Program expenditures in 1966 were approximately $2 million.

Concentration on the needs of a particular school system permits a high degree of involvement by that system and ultimately should satisfy the training needs within that system for a reasonable period of time. Many schools should then be able to undertake their own teacher improvement programs, using the models and contacts already established by the Cooperative College-School Science Program grant. Some examples of programs supported in this area will illustrate the possibilities.

Physics Teaching in the State of Missouri—Several physicists from college faculties in Missouri, with the cooperation of the Missouri State Department of Education, surveyed the academic qualifications of the State's physics teachers, and found very few teachers who could be considered qualified according to minimal standards of course preparation. Four institutions, therefore, collaborated in proposing to the National Science Foundation a massive upgrading of the physics teachers throughout the State.

The program began with a series of spring meetings and visits to schools, designed to interest the teachers in the program of self-improvement. Then, during the summer of 1966, approximately 25 teachers attended each of the 4 institutions. Those who had the lowest level of academic preparation were given introductory background course work, while those at the highest level renewed their familiarity with mathematics and advanced concepts of physics.

The summer sessions were followed by periodic meetings concerned with the introduction of better physics materials and experiments into the classroom, with the State department of education retaining a strong interest in this aspect.

The program is expected to continue for 1 or 2 more years, involving additional teachers and giving more advanced training in physics to the teachers at the lower levels in 1966.

This coordinated approach toward upgrading the teachers in a single discipline within a limited geographical area has already stimulated interest on the part of other disciplines and other States.

Elementary School Mathematics in Large Urban School Systems—The Madison Project, now based at Webster College, Webster Groves, Mo., has developed a coordinated set of materials designed to enrich the elementary mathematics program rather than to supplant it. As a result of this experience several large cities have decided to start their elementary mathematics reform by introducing Madison Project materials. A grant was made to Webster College, which conducted intensive familiarization sessions during the summer in Chicago, New York City, and San Diego, followed by frequent contact during the 1966–67 academic year.

At least 1,800 teachers were involved in these sessions. They form a nucleus of resource teachers in their own schools. Leaders from among them will conduct training for their own school systems with a minimum of guidance from the Webster College staff. At that stage the project will become self-supporting, with the school systems assuming full responsibility for introduction of the program and training of teachers.

Activities for High School Students

The principal means through which NSF aids high school students directly is the Secondary Science Training Program designed to provide challenging classroom work or research participation for very talented high school students interested in science, mathematics, or engineering. The success of this effort has stimulated summer sessions for superior students in all academic subjects. The Foundation's program, by working through colleges and research laboratories, helps to set a high standard for such activities. In 1966, 125 grants were made to 109 institutions which provided training for 5,738 students at a cost of $1.6 million.

Only a small proportion of the school population possesses both the ability and the motivation to become scientists and engineers, and it is impossible to predict just which students will complete the long and rigorous course of study. Youths selected to participate in Foundation-supported activities are generally felt to possess the necessary ability and interest. They are given a substantial boost by being brought into close contact with mature scientists, thus broadening and deepening their views of the scientific enterprise.

An important incidental result of this exposure is the realization by some bright students that they really should not pursue a scientific career, that their real interests lie in other areas.

Classroom instruction in science and mathematics in depth beyond that available in high school or early college courses is often a part of this training. An example is a project supported in fiscal year 1966 which involved 82 carefully selected high school students in an 8-week course in mathematics.

Special Summer Mathematics Course for High-Ability High School Students—The aim of the course, held at Ohio State University, was to stay within the boundaries of mathematics while developing the students' powers of observation and intellectual curiosity. The course was in-

Figure 29.—***These high school students are measuring the latent heat of vaporization of liquid nitrogen in a laboratory. They are participating in the NSF Secondary Science Training Program for High-Ability Students.***

tended for students whose ultimate career choices would be in science or engineering, as well as mathematics. Number theory was selected as the basic vehicle for all students. Problem seminars were held for smaller groups. In addition, each students could study higher algebra and take part in classes or seminars in logic, group representation theory, combinatorial mathematics, or experimental work with the computer.

Each course was taught by a member of the Ohio State University mathematics faculty. The staff also included 12 former participants of the Secondary School Science Training Program who are now undergraduate mathematics majors. They served as teaching assistants and dormitory supervisors making their advice and counsel available to the young participants almost around the clock. It was obvious that the students appreciated the challenge of this intellectually stimulating training.

Several additional activities to stimulate student interest in science are supported by the Foundation. (In fiscal year 1966 the expenditures for these activities totaled approximately $422,000.) One highly regarded

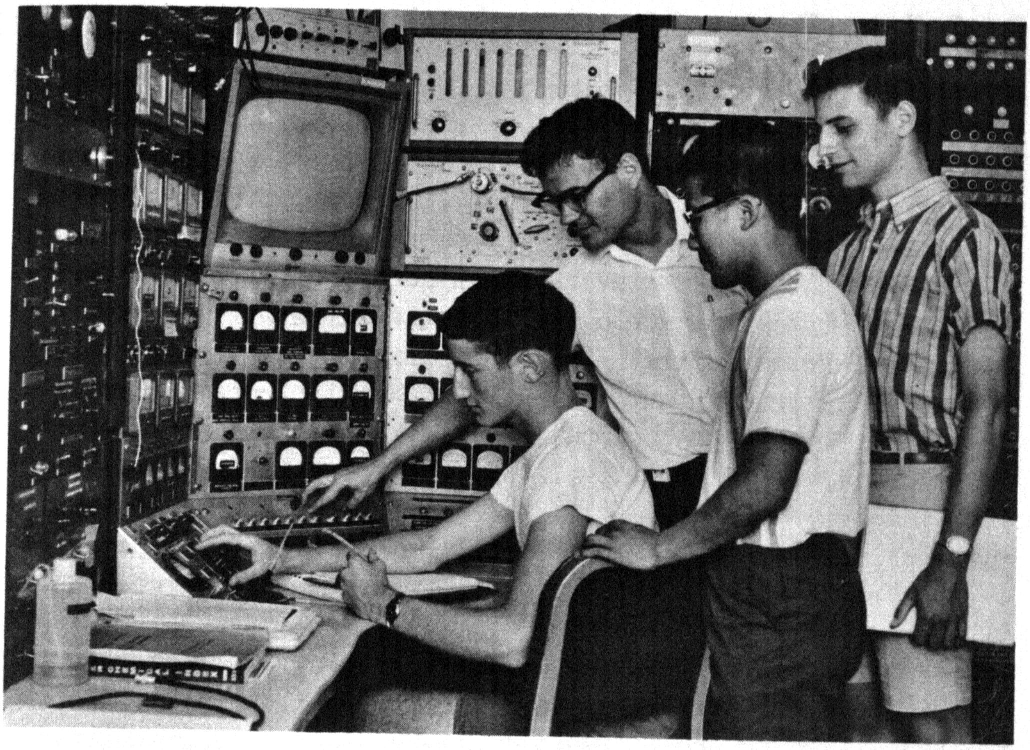

Figure 30.—***A physics professor at the University of Illinois explains the operation of the school's Cyclotron Control Center to high school students taking part in the Secondary Science Training Program.***

project is the Holiday Science Lectures—a series of high-level talks by outstanding scientists to carefully selected students. These lectures are given in about 10 cities during the winter holidays. The American Association for the Advancement of Science administers this program under an NSF grant.

Another activity is the research paper-reading sessions of Junior Academies of Science. Students are invited, after careful screening, to read papers about their own investigations before a professional audience of teachers and scientists. The high school student who has devoted great effort of high quality to a scientific investigation is thus given an opportunity to report on his own work and defend it before experts.

Many of the papers read in the spring of 1966 were most impressive in concept and execution of the research reported.

Grants were made in 13 States to Academies of Science, the parent organizations of the Junior Academies, to support these annual sessions.

A few special projects in science and mathematics designed for disadvantaged students were supported in the summer of 1966. In the future, it is expected that the Office of Economic Opportunity's Project Upward Bound and similar efforts supported by the U.S. Office of Education, which are not restricted to the support of science and mathematics, will carry this important training activity forward.

Pre-College Teacher Education Activities

To a very large extent the quality of education provided for our youth depends upon the competence of teachers. Coping with the problems that face these teachers is a primary concern of the National Science Foundation. Through NSF support of teacher-training institutes an effective start was made in providing many of them with necessary supplementary instruction. However, only about half of the secondary school teachers of these subjects, and a very small fraction of the key elementary school teachers, have participated in the various NSF-sponsored teacher education activities.

In addition to its concern about the needs of the already active but less qualified science and mathematics teachers, the Foundation recognizes that many new teachers are not fully trained for their tasks. New approaches to the solution of such critical problems are being explored, while progress continues to be made in the more well-established NSF training programs.

This year approximately 43,400 secondary school teachers of science and mathematics were afforded study and training opportunities in 851 NSF-supported instructional projects—institutes, research participation, and other special projects. The teacher-participant group represents about 20 percent of the Nation's science and mathematics teachers of grades 7 through 12.

Institutes cover a full spectrum of study opportunities for secondary school teachers, including such variety as summer institutes for junior high teachers who may have never formally studied the sciences which they have to teach, academic year institutes for recent graduates of colleges with inadequate science programs, summer institutes especially designed for science supervisors, and in-service institutes to prepare teachers in the new curricular materials.

The Research Participation Program permits some of the best prepared teachers to conduct research under the direction of distinguished scientists during the summer. The understanding of the research process gained from this activity provides gifted teachers with the kind of experience that greatly improves their effectiveness in the classroom. In some cases, the teachers are supported by the grants in continuing their research projects during the academic year at their home schools.

Some 2,000 teachers will receive master's degrees in the teaching of science principally as a result of institute participation and, possibly, thesis research under the Research Participation Program.

Including grants made in 1966, the Foundation has supported during the last 8 years over 500 institutes involving 20,000 elementary school personnel in science and mathematics. In these institutes the emphasis has been on the training of key individuals who are then prepared to take the lead in modernizing the curriculum, and also to conduct in-service training for their colleagues. As a result, a cadre of trained individuals is

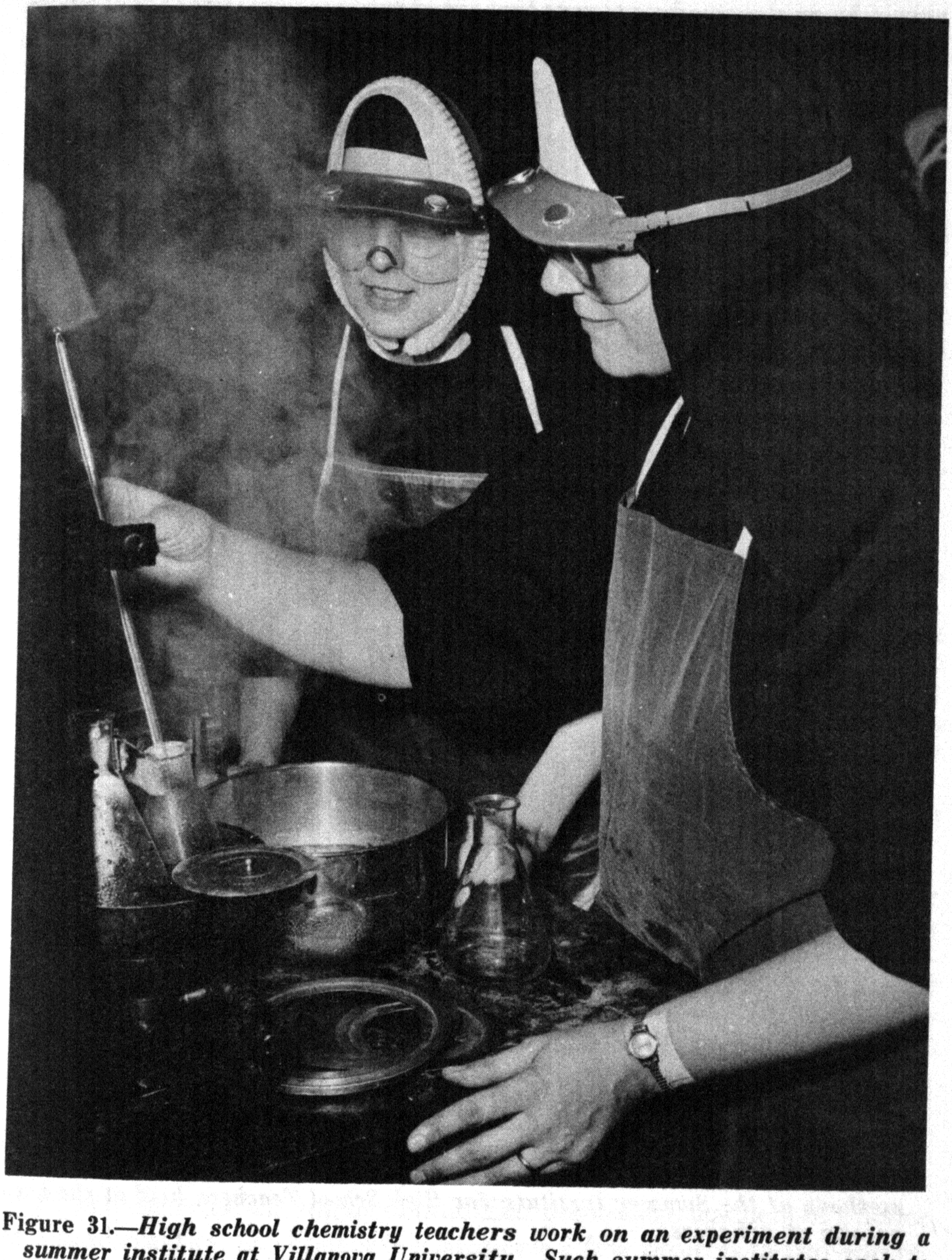

Figure 31.—***High school chemistry teachers work on an experiment during a summer institute at Villanova University. Such summer institutes seek to improve the teaching of science in secondary schools.***

now in existence who should be able to use to great advantage the funds for State and local training activities available under recent Federal education legislation. The Foundation has, therefore, terminated the institute programs for elementary school personnel. At the same time, the Foundation has extended its support of the Cooperative College-School Science Program to include elementary school activities.

Special projects for the supplementary training of secondary school teachers this year consisted primarily of conference-type sessions similar

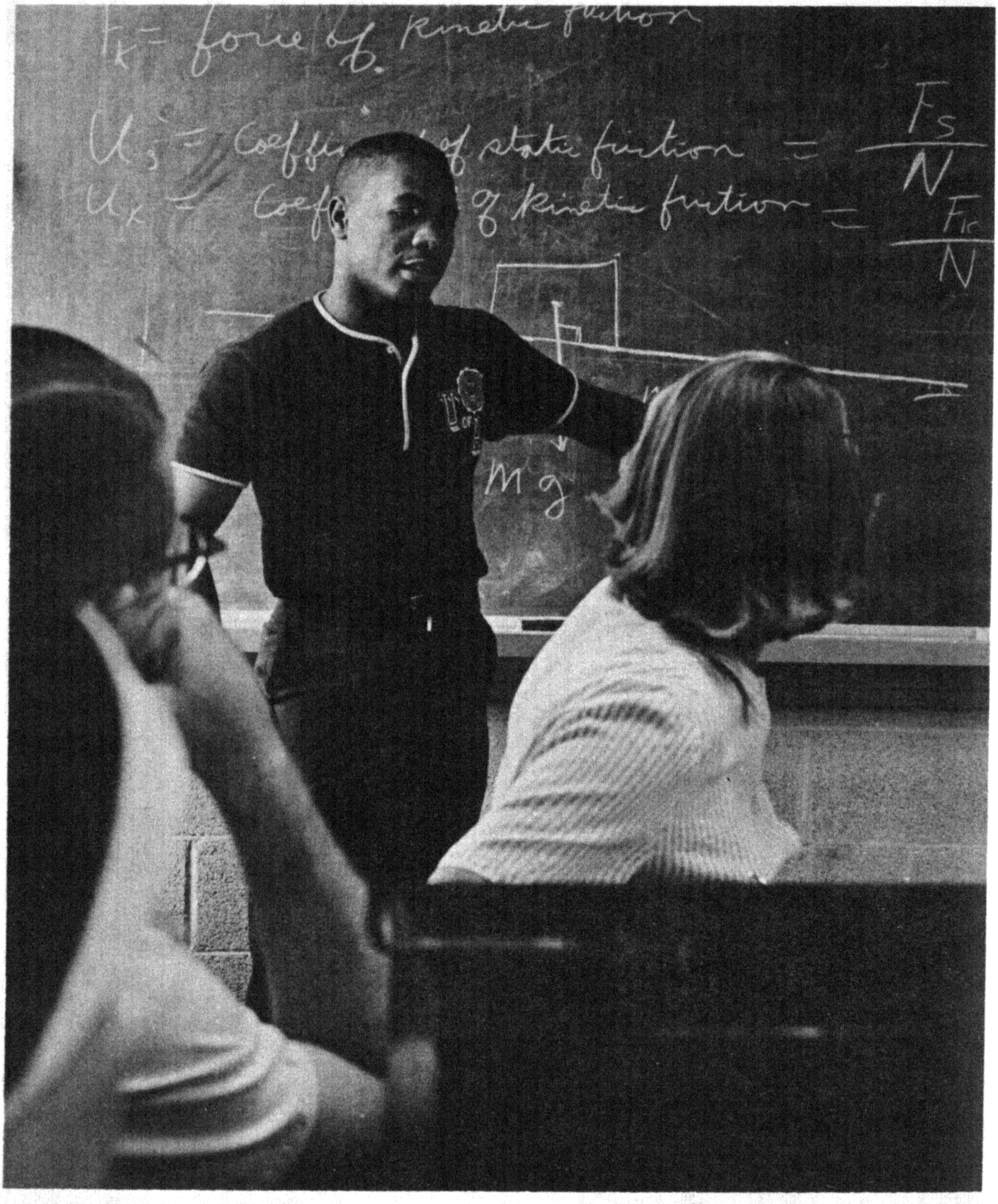

Figure 32.—***A high school teacher of physics discusses improved teaching methods at the Summer Institute for High School Teachers held at the University of Arkansas.***

to in-service institutes, but of much shorter duration. Significant among these were a project of the National Association of Biology Teachers to conduct 3-day teacher seminars on the "new biology" at 9 centers in various parts of the United States, and a project of the Biological Sciences Curriculum Study (BSCS) group to conduct 50 intensive, 5-day training sessions nationwide, for teachers who will be using the BSCS special materials. Six other projects offered seminars of 1 to 5 days' duration on a statewide or regional basis.

In addition there were some special-purpose projects for general science teachers in rural Mississippi, for seventh- and eighth-grade teachers in elementary schools in Appalachian Tennessee, for teachers of a new curriculum in earth science in Idaho, and for teachers who wished to participate in forestry research in Michigan.

The following table provides a statistical summary of the fiscal year 1966 teacher education activities:

Table 5.—Pre-College Teacher Education Activities, Fiscal Year 1966

Program	Proposals Received			Grants Awarded		
	Number	Participants	Amount	Number	Participants	Amount
Secondary school teachers:						
Academic year institutes	86	2,302	$15,321,284	63	1,547	$10,018,706
Summer institutes and conferences	754	31,455	37,403,630	457	20,528	22,498,052
In-service institutes	366	17,769	4,821,344	266	13,445	2,916,830
Research participation	79	661	1,443,244	53	360	719,237
Special projects	29	13,097	836,586	21	7,646	462,656
Subtotal	1,314	65,284	59,826,088	860	43,526	36,615 481
Elementary school personnel:						
Summer institutes	124	4,739	4,482,315	26	926	742,687
In-service institutes	132	8,081	1,323,526	55	4,225	458,088
Subtotal	256	12,820	5,805,841	81	5,151	1,200,775
Total	1,570	78,104	65,631,929	941	48,677	37,816,256

Pre-Service Teacher Training

To help increase the supply of qualified pre-college teachers of science and mathematics, the Foundation supports a few projects to provide refresher or advanced training for mature individuals who are changing careers with the intent of becoming teachers. Projects at Florida State University and the University of South Dakota are preparing a total of 25 retired Armed Services personnel to become teachers of high school physics. Another, at Rutgers—the State University, provides part-time instruction in mathematics for about 90 housewives who will return to teaching careers.

Four special projects were supported this year to improve the training of individuals who themselves train teachers. Two projects involved professors of science education from small colleges and were oriented

Figure 33.—***Attending a Summer Institute in Experimental Psychology, a high school teacher uses mirror-drawing to study learning and transfer training.***

toward a survey of new course content materials. A third provided special training to selected high school teachers with master's degrees so that they could assist a State department of education in in-service work with elementary teachers. The fourth project provided the opportunity for a few U.S. mathematics educators to observe Soviet secondary training in mathematics and computing while they were in the Soviet Union for the International Congress of Mathematicians.

Seven grants totaling $156,805 were awarded for this activity in fiscal year 1966.

INSTITUTIONAL PROGRAMS

National strength in science depends largely upon the viability and growth of the Nation's institutions of higher education. While grants for individual research projects may serve to strengthen specific segments of these institutions, they do not provide the broadly based and comprehensive support needed for the general improvement of science programs. To help meet these broader needs, several Federal agencies in recent years have begun programs of institutional support. The Foundation shares in this activity through its programs of University Science Development (formerly Science Development), Graduate Science Facilities, Institutional Grants, and—added for fiscal year 1967—a Departmental Science Development Program and a College Science Improvement Program. The departmental program is designed to enhance scientific competence in institutions where a department's research record marks it as a leader and an example for its sister departments. The college program is directed primarily toward improving science education at predominantly undergraduate institutions.

In all of these institutional programs, the Foundation tries to avoid any encroachment upon the autonomy of universities and colleges. Its aim is to provide institutions with the means to carry out their own plans for development and to adapt to the changing needs of their own institutions.

UNIVERSITY SCIENCE DEVELOPMENT PROGRAM

Originally called the Science Development Program, this was initiated in response to the nationwide need for more outstanding universities performing distinguished work in science. Through large grants to a limited number of strong universities, the Foundation hopes to accelerate their development into institutions with broadly based scientific excellence. Institutions already recognized as excellent are not encouraged to apply for the grants.

University science development grants are made after thorough evaluation of comprehensive institutional proposals. The evaluation attempts to determine that a university applying for a grant has well-conceived plans for reaching its objectives, a sound foundation of quality in the departments seeking support, good administrative leadership, and financial resources to maintain the new level of quality achieved under a grant.

By the end of fiscal year 1966, the Foundation had received 80 proposals for university science development grants and had completed its evaluation of all but 15 of these. Ten grants—one a supplement to an earlier grant—were made during the year for a total of $36,375,000. In all, 17 institutions have now received these science development grants, and the awards total $63,769,000. Each of the grants is for a 3-year period. Institutions making good progress toward their goals during the grant period may qualify for supplementary assistance for 2 years.

There are usually three major components in a university science development grant: Personnel, equipment, and facilities. As the institutions must also make substantial contributions to the development program, they assume the burden of partial or complete financing of one or more of these elements. The 10 institutions receiving grants in fiscal year 1966 proposed to allocate the funds as follows: Personnel, 41.1 percent; facilities, 30.5 percent; and equipment, supplies, and related items, 28.4 percent. By area of science, the percentages of proposed allocations were: Physics, 23.2; biological sciences, 16.5; chemistry, 12.6 engineering, 12.5; mathematics, 9.1; astronomy, 4.1; psychology, 3.5; geology, 3.3; and interdisciplinary programs, 15.2. Six grants contained funds for physics, six for mathematics, five for chemistry, three for biology, three for engineering, three for interdisciplinary programs, two for geology, one for astronomy, and one for psychology.

As in the first year of the program, university science development grants in fiscal year 1966 were awarded to institutions located in many areas of the Nation. Grants were made to institutions in six of the nine geographic divisions of the United States. Of the 17 institutions receiving grants since the inception of the program, 3 each are located in the Middle Atlantic, South Atlantic, East North Central, and West South Central divisions; 2 each in the Mountain and Pacific divisions; and 1 in the West North Central division. Thus, all but 2 geographic divisions (New England and East South Central) are represented by the 17 institutions.

While the program is too new to permit an adequate evaluation of its effectiveness, initial investigation has indicated two salutory effects. First is the profound psychological effect on a university of receiving a grant. It has resulted in other parts of the university, including those involved in nonscientific activities, raising their goals and aspirations. The other effect is that, even at those institutions failing to receive grants, the planning process involved in preparing a proposal for submission to the Foundation has stimulated the institution to make an introspective examination—to evaluate its own strengths and weaknesses, to take stock of its resources, human as well as material, and to consider most seriously its overall goals. This has been a very beneficial exercise for most institutions, and has led to the formulation of more realistic plans than might otherwise have been the case.

GRADUATE SCIENCE FACILITIES

The development of institutional strength requires heavy expenditures for science buildings. Through its Graduate Science Facilities Program, the Foundation assists universities and colleges in constructing or renovating laboratories and other facilities for basic research and graduate research training. This assistance, which requires at least equal matching with non-Federal funds, is sometimes extended in cooperation with other Federal agencies, and such joint funding is becoming more frequent. Since the funds available to the program are far too limited to meet the massive needs of colleges and universities for science facilities, the Foundation limits support to institutions that award graduate degrees in science, and places primary emphasis on the existing quality of science training and research programs in reaching its decisions.

In fiscal year 1966, the program received 114 facilities proposals requesting $56.6 million. Fifty-two grants were awarded, amounting to a total of 16.2 million. Some of these grants are for planning purposes; awards for construction would be considered in the following fiscal year.

The 52 facilities grants were allocated among disciplines as follows:

	Percent		*Percent*
Chemistry	25	Biophysics, biochemistry, and microbiology	7
Engineering	18	Earth and atmospheric sciences and astronomy	6
Plant sciences	16	Physics	2
Behavioral sciences	15	Mathematics	1
Animal Sciences	10		

Slightly more than half of the funds were allotted to the physical sciences, a drop from fiscal years 1960–65 when nearly two-thirds of the funds went to the physical sciences. Although this seems to be a reversal of the former upward trend in this program of support of the physical sciences, a single year's experience is not a decisive indication. Distribution of the funds may vary from year to year in accordance with the relative merit of proposals and the size of grants.

Since the inception of the program in 1960, the Foundation has made 833 facilities grants; 617 of the projects were completed by June 30, 1966.

Figure 34.—***Building C of Revelle College, University of California, San Diego.***

Figure 35.—***Engineering Science Building at the University of Texas.***

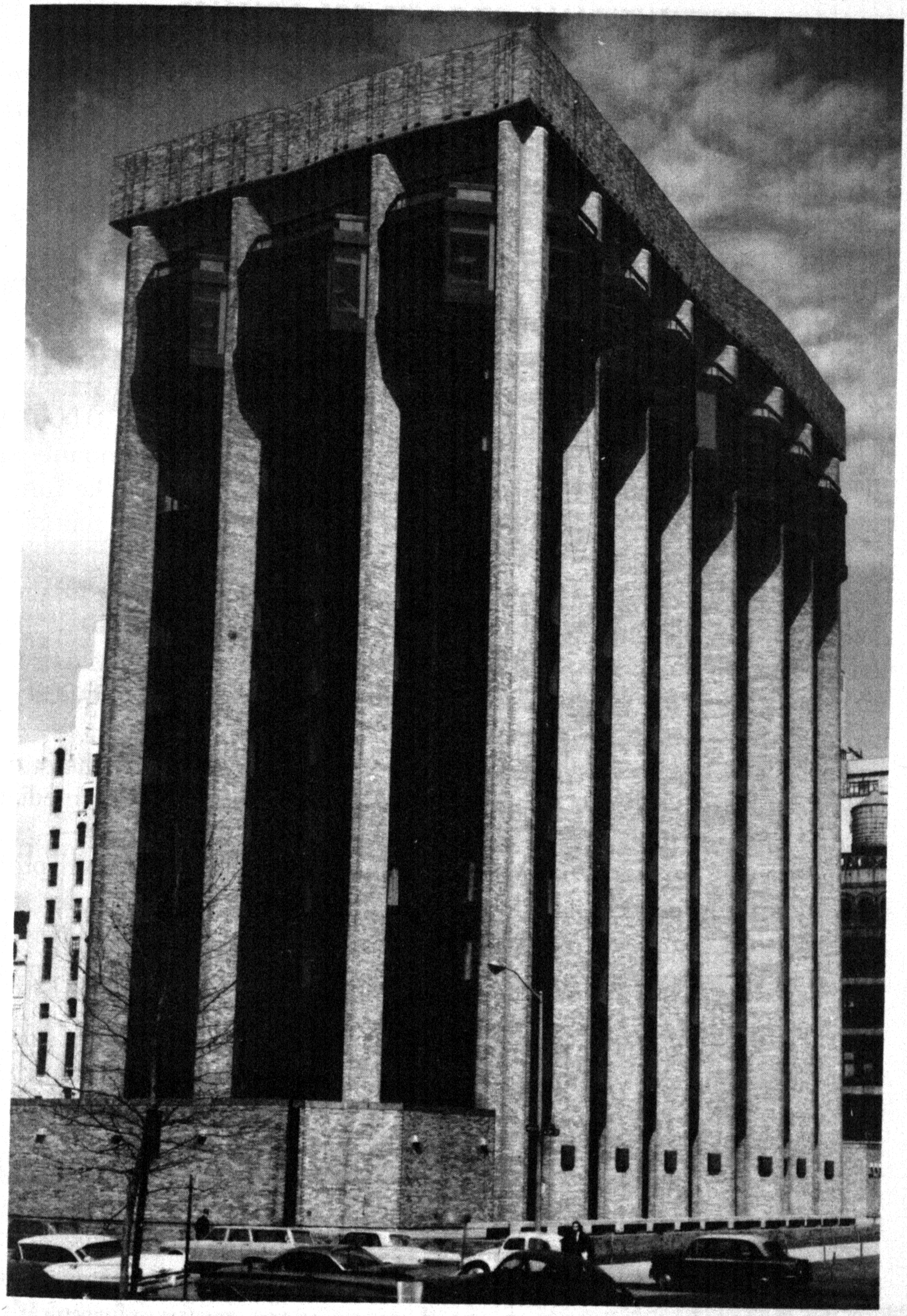

Figure 36.—*Warren Weaver Hall of the New York University.*

Increasing enrollments at colleges and universities throughout the United States have brought a need for new classroom and laboratory facilities. These photographs show a sample of new campus structures, the science portions of which have been aided by NSF grants.

INSTITUTIONAL GRANTS FOR SCIENCE

Colleges and universities need funds that can be used flexibly to maintain the quality of their science programs, to manage adjustments to changing conditions, and to take advantage of special opportunities. Such funds safeguard institutional autonomy, which is threatened if college and university officers lack resources for innovation and for the guidance and control of their institutional development.

The Foundation provides such funds to universities and colleges through its Institutional Grants Program. These grants are proportional to the amount of support the institutions have received from the Foundation's research programs and two programs of research training. A tapered formula provides for equal matching of the first $10,000 of the base, thus, especially benefiting institutions with small amounts of research grants. The institutions themselves determine how the funds will be spent for direct costs of scientific activities and report annually on the use of the funds.

In fiscal year 1966, the Foundation made institutional grants totaling more than $14.5 million to 401 colleges and universities in all 50 States, the District of Columbia, and Puerto Rico. The grants ranged from $700 to $154,728. Over four-fifths of the grants were for $10,000 or more, and 50 grants were larger than $100,000.

Since 1961, more than 550 institutions of higher education have received institutional grants totaling more than $50 million. The median award has risen from $1,220 in 1961 to $16,900 in 1966.

The grants are used for a variety of purposes: faculty research projects, student stipends, books and periodicals for science libraries, research travel, computer costs, and honoraria for visiting lecturers. Nearly half of the funds have been spent for research and instructional equipment.

The flexibility of the grants, even though they are relatively small, makes it possible for institutions to use them for important developmental purposes. For example, a university specializing in marine sciences accumulated institutional grant funds until it could make an award of $100,000 for an interdisciplinary program in ocean engineering. Through a combination of basic research and development, the university will attack the problem of marine corrosion, which causes a multibillion-dollar loss each year, seek the answers to unsolved questions of the flow of ocean currents, and develop new means of exploiting marine fisheries as a major source of food for the world's expanding population. Biological and physical scientists and engineers will work cooperatively upon fundamental problems whose solutions may result in widespread human benefits.

SCIENCE INFORMATION

The Foundation's science information activities are directed toward making the results of research readily available to this country's scientists and engineers. To reach this goal, the Foundation is concentrating its efforts on developing effective and comprehensive information systems serving the scientific disciplines, and establishing workable relationships between the information systems of the professional community and those largely mission-oriented systems maintained by Federal agencies. In furtherance of these efforts, NSF in fiscal year 1966 awarded 167 grants and contracts totaling about $11.6 million. Involved were 33 scientific societies, 34 universities and colleges, 4 library associations, 3 museums, 6 Federal agencies, and 6 international organizations.

Nature of the Problem

Science information has been compared to a natural resource without which the Nation's progress in science and technology would be slow or nonexistent. The efficient production, preservation, and exploitation of science information is complicated by many factors, including the rapid annual increase in scientific and technical literature (it has been said that the volume doubles every 15 years); the rising tendency toward fragmentation and specialization within scientific disciplines; lack of effective connections between information systems of one discipline and those of others; inadequacy of individual discipline-oriented systems to serve multidisciplinary information needs; and shortage of trained professional science information personnel.

Many scientific organizations and commercial firms operate information systems that serve relatively homogeneous populations of users. Many Federal agencies (e.g., HEW, NASA, AEC, Department of Agriculture) operate mission-oriented information systems. That much duplication of input and output effort occurs among Federal and non-Federal systems is accepted as a fact, and there is an urgent need to enlarge, modernize, and coordinate them.

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Improving Existing Systems

It is clear that the role most appropriate for the Foundation is the strengthening of discipline-oriented systems, and enabling those responsible for them to establish interconnections among and between them and the Federally operated systems. More than $6 million (52%) of the available fiscal year 1966 funds were expended in discipline-oriented activities.

Support was also given to the study of basic information processing problems, to both national and international organizations, involving both disciplinary and interdisciplinary information services, and to Federal information responsibilities that fall between discipline interests on the one hand and the mission interests on the other. Approximately $5.6 million were used to support these activities.

In the Federal area, the Foundation continued its support of the Science Information Exchange, the National Referral Center for Science and Technology, and at the same time initiated an evaluation and review of these services. It also participated in the activities of the Committee on Scientific and Technical Information (COSATI) of the Federal Council for Science and Technology.

In the non-Federal area, NSF provided assistance to the library associations (recognizing that library systems are a significant component in the total national information network or "national system"); established two university-based science information research centers—one at the University of California (Los Angeles) and the other at the Ohio State University; and provided funds for the establishment of a Committee on Scientific and Technical Communications (SATCOM) in the National Academy of Sciences-National Academy of Engineering.

The Foundation continued to provide modest financial support to the science information programs of international nongovernmental organizations, such as the International Federation for Documentation and the Abstracting Board of the International Council of Scientific Unions. In addition, it kept in close touch with international governmental organizations such as the Organization for Economic Cooperation and Development, and provided assistance to Federal agencies with responsibility for participation in international scientific and technical information activities. Support was continued for translations and for the preparation and publication of directories and guides that provide the U.S. scientist and engineer with information on foreign scientific organizations.

Developing National Systems

Largely as a result of the Foundation's stimulation and encouragement, often including financial assistance, considerable progress in the development of national information systems was noted during fiscal year 1966, including the following:

Chemistry.—The American Chemical Society continued its development of a chemical compound registry system and related automation of chemical information services. With respect to the broader aspect of a national chemical information system, the American Chemical Society initiated a program to develop an organizational capability to design and implement such a system.

Mathematics.—The American Mathematical Society has undertaken a study of communication between mathematicians and their need for various kinds of information and services.

Physics.—The American Institute of Physics has undertaken projects concerned with developing improved indexing techniques of the primary

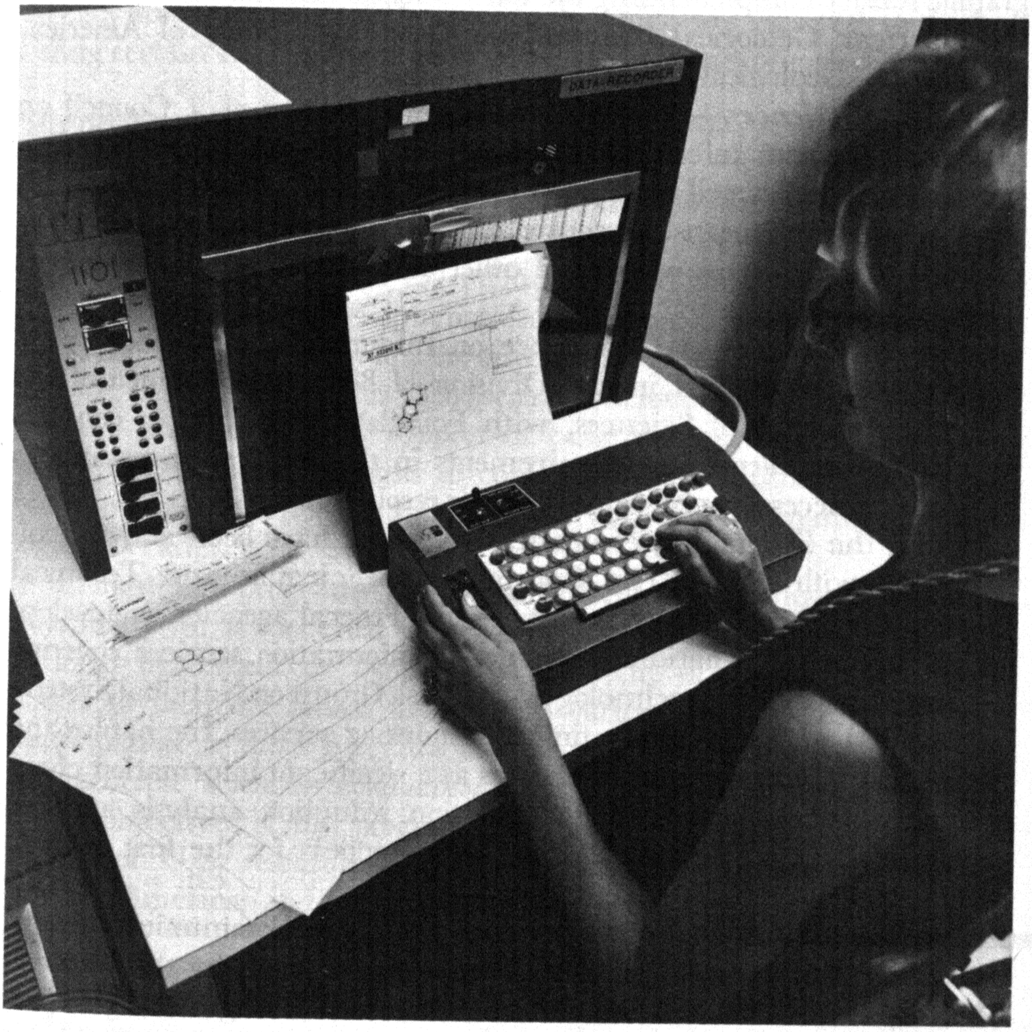

Figure 37.—***The National Science Foundation continues to support improvement in the storage and dissemination of scientific information. In an experimental project at Chemical Abstracts Service, complex chemical information is keyboarded directly onto magnetic tape by means of a data recorder. This is one of many steps in the automated system of collecting, analyzing, cataloging, and eventually disseminating chemical information.***

physics literature in order to make it responsive to the requirements of different groups of physicists and to apply these techniques to the secondary abstracting services that help subsequent retrieval. Such projects are particular examples of the AIP's larger efforts leading to a systematic resolution of the physicists' information requirements.

Engineering.—The three organizations (Engineers Joint Council, United Engineering Trust, and Engineering Index, Inc.) concerned with the information needs of the engineering profession have established a committee which has begun work on establishment of a national engineering information system. Continued support was provided for improvement of present engineering abstracting and indexing services during the year.

Environmental sciences.—A cooperative, computer-based bibliographic service comprehending the earth sciences has been established by the American Geological Institute, the Geological Society of America, and the U.S. Geological Survey.

Biological sciences.—A movement toward creation of a Council on Biological Sciences Information has advanced significantly. The purpose of such a Council is to improve biological communications and develop practical means of connecting the existing biological society information subsystems with each other and into a national biological information network.

Social sciences.—A Committee on Information in the Behavioral Sciences was established in the Division of Behavioral Science of the National Academy of Sciences, with Foundation support, to consider information problems and requirements in the social sciences and to recommend necessary programs for their resolution.

Within the Federal Government, two groups have been actively collaborating with NSF. The Committee on Scientific and Technical Information (COSATI), representing the Federal agencies, is developing guidelines for a national network of information services covering all areas of science and technology. Its Task Group on National Systems has initiated studies of abstracting and indexing services, the nature and role of oral informal communications as a significant information channel, and of the problems of data collection, reduction, analysis, and dissemination. The NSF provided financial support for the first of these studies.

The Committee on Scientific and Technical Communication was established during fiscal year 1966, with NSF support, by the National Academy of Sciences and the National Academy of Engineering to provide assurance that the total scientific community would have a voice in national systems planning. SATCOM has representatives from the major scientific disciplines and from the engineering societies.

INTERNATIONAL SCIENCE ACTIVITIES

International science activities of the National Science Foundation are of two general types: (*a*) those funded by NSF, which have the basic intent of strengthening U.S. science, and (*b*) those funded by the Agency for International Development, which are directed toward assisting certain foreign countries to develop their scientific resources.

Strengthening U.S. Science

By far the greater volume of NSF international activities arises within the Foundation's regular activities. For example, NSF National Research Programs (see page 45) include several which involve U.S. participation in cooperative international science activities, such as the Antarctic Research Program, the International Years of the Quiet Sun, and the United States-Japan Cooperative Science Program. The regular NSF programs for the support of basic research also afford opportunity for American scientists to cooperate in such other international programs as the Upper Mantle Project and the International Hydrological Decade.

International programs of this type become active when the need and desirability for a concerted effort have been given expression by international agreement or by the establishment of special international bodies to facilitate liaison among the various national efforts. U.S. participation in these programs consists principally of Federal support for academic scientists conducting their own research that contributes to the objectives of the program. There are, however, numerous instances of U.S. research in foreign lands and research collaboration between American and foreign scientists.

Research-Related Support

The regular support programs of the Foundation may provide funds for research conducted abroad or in collaboration with foreign scientists, for attendance at international scientific meetings, for international exchange of scientific information, and for participation in education and training programs. Few NSF grants are made to foreign institutions and only when exceptional conditions justify U.S. support to the foreign recipient. (In fiscal year 1966, there were 28 awards to foreign institutions totaling approximately $684,000.)

Although NSF awards are rarely made to international scientific organizations, U.S. organizations (principally the National Academy of Sciences) are provided support to maintain adequate representation of U.S. scientific interests in the deliberations and programs of private international scientific organizations, such as the International Council of Scientific Unions, the International Federation for Documentation, and the Pacific Science Association.

Education-Related Support

Contacts between individual American and foreign scientists are encouraged and supported through fellowship and exchange programs. Of the 4,336 fellowships awarded in fiscal year 1966 to U.S. citizens, 256 provided for tenure at a foreign institution; 66 U.S. citizens received NSF-administered North Atlantic Treaty Organization Fellowships for study in institutions of other NATO member countries. Under the NSF Senior Foreign Scientist Fellowship Program, provision was made for 51 American institutions to be visited by that number of eminent foreign scholars. Under the NSF-supported program for exchange of scientists between the National Academy of Sciences, U.S.A., and the Academy of Sciences, U.S.S.R., there was participation by 18 American and 23 Soviet scientists. Travel grants were provided to 67 young American scientists for attendance at 41 Advanced Study Institutes sponsored by NATO.

Other travel grants enabled approximately 646 American scientists to visit locations abroad, principally for the purpose of attending international scientific meetings. A total of 121 foreign educators were placed in NSF-sponsored teaching institutes held at various U.S. colleges and universities. In addition, a number of these institutes were served by visiting foreign lecturers.

Development Assistance Programs

Under the terms of a general agreement with the Agency for International Development (AID), the Foundation continues to help advance the state of science education in the developing areas of the world. This assistance is based in part on experience gained through Foundation-supported work in course content development and teacher training in the United States. Science educators in many of these nations are being helped in their attempts to adapt the new U.S. science materials for experimental use in their own countries.

Latin America

With funding from AID, the Foundation has since 1963 administered two science education programs, one in Central America, and the other in the remaining countries of Latin America.

The Central American program assists the Superior Council of the Central American Universities (CSUCA) to develop basic science and mathematics courses in the member universities. This program provides for visits of subject-matter specialists and for initiating short regional seminars for university professors.

An experimental project in the teaching of physics is being supported in which young physics professors from the Central American universities spend a year at the University of Texas where they receive specially designed training in physics courses for the junior and senior years of undergraduate education. In the beginning, the participants receive their training in Spanish; later they enter the regular classes of the university's physics department.

India

In February 1966, the Foundation was requested by the AID mission in New Delhi to assume the responsibility for a program of helping to improve science teaching in India. The Foundation's efforts will build upon the summer science institutes AID has sponsored in India for the past few years. To carry out its new commitments the Foundation has opened a liaison office in New Delhi. Foundation representatives will cooperate directly with Indian science educators and officials of the Indian Government in organizing and supervising the continuing summer science institutes, and in developing indigenous science teaching materials and projects.

International Organizations

The Foundation continues to act as a catalyst in developing more significant involvement of U.S. agencies in international organizations with broad scientific missions, such as the Organization for Economic Cooperation and Development (OECD) and UNESCO. It is responsible for coordinating the various interests of U.S. agencies in the science activities of such international organizations. The State Department is responsible for diplomatic activities.

SCIENCE POLICY PLANNING

The Foundation's science policy planning activities consist of three interrelated aspects: (*a*) Data collection, processing, and analysis; (*b*) internal agency program analysis, planning, and policy formulation; and (*c*) long-range planning and policy studies. These represent an integrated effort designed to produce more effective development and utilization of the Nation's resources for research and education in the sciences.

In fulfilling this purpose, the Foundation works closely with the Office of Science and Technology and with many other Federal and non-Federal organizations concerned with science.

The Foundation's interest and responsibility in science policy planning center on the effective development and utilization of two critical national resources for science: (*a*) Scientific, engineering, and related professional and technical manpower, and (*b*) institutions in which such manpower is educated and trained and in which research is conducted. Developed over a 15-year period, the continuing program of systematic collection and analysis of interrelated data concerning the allocation, deployment, and utilization of these science resources provides an essential base for science policy studies and program management. The data and analyses are of demonstrated value to the many science-oriented segments of the Executive Branch, the Congress, industry, universities, professional societies, the scientific community, and the public at large.

Scientific Manpower Studies

The Foundation is authorized and directed by its basic act to "provide a central clearinghouse for information covering all scientific and technical personnel." Since such data are collected by many Federal agencies, NSF has also been assigned "focal agency responsibility" to assure that projects and systems are coordinated and that the data will interlock.

Manpower Publications

During the fiscal year many periodic and special studies of scientific and technical manpower were made. Included were the compilation and analysis of data for a review of the entire area of college-trained technical manpower by a Congressional subcommittee. A comprehensive "fact book," *Scientific and Technical Manpower Resources,* was published, as were summaries of work in the manpower area in process in 11 agencies.

Among the significant findings reported during 1966 was the fact that while total earned doctorates awarded per year rose about 70 percent from 1960 to 1965, those in engineering rose more than 160 percent and in mathematics about 150 percent; however, even with these striking advances, total doctorates awarded in physical sciences, mathematics, and engineering rose only from 32 percent of all earned doctorates in 1960 to 34 percent in 1965.

National Register

Another major manpower activity required by basic legislation is the maintenance of the National Register of Scientific and Technical Personnel. Information gathered biennially by questionnaires to individual scientists and engineers provides a unique and invaluable source of detailed data. National Register information, derived from individual replies accumulated in computer systems, permits numerous types of cross-sectional, historical, and interrelational analyses. In addition, the Register provides a source for the identification and location of specialized personnel to meet national emergency requirements.

As the fiscal year closed, the 12 professional scientific societies that work with the National Register were distributing questionnaires to their members and other scientists. The new registration of scientists is expected to rise from about 225,000 to more than 300,000. Additional analyses, covering a 10-year span, were made from National Register records. These covered the geographical mobility of scientists as well as their mobility among fields. Many special tabulations were also prepared for use by various Government agencies.

With respect to engineers, plans were developed to requestion the 60,000 who were registered in 1964, and to send questionnaires to 100,000 additional engineers from membership lists of more than 40 engineering societies.

Science Funding Studies

The Foundation has responsibility for preparation and publication of the annual Government-wide *Federal Funds for Research, Development, and Other Scientific Activities.* The Foundation also conducts or supports many other serial or periodic studies, including the annual survey of research and development in industry performed by the Bureau of the Census with Foundation support. The latest reports in these series show a reduced growth rate in Federal support of research and development with, however, a smaller reduction in the growth rate for basic research support than in that for applied research and development. The studies also show that financing of research and development by the private industry sector has increased considerably.

Federal Funding for Academic Institutions

The Foundation has also been heavily involved in the implementation of a directive issued by the President on September 13, 1965. This declared that research support should seek not only scientific results but also be administered "with a view to strengthening academic institutions and increasing the number of institutions capable of performing research of high quality." In order to provide for implementation of the directive, the Federal Council for Science and Technology established a Committee on Academic Science and Engineering (CASE), chaired by the Director of the Foundation and furnished with NSF staff support. One product has been the design and implementation of the first Government-wide compatible reporting system concerning Federal support for universities and colleges on an institution-by-institution basis. It covers funds for research and development, R. & D. plant, institutional support, other science-related activities, and nonscience activities. The first report on these data was issued in October 1966. It shows that:

- Federal support was relatively heavy in institutions with large science and engineering programs.
- Nearly half of Federal support for colleges and universities was for research and development, and about one-twentieth for R. & D. plant.
- About one-quarter was for undergraduate facilities and other educational activities, such as fellowships and training in fields other than science.

Development work was also begun and considerable progress made by CASE on a second phase involving Federal funding reports on a project-by-project basis that will provide more detailed information in a more sophisticated format. This new system will make feasible a wide variety of additional analyses for planning and programing purposes.

The operational requirements of the CASE system emphasized the pressing need for a uniform categorization and coding system for academic institutions, systems of institutions, and branches. To meet this need the Foundation led a cooperative effort in the development of a single institutional directory to facilitate the storage and retrieval of all types of information relating to academic institutions. Agreements have now been reached among key Federal and non-Federal organizations on the basic framework for the new system, that initially will encompass all institutions of higher education in the United States.

Science Education Studies

Surveys were conducted concerning college freshmen, college graduates, graduate students, and science doctorates. Further progress of science graduates was also traced through career studies. Considerable progress was made on the analysis of recently acquired detailed information concerning doctoral education in the sciences—data on faculty, graduate students and their financial support, and types and levels of degrees awarded. Issued during the year, with partial Foundation support, was the American Council on Education study *An Assessment of Quality in Graduate Education.*

Institutional Development Studies

Three studies of university growth and development were continued. Their objective is the development of mathematical models of university cost structure and physical facilities, as well as university faculty, student body, and other factors. These and related studies should contribute to a better understanding of institutional development, both quantitatively and qualitatively. Also work was begun on a 2-year sponsored study of "The Outlook for Higher Education to 1980," including planning capabilities and goals, prospects for innovation, and forecasts of changes in student enrollments and faculty.

Studies of Non-Academic Institutions

A survey was made of science activities in nonacademic, nonprofit institutions, including research institutes, professional societies, and philanthropic foundations. Several major surveys and analyses were made of industrial research and development. In addition, arrangements have been made for improving exchange of policy and program information with large research-oriented industrial corporations, the National Industrial Conference Board, the Industrial Research Institute, and with such philanthropic foundations as Ford, Sloan, Rockefeller, Russell Sage, and the Carnegie Corp.

Studies are underway dealing with industrial adoption of new technological advances. Two conferences were supported by the Foundation—one dealing with research on creativity, continuing a series initiated in 1955; the other, with technology transfer and innovation.

Science Policy Studies

With respect to fundamental problems in the science policy field, studies were conducted by members of the Foundation staff and also performed by other organizations with Foundation support and coordination. Thus, continuing financial support of the National Academy of Sciences' Committee on Science and Public Policy (COSPUP) has resulted in three major reports issued during the year: *Chemistry: Oppor-*

tunities and Needs (the Westheimer Report), *Digital Computer Needs in Universities and Colleges* (the Rosser Report), and *Physics: Survey and Outlook* (the Pake Report).

During the year, a fourth report prepared under the auspices of COSPUP, *The Plant Sciences: Now and in the Coming Decade* (the Thimann Report), was also completed. Two new surveys covering the mathematical and life sciences were initiated.

Analytical studies are in process dealing with such policy-oriented subjects as mechanisms used by the Federal Government to support scientific research in universities; the patterns of Federal expenditures for academic science; resource allocation processes and decision points in the Federal Government; and criteria for resource allocation. Special attention is being given to the subject of institutional and geographic distribution of Federal funds in relation to scientific activities and manpower.

International Science Policy Planning

A major effort during the year consisted of preparation of a study of United States science policy for UNESCO's Science Policy Division. In addition, the Foundation provided the Organization for Economic Cooperation and Development with the United States data for the International Statistical Year and for the OECD study of international migration of scientists and engineers.

Three studies were completed or published during the fiscal year dealing with foreign science resources: *Scientific and Engineering Manpower in Communist China, Women in the Soviet Economy,* and *Scientific Manpower in the Arab Countries.*

Other Activities

The Foundation has begun to implement the Planning-Programing-Budgeting System (PPB), which was developed originally in the Department of Defense and had not before been applied formally in the civilian Federal agencies. Hence, the Foundation is pioneering in attempts to apply PPB to programs in support of basic research and education in the sciences. The results of this first attempt should assist in further development of the system. The initial effort has aided Foundation management in determining long-range needs in the allocation of resources among progams and activities, and in the evaluation of the effectiveness of ongoing and future operations.

NSF also acquired an IBM 360/30 computer system during the year, which will be of immense value in data storage, retrieval, and analysis of internal NSF and of Government-wide information pertaining to science and technology. The system will also provide necessary facilities for nationwide studies of science resources and programs, and will be of potentially great value for projections of trends and the evaluation of probable consequences of alternative program actions.

Finally, mention should be made of the preparation of special compilations and studies concerning past and present programs of the Foundation for the Subcommittee on Science, Research, and Development (Chairman, Representative Emilio Q. Daddario) of the House Committee on Science and Astronautics. The hearings resulted in a bill to amend the National Science Foundation Act, which passed the House of Representatives but did not come to a vote in the Senate during the 89th Congress. Its provisions, if enacted, would have considerably increased the Foundation's planning responsibilities and activities. In addition, recent proposals before the Congress and major problems being considered in the Executive Branch and elsewhere point clearly toward an increasingly urgent need for new and more comprehensive information and for important policy and planning studies.

APPENDIX A

National Science Board, Staff, Committees, and Advisory Panels

NATIONAL SCIENCE BOARD

Terms Expire May 10, 1968

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EDWARD L. TATUM, Professor, The Rockefeller University, New York, N.Y.
*RALPH W. TYLER (Vice Chairman), Director, Center for Advanced Study in the Behavioral Sciences, Stanford, Calif.

Terms Expire May 10, 1970

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JULIAN R. GOLDSMITH, Associate Dean, Division of the Physical Sciences, University of Chicago, Chicago, Ill.
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*Member Executive Committee.

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JULIUS A. STRATTON, Chairman of the Board, The Ford Foundation, New York, N.Y.

F. P. THIEME, Vice President, University of Washington, Seattle, Wash.

Terms Expire May 10, 1972

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ATHELSTAN F. SPILHAUS, Professor of Physics, University of Minnesota, Minneapolis, Minn.

RICHARD H. SULLIVAN, President, Reed College, Portland, Oreg.

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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Genetic Biology	Herman W. Lewis (Acting)
Section Head for Environmental and Systematic Biology	Robert K. Godfrey
Program Director:	
Environmental Biology	Robert F. Inger
Systematic Biology	Robert K. Godfrey (Acting)
Section Head for Molecular Biology	Eugene L. Hess
Program Director for:	
Biochemistry	David W. Krogmann
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Chief Scientist—Continued	
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National Register of Scientific and Technical Personnel	Milton Levine
Science Education Studies	(Vacant)
Scientific Manpower Studies	Norman Seltzer
Special Analysis	Robert W. Cain

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Charles Olmsted, Department of Botany, University of Chicago, Chicago, Ill.

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Nathan M. Newmark, Head, Department of Civil Engineering, University of Illinois, Urbana, Ill.
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Thomas F. Malone, Second Vice President, Research Department, Travelers Insurance Co., Hartford, Conn.
Arthur W. Murphy, Professor of Law, Columbia University Law School, New York, N.Y.
Summer T. Pike, Vice President, Trident Packing Co., Inc., Lubec, Maine

* This Commission was terminated as of December 1965.

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Laurence Irving, Director, Institute of Arctic Biology, University of Alaska, College, Alaska.

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Dell Hymes, Department of Anthropology, University of Pennsylvania, Philadelphia, Pa.

Irving Rouse, Department of Anthropology, Yale University, New Haven, Conn.

Lauriston Sharp, Department of Anthropology, Cornell University, Ithaca, N.Y.

Evon Z. Vogt, Department of Anthropology, Harvard University, Cambridge, Mass.

Advisory Panel for Astronomy

(Chairman: Marshal H. Wrubel)

Radio Astronomy

A. Edward Lilley, Harvard College Observatory, Cambridge, Mass.

Cornell H. Mayer, U.S. Naval Research Laboratory, Washington, D.C.

Gart Westerhout, Department of Physics and Astronomy, University of Maryland, College Park, Md.

Optical Astronomy

Armin J. Deutsch, Mount Wilson and Palomar Observatories, Pasadena, Calif.

George B. Field, Leuschner Observatory, University of California, Berkeley, Calif.

John T. Jefferies, Institute of Geophysics, University of Hawaii, Honolulu, Hawaii.

Donald E. Osterbrock, Washburn Observatory, University of Wisconsin, Madison, Wis.

George Wallerstein, Astronomy Department, University of Washington, Seattle, Wash.

Marshal H. Wrubel, Goethe Link Observatory, Indiana University, Bloomington, Ind.

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Alastair G. W. Cameron, Institute for Space Studies, National Aeronautics and Space Administration, New York, N.Y.

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Cecil E. Leith, Jr., Lawrence Radiation Laboratory, University of California, Livermore, Calif.

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Sanford S. Atwood, President, Emory University, Atlanta, Ga.

Rolf L. Bolin, Hopkins Marine Station, Stanford University, Pacific Grove, Calif.

S. F. Carson, Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

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Vernon I. Cheadle, Chancellor, University of California, Santa Barbara, Calif.

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Jerome Cox, Jr., Computer Research Laboratory, Washington University, St. Louis, Mo.

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Herbert Friedmann, Los Angeles County Museum, Los Angeles, Calif.

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Robert Hiatt, Vice President for Academic Affairs, University of Hawaii, Honolulu, Hawaii.

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Albert Rubenstein, Professor of Industrial Engineering, Northwestern University, Evanston, Ill.

Gardiner L. Tucker, Director of Research, International Business Machines Corp., Yorktown Heights, N.Y.

Ralph J. Watkins (Chairman), Vice President, Surveys and Research Corp., Washington, D.C.

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Drew Schwartz, Department of Botany, Indiana University, Bloomington, Ind.
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William L. Kissick, Chief, Division of Public Health Methods, Office of Surgeon General, Public Health Service, Washington, D.C.
Alexander Mood, Assistant Commissioner for Educational Statistics, U.S. Office of Education, Washington, D.C.
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George D. Mostow, Department of Mathematics, Yale University, New Haven, Conn.

Elias M. Stein, Department of Mathematics, Princeton University, Princeton, N.J.

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Melvin Cohn, Salk Institute for Biological Studies, San Diego, Calif.

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Leon Levintow, Department of Microbiology, University of California, School of Medicine, San Francisco, Calif.

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Philip Siekevitz, Rockefeller University, New York, N.Y.

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Parke A. Dickey, Department of Geology, University of Tulsa, Tulsa, Okla.

John Lyman, Bureau of Commercial Fisheries, Department of Interior, Washington, D.C.

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Lawson M. McKenzie, Scientific Laboratory, Ford Motor Co., Dearborn, Mich.

Hugh McManus, Department of Physics and Astronomy, Michigan State University, East Lansing, Mich.

George E. Pake, Washington University, St. Louis, Mo.

Gerald C. Phillips, Department of Physics, Rice University, Houston, Tex.

Arthur L. Schawlow, Department of Physics, Stanford University, Stanford, Calif.

Michael Tinkham, Department of Physics, University of California, Berkeley, Calif.

John S. Toll (Chairman), President's Office, State University of New York, Stony Brook, Long Island, N.Y.

Bernard Waldman, Department of Physics, University of Notre Dame, Notre Dame, Ind.

William D. Walker, Department of Physics, University of Wisconsin, Madison, Wis.

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George W. Barlow, Department of Zoology, University of Illinois, Urbana, Ill.

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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

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Bernard F. Burke, Carnegie Institution of Washington, Washington, D.C.

Paul Chenea, Division of Engineering Sciences, Purdue University, Lafayette, Ind.

L. J. Chu, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

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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., Observatory, University of Illinois, Urbana, Ill.

James H. Trexler, Naval Research Laboratory, Washington, D.C.

Advisory Panel for Regulatory Biology

Ira L. Baldwin, University of Wisconsin, Madison, Wis.

David W. Bishop, Department of Embryology, Carnegie Institution of Washington, Baltimore, Md.

Dietrich Bodenstein, Department of Biology, University of Virginia, Charlottesville, Va.

A. C. Braun, Rockefeller University, New York, N.Y.

Ian E. Bush, Worcester Foundation for Experimental Biology, Shrewsbury, Mass.

Milton Fingerman, Department of Biology, Tulane University, New Orleans, La.

H. O. Halvorson, Department of Agricultural Biochemistry, University of Minnesota, St. Paul, Minn.

A. Van Harreveld, Division of Biology, California Institute of Technology, Pasadena, Calif.

Teru Hayashi, Department of Zoology, Columbia University, New York, N.Y.

Graham Hoyle, Department of Biology, University of Oregon, Eugene, Oreg.

A. C. Leopold, Department of Horticulture, Purdue University, Lafayette, Ind.

George Sayers, Department of Physiology, School of Medicine, Western Reserve University, Cleveland, Ohio

Robert P. Scheffer, Department of Botany, Michigan State University, East Lansing, Mich.

Sidney Solomon, University of New Mexico, School of Medicine, Albuquerque, N. Mex.

Advisory Panel for Science Development

Carl W. Borgmann, Director, Program in Science and Engineering, The Ford Foundation, New York, N.Y.

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Dale R. Corson, Provost, Cornell University, Ithaca, N.Y.

Colgate W. Darden, Jr., Norfolk, Va.

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William B. Harrell, Vice President—Special Projects, University of Chicago, Chicago, Ill.

Lyle H. Lanier, Executive Vice President and Provost, University of Illinois, Urbana, Ill.

John R. Pierce, Executive Director, Research—Communications Sciences Division, Bell Telephone Laboratories, Murray Hill, N.J.

Advisory Panel for Sociology and Social Psychology

Albert H. Hastorf, Department of Psychology, Stanford University, Stanford, Calif.

Irving L. Janis, Department of Psychology, Yale University, New Haven, Conn.

Alan C. Kerckhoff, Department of Sociology, Stanford University, Stanford, Calif.

Gardner Lindzey, Department of Psychology, University of Texas, Austin, Tex.

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Ivan D. Steiner, Department of Psychology, University of Illinois, Urbana, Ill.

Guy E. Swanson, Department of Sociology, University of Michigan, Ann Arbor, Mich.

Percy H. Tannenbaum, Center for Advanced Study in the Behavioral Sciences, Stanford, Calif.

Advisory Panel for Systematic Biology

Kenton L. Chambers, Department of Botany and Plant Pathology, Oregon State University, Corvallis, Oreg.

Arthur J. Cronquist, New York Botanical Garden, Bronx, N.Y.

Joel W. Hedgpeth, Marine Science Laboratory, Newport, Oreg.

Terry W. Johnson, Department of Botany, Duke University, Durham, N.C.

Charles D. Michener, Department of Entomology, University of Kansas, Lawrence, Kans.

Everett C. Olson, Department of Geophysical Sciences, University of Chicago, Chicago, Ill.

Charles G. Sibley, Department of Biology, Yale University, New Haven, Conn.

James A. Slater, Department of Zoology and Entomology, University of Connecticut, Storrs, Conn.

Franklin Sogandares, Department of Biology, Tulane University, New Orleans, La.

Wilson N. Stewart, Department of Botany, University of Illinois, Urbana, Ill.

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Sidney Fernbach, Head, Computation Division, Lawrence Radiation Laboratory, Livermore, Calif.

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Paul Herget, Director of Observatory, University of Cincinnati, Cincinnati, Ohio

Frederick A. Matsen, Department of Chemistry, University of Texas, Austin, Tex.

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William R. Sears, Director, Center for Applied Mathematics, Cornell University, Ithaca, N.Y.

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Advisory Panel for Weather Modification

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Archie M. Kahan, Office of Atmospheric Water Resources, Bureau of Reclamation, Department of the Interior, Denver, Colo.

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Yale Mintz, Department of Meteorology, University of California, Los Angeles, Calif.

Bernard Vonnegut, Arthur D. Little, Inc., Acorn Park, Cambridge, Mass.

APPENDIX B

Financial Report for Fiscal Year 1966

SALARIES AND EXPENSES APPROPRIATION

RECEIPTS		
Appropriated for fiscal year 1966	$479, 999, 000	
Unobligated balance from fiscal year 1965	8, 524, 343	
Total availability		$488, 523, 343
OBLIGATIONS		
Support of Scientific Research:		
Basic Research Project Support:		
Biological and medical sciences	50, 084, 445	
Mathematical and physical sciences	56, 327, 999	
Engineering	18, 027, 844	
Social sciences	12, 223, 455	
Environmental sciences	21, 091, 544	
Subtotal	157, 755, 287	
Specialized Research Facilities:		
Specialized biological facilities	3, 542, 396	
Oceanographic research facilities	2, 370, 718	
University atmospheric research facilities	799, 776	
University physics research facilities	6, 495, 768	
Engineering research facilities	1, 175, 000	
Social sciences research facilities	771, 200	
Subtotal	15, 154, 858	
Specialized Research Equipment:		
Biological equipment	500, 000	
Chemistry research instruments	2, 360, 003	
University astronomy research instruments	1, 362, 750	
Subtotal	4, 222, 753	
National Research Programs:		
Antarctic research program	8, 362, 896	
Ocean sediment coring program	5, 400, 000	
Weather modification program	1, 851, 381	
United States-Japan cooperative program	708, 846	
Indian Ocean expedition	1, 067, 707	
International Year of the Quiet Sun	1, 617, 283	
Deep crustal studies of the earth (Mohole)	16, 970, 270	
Subtotal	35, 978, 383	

Support of Scientific Research—Continued		
National Research Centers:		
National Radio Astronomy Observatory	$4, 933, 730	
Kitt Peak National Observatory	6, 186, 270	
Cerro Tololo Inter-American Observatory	1, 425, 900	
National Center for Atmospheric Research	10, 471, 905	
Subtotal	23, 017, 805	
Subtotal, support of scientific research		$236, 129, 086
Science Education Support:		
Advanced Science Training for Individuals:		
Fellowships and traineeships	44, 484, 949	
Improvement of Quality of Instructional Programs:		
Course content improvement	15, 563, 952	
Instructional equipment for undergraduate students	7, 736, 045	
Cooperative college-school program	1, 957, 426	
Subtotal	25, 257, 423	
Improvement of Quality and Competence of Instructional Staff and Students:		
Supplemental training of teachers:		
Institutes	40, 530, 600	
Research participation	2, 100, 260	
Supplemental projects	882, 361	
Science education for students	8, 555, 365	
Special projects	2, 494, 267	
Subtotal	54, 562, 853	
Subtotal, science education support		124, 305, 225
Institutional Support for Science:		
Institutional Science Improvement:		
University science development	36, 375, 000	
Departmental science development	2, 367, 429	
Subtotal	38, 742, 429	
Maintaining Institutional Strength in Science:		
Institutional grants for science	14, 517, 899	
Graduate science facilities	16, 216, 676	
Academic computational facilities and operations	8, 899, 100	
Subtotal	39, 623, 675	
Subtotal, institutional support for science		78, 376, 104
Science Information Activities:		
Support of publications and services	5, 276, 067	
Systems development and improvement	2, 523, 070	
Science information research and studies	3, 646, 349	
Subtotal, science information activities		11, 445, 486

Planning and Policy Studies:		
Collection and evaluation of data on national resources for science and technology	$956, 317	
Studies related to policy in program planning	1, 052, 284	
Subtotal, planning and policy studies		$2, 008, 601
International Science Activities:		
International science support	136, 237	
International science exchange	763, 763	
Subtotal, international science activities		900, 000
Program Development and Management		13, 089, 082
Total, NSF		466, 253, 584
Allocations to other Government agencies		174, 600
Total obligations, fiscal year 1966		466, 428, 184
Transfer to other Government agencies		317, 979
Unobligated balance carried forward to fiscal year 1967		21, 777, 180
Total		488, 523, 343

TRUST FUND

Receipts

Unobligated balance from fiscal year 1965	7, 518
Donation from private sources	618
Total availability	8, 136

Obligations

Total obligations fiscal year 1966	229
Unobligated balance carried forward into fiscal year 1967	7, 907
Total	8, 136

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 six 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, royaltyfree worldwide license:

Patent No. 3,208,826 entitled "Method of Analyzing Water Samples for Deuterium Content" was issued on September 28, 1965, on an invention made by Edward M. Arnett during the course of research supported by grants to the University of Pittsburgh, Pittsburgh, Pa. The invention relates to a method of analyzing water samples for deuterium content by means employing a standard gas chromatography instrument.

Patent No. 3,221,062 entitled "Nitration Process" was issued on November 30, 1965, on an invention made by Oscar L. Wright during the course of research supported by grants to the Rockhurst College, Kansas City, Mo. This invention relates to the nitration of aromatic compounds, more particularly to nitration reactions wherein more than one reaction product is ordinarily obtainable.

Patent No. 3,230,643 entitled "Atomic Model" was issued on January 25, 1966 on an invention made by Gregory Mathus during the course of research supported by a grant to Harvard University, Cambridge, Mass. The invention relates to models for exhibiting certain physical characteristics of molecules.

Patent No. 3,244,969 entitled "Electron Orbiting Tubes for Ion Measurement and Gettering Pumps" and Patent No. 3,244,990 entitled "Electron Vacuum Tube Employing Orbiting Electrons" were issued on April 5, 1966, on inventions made by Raymond G. Herb and Theodore E. Pauly during the course of research supported by grants to the University of Wisconsin, Madison, Wis. These inventions relate to electron orbiting devices and pertain particularly to devices which have important applications to ion gages, electrometer tubes, amplifying devices, and ion-getter vacuum pumps.

Patent No. 3,261,274 entitled "Underwater Camera and Recovery Apparatus" was issued on July 19, 1966, on an invention made by Logan O. Smith during the course of research supported by grants to the University of Southern California, Los Angeles, Calif. This invention relates to an underwater camera and recovery apparatus which is adapted to recover samples of the subject matter photographed by the camera.

APPENDIX D

National Science Foundation-Supported Scientific Conferences, Symposia, and Advanced Science Seminars Held During Fiscal Year 1966

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE BIOLOGICAL AND MEDICAL SCIENCES

ENVIRONMENTAL INFLUENCES ON REPRODUCTION PROCESSES.—Michigan State University, East Lansing, Mich.; July 30–31, 1965; Chairman: William Hansel, Cornell University; Sponsor: American Society of Animal Science.

XII INTERNATIONAL ENTOMOLOGICAL CONGRESS.—London, England; July 8–16, 1965; Chairman: R. H. Nelson, Entomological Society of America; Sponsor: Entomological Society of America.

X INTERNATIONAL BOTANICAL CONGRESS.—Edinburgh, Scotland; Aug. 3–12, 1965; Chairman: B. L. Turner, University of Texas; Sponsor: Botanical Society of America.

SYMPOSIA OBSERVING THE MENDEL CENTENNIAL.—Fort Collins, Colo.; Sept. 8–11, 1965; Chairman: R. A. Brink, University of Wisconsin; Sponsor: Genetics Society of America.

SYMPOSIUM ON THE ROLE OF COPPER IN BIOLOGY.—Harriman, N.Y.; Sept. 8–10, 1965; Chairman: Jack Peisach, Yeshiva University; Sponsor: Albert Einstein College of Medicine, Yeshiva University.

CONFERENCE ON YEAST GENETICS.—Seattle, Wash.; Sept. 13–14, 1965; Chairman: Herschel L. Roman, University of Washington; Sponsor: University of Washington.

SYMPOSIUM ON THE NATURE AND STRUCTURE OF ANTIBODIES AND GAMMA GLOBULIN.—New York, N.Y.; Sept. 13, 1965; Chairman: William Stein, Rockefeller University; Sponsor: American Chemical Society.

SYMPOSIUM ON PROTEIN STRUCTURE.—New York, N.Y.; Sept. 14, 1965; Chairman: William Harrington, Johns Hopkins University; Sponsor: American Chemical Society.

SYMPOSIUM ON OSCILLATORY REACTIONS IN CELLULAR CHEMISTRY.—New York, N.Y.; Sept. 14, 1965; Chairman: Britton Chance, University of Pennsylvania; Sponsor: American Chemical Society.

SYMPOSIUM ON DETERMINANTS ON PROTEIN CONFORMATIONS.—New New York, N.Y.; Sept. 14, 1965; Chairman: C. B. Anfinsen, National Institutes of Health; Sponsor: American Chemical Society.

SYMPOSIUM ON SYSTEMATICS.—St. Louis, Mo.; Oct. 15–16, 1965; Chairman: H. C. Cutler, Missouri Botanical Garden; Sponsor: Missouri Botanical Garden.

International Congress for Chemotherapy.—Washington, D.C.; Oct. 17–21, 1965; Chairman: David Perlman, Squibb Institute for Medical Research; Sponsor: American Society for Microbiology.

Regional Meetings of the Society for Development Biology:

I. Problems in growth and differentiation.—Alta, Utah; Oct. 15–17, 1965; Chairman: E. W. Hanly, University of Utah; Sponsor: University of Utah.

II. Growth and differentiation.—Notre Dame, Ind.; March 17–18, 1966; Chairmen: Julian Haynes and Kenyon Tweedell, University of Notre Dame; Sponsor: University of Notre Dame.

III. Frontiers in developmental biology: Regulatory Mechanisms in and Analysis of Differentiation.—Storrs, Conn.; Apr. 7–9, 1966; Chairmen: H. Laufer and L. Pierro, University of Connecticut; Sponsor: University of Connecticut.

IV. Organellogenesis.—Ames, Iowa; May 19–21, 1966; Chairmen: John Arnold and L. Evans Roth, State University of Iowa; Sponsor: State University of Iowa.

Verbal Behavior Theory and its Relation to General Stimulus-Response Theory.—Lexington, Ky.; Mar. 12–15, 1966; Chairman: Theodore Dixon, University of Kentucky; Sponsor: The University of Kentucky Research Foundation.

A Symposium on the Mechanisms of Sensitivity and Resistance to Antibacterical Agents.—Atlantic City, N.J.; Apr. 12, 1966; Chairman: Jack Strominger, University of Wisconsin; Sponsor: American Society for Pharmacology and Experimental Therapeutics, Inc.

Theoretical Issues in the Experimental Analysis of Behavior.—Tempe, Ariz.; Apr. 15–17, 1966; Chairman: Arthur J. Bachrach, Arizona State University; Sponsor: Arizona State University.

Conference on Lateral Line Detectors.—New York, N.Y.; Apr. 18–19, 1966; Chairman: Phyllis H. Cahn, Yeshiva University; Sponsor: Yeshiva University.

A Symposium on the Structure and Function of Bacterial Surfaces.—Los Angeles, Calif.; May 3, 1966; Chairmen: Jack Strominger, University of Wisconsin, and Milton Salton, New York University; Sponsor: American Society for Microbiology.

Second Conference on Lens Differentiation.—Morgantown, W. Va.; May 3–5, 1966; Chairman: Randall Reyer, West Virginia University; Sponsor: West Virginia University.

Third Neurospora Information Conference.—Oak Ridge, Tenn.; May 12–14, 1966; Chairman: Rowland W. Davis, University of Michigan; Sponsor: University of Michigan.

The Theory of Temporal Factors in Vision and Visual Perception.—Rochester, N.Y.; June 6–8, 1966; Chairman: Robert M. Boynton, University of Rochester; Sponsor: University of Rochester.

SYMPOSIUM ON EUTROPHICATION.—Madison, Wis.; June 11–16, 1967; Chairman: Gerard A. Rohlich, University of Wisconsin; Sponsor: National Academy of Sciences-National Research Council.

THIRTY-FIRST COLD SPRING HARBOR SYMPOSIUM.—Cold Spring Harbor, Long Island, N.Y.; June 2–9, 1966; Chairman: John Cairns, Cold Spring Harbor Laboratory of Qantitative Biology; Sponsor: Cold Spring Harbor Laboratory of Quantitative Biology.

TWENTY-FIFTH ANNUAL MEETING OF THE SOCIETY FOR DEVELOPMENTAL BIOLOGY.—Haverford, Pa.; June 15–17, 1966; Chairman: Howard Schneiderman, Western Reserve University; Sponsor: The Society for Developmental Biology.

SYMPOSIUM ON THE SYSTEMATICS OF SNAKES OF THE FAMILY COLUBRIDAE.—Miami Beach, Fla.; June 20, 1966; Chairman: Kenneth S. Norris, University of California, Los Angeles; Sponsor: Herpetologists' League.

GORDON RESEARCH CONFERENCE ON NUCLEIC ACIDS.—New Hampton, N.H.; June 20–24, 1966; Chairman: Paul Berg, Stanford University; Sponsor: Gordon Research Conferences, Inc.

GORDON RESEARCH CONFERENCE ON INTERACTION AND TRANSPORT IN PHYSICAL, CHEMICAL, AND BIOLOGICAL SYSTEMS.—Andover, N.H.; June 20–24, 1966; Chairman: Fred Snell, University of Buffalo; Sponsor: Gordon Research Conferences, Inc.

GORDON RESEARCH CONFERENCE ON PROTEINS.—New Hampton, N.H.; June 27–July 1, 1966; Chairman: William Stein, Rockefeller University; Sponsor: Gordon Research Conferences, Inc.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE ENGINEERING SCIENCES

CONFERENCE ON THE APPLICATION OF ENGINEERING PROBLEMS TO APPALACHIA.—Morgantown, W. Va.; Aug. 2–5, 1965; Chairman: Chester A. Arents, West Virginia University; Sponsors: Engineering Foundation and West Virginia University.

SPECIAL LECTURE AT THE EIGHTH NATIONAL HEAT TRANSFER CONFERENCE.—Los Angeles, Calif.; Aug. 8–11, 1965; Chairman: A. D. Kraus, Honeywell Aeronautical Division; Sponsors: American Society of Mechanical Engineers and American Institute of Chemical Engineers.

NATIONAL CONFERENCE ON CREATIVE ENGINEERING EDUCATION.—Woods Hole, Mass.; Sept. 1–4, 1965; Chairman: Charles Stark Draper, Massachusetts Institute of Technology; Sponsors: U.S. Department of Commerce and National Academy of Engineering.

STUDY AND SYMPOSIA ON PERFORMANCE CONCEPT IN BUILDING.—Chicago, Ill.; Oct. 26–27, 1965, and New Orleans, La., Mar. 29–30, 1966; Chairman : Phillip Will, Jr.; Perkins and Will, Chicago, Ill.; Sponsors: National Research Council-Building Research Advisory Board.

Symposium on the Mechanics of Viscoelastic Fluids.—Philadelphia, Pa.; Dec. 5–9, 1965; Chairmen: A. B. Metzner, University of Delaware, and D. G. Thomas, Oak Ridge National Laboratory; Sponsor: American Institute of Chemical Engineers.

Conference on Earthquake Engineering Research.—Pasadena, Calif.; Dec. 20, 1965; Chairman: D. E. Hudson, California Institute of Technology; Sponsor: California Institute of Technology.

International Symposium on Spatial Aerial Triangulation.—Urbana, Ill.; Feb. 28–Mar. 4, 1966; Chairman: H. M. Karara, University of Illinois; Sponsor: American Society of Photogrammetry.

Conference on Recent Contributions in Shell Theory.—Houston, Tex.; Apr. 4–6, 1966; Chairman: D. Muster, University of Houston; Sponsor: University of Houston.

Conference on Marine Geotechnique.—Urbana, Ill.; May 1–4, 1966; Chairmen: Adrian F. Richard, University of Illinois, and Wyman Harrison, Coast and Geodetic Survey; Sponsor: University of Illinois.

Symposia on Aspects of Chemical Engineering.—Columbus, Ohio; May 15–18, 1966; R. B. Filbert, Battelle Memorial Institute; Sponsor: American Institute of Chemical Engineers.

Conference on Standardization of the Measurement of Sediment Flow.—New York, N.Y.; May 23–24, 1966; Chairman: Sri K. K. Framji, India; Sponsor: American Standards Association.

Fifth U.S. National Congress on Applied Mechanics.—Minneapolis, Minn.; June 14–17, 1966; Chairman: Professor B. J. Lazan, University of Minnesota; Sponsors: University of Minnesota and U.S. National Committee on Theoretical and Applied Mechanics.

International Institute of Refrigeration, Commission I Meeting.—Boulder, Colo.; June 16–18, 1966; Chairman: K. D. Timmerhaus, University of Colorado; Sponsors: University of Colorado, National Bureau of Standards, and International Institute of Refrigeration.

1966 Conference on Precision Electromagnetic Measurements.—Boulder, Colo.; June 21–24, 1966; Chairman: John T. Henderson, National Research Council; Sponsors: National Bureau of Standards, Institute of Electrical and Electronics Engineers, and International Scientific Radio Union.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE ENVIRONMENTAL SCIENCES

Weather Modification Section of the Fifth Berkeley Symposium on Mathematical Statistics and Probability.—Berkeley, Calif.; June 21–July 18, 1965, and Dec. 27–28, 1965; Chairmen: Lucien M. LeCam and Jerzy Neyman, University of California, Berkeley; Sponsor: University of California, Berkeley.

Symposium on the Economic and Social Aspects of Weather Modification.—Boulder, Colo.; July 8–10, 1965; Chairman: W. R. Derrick Sewell, University of Chicago; Sponsors: University of Chicago and National Center for Atmospheric Research.

1965 NATIONAL CLAY MINERALS CONFERENCE.—Berkeley, Calif.; Aug. 23-26, 1965; Chairman: Joseph A. Pask, University of California, Berkeley; Sponsors: Clay Minerals Society and University of California, Berkeley.

THE SEVENTH INTERNATIONAL CONGRESS OF THE INTERNATIONAL ASSOCIATION OF QUATERNARY RESEARCH.—Boulder and Denver, Colo.; Aug. 30-Sept. 5, 1965; Chairman: Gerald M. Richmond, U.S. Geological Survey, Denver; Sponsors: National Academy of Sciences-National Research Council, Office of Naval Research, Air Force Office of Scientific Research, and private industry.

FIRST NATIONAL SYMPOSIUM ON HAIL SUPPRESSION.—Dillon, Colo.; Oct. 14-16, 1965; Chairmen: Verner E. Suomi, University of Wisconsin, and Guy G. Goyer, National Center for Atmospheric Research; Sponsor: National Center for Atmospheric Research.

SYMPOSIUM ON TIME AND STRATIGRAPHIC PROBLEMS IN THE EVOLUTION OF MAN.—Washington, D.C.; Oct. 16, 1965; Chairman: M. G. Wolman, Johns Hopkins University; Sponsors: National Academy of Sciences-National Research Council and Wenner-Gren Foundation.

INTERNATIONAL CONFERENCE ON TROPICAL OCEANOGRAPHY.—Miami Beach, Fla.; Nov. 17–24, 1965; Chairman: Fritz Koczy, University of Miami; Sponsor: University of Miami.

IUTAM SYMPOSIUM ON ROTATING FLUID SYSTEM.—La Jolla, Calif.; Mar. 28-Apr. 1, 1966; Chairman: George Carrier, Harvard University; Sponsors: International Union of Theoretical and Applied Mechanics and University of California, San Diego.

SIXTH INTERNATIONAL CONFERENCE ON CONDENSATION NUCLEI.—Albany, N.Y., and University Park, Pa.; May 9–11 and May 12–13, 1966; Chairman: Vincent J. Schaefer, State University of New York; Sponsors: State University of New York, Albany, Pennsylvania State University, International Association for Meteorology and Atmospheric Physics of the International Union of Geodesy and Geophysics, and the American Society for Testing Materials.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE MATHEMATICAL AND PHYSICAL SCIENCES

FIFTH BERKELEY SYMPOSIUM ON MATHEMATICAL STATISTICS.—Berkeley, Calif.; June 21–July 18, 1965; Chairmen: Lucien LeCam and Jerzy Neyman, University of California, Berkeley; Sponsors: Office of Naval Research, Air Force Office of Scientific Research, and University of California, Berkeley.

POSITRON ANNIHILATION CONFERENCE.—Detroit, Mich.; July 27–29, 1965; Chairman: Leonard O. Roellig, Wayne State University; Sponsors: University of North Carolina, Advance Research Projects Agency, Army Research Office—Durham, National Aeronautics and Space Administration, and Wayne State University.

Gordon Research Conference on Photonuclear Reactions.—Tilton, N.H.; Aug. 9–13, 1965; Chairman: W. D. Whitehead, University of Virginia, and Vice Chairman: George R. Bishop, Ecole Normale Superieure, Orsay, France; Sponsors: Air Force Office of Scientific Research and Gordon Research Conferences, Inc.

Canadian Mathematical Congress and Seminar, 1965.—Quebec, Canada; Aug. 16–Sept. 7, 1965; Chairman: Leland F. S. Ritcey, Canadian Mathematical Congress; Sponsor: Canadian Mathematical Congress.

Gordon Research Conference on Nuclear Structure and Nuclear Models.—Meriden, N.H.; Aug. 23–27, 1965; Chairman: Steven A. Moszkowski, University of California, Los Angeles; Sponsor: Gordon Research Conferences, Inc.

Colloquium on Interstellar Grains.—Troy, N.Y.; Aug. 24–26, 1965; Chairman: J. Mayo Greenberg, Rensselaer Polytechnic Institute; Sponsors: State University of New York, National Aeronautics and Space Administration, and Rensselaer Polytechnic Institute.

Second International Symposium on Organometallic Chemistry.—Madison, Wis.; Sept. 1–5, 1965; Chairman: Robert C. West, University of Wisconsin; Sponsors: Army Research Office—Durham, and University of Wisconsin.

International Color Center Symposium.—Urbana, Ill.; Oct. 11–13, 1965; Chairman: W. Dale Compton, University of Illinois; Sponsors: Harshaw Chemical Company, Atomic Energy Commission, Advanced Research Projects Agency, and University of Illinois.

Conference on Uses of Electronic Computers in Chemistry.—Bloomington, Ind.; Nov. 1–2, 1965; Chairman: Harrison Shull, Indiana University; Sponsors: National Academy of Sciences-National Research Council and Indiana University.

Fourth Eastern United States Theoretical Physics Conference.—Stony Brook, N.Y.; Nov. 26–27, 1965; Chairman: Max Dresden, State University of New York; Sponsor: State University of New York, Stony Brook.

Conference on Observational Aspects of Cosmology.—Coral Gables, Fla.; Dec. 15–17, 1965; Chairman: S. Fred Singer, University of Miami; Sponsors: National Aeronautics and Space Administration, Office of Naval Research, and University of Miami.

New Mexico State University Mathematics Symposia.—University Park, N. Mex.; Dec. 1965–Jan. 1966; Chairman: Ralph B. Crouch, New Mexico State University; Sponsor: New Mexico State University.

Third Coral Gables Conference on Symmetry Principles at High Energy.—Coral Gables, Fla.; Jan. 20–22, 1966; Chairman: Behram Kursunoglu, University of Miami; Sponsors: Air Force Office of Scientific Research, National Aeronautics and Space Administration, Office of Naval Research, Atomic Energy Commission, and University of Miami.

Scientific Conference on Intermediate Energy Physics.—Williamsburg, Va.; Feb. 10–12, 1966; Chairman: Robert T. Siegel, College of William and Mary; Sponsors: Air Force Office of Scientific Research, Atomic Energy Commission, National Aeronautics and Space Administration, and College of William and Mary.

Conference on Topology.—Ann Arbor, Mich.; Mar. 10–12, 1966; Chairman: Frank A. Raymond, University of Michigan; Sponsor: University of Michigan.

Conference on a Review of Modern Optics.—Washington, D.C.; Mar. 14, 1966; Chairman: R. Madden, National Bureau of Standards; Sponsor: Optical Society of America.

Conference on Isobaric Spin in Nuclear Physics.—Tallahassee, Fla.; Mar. 17–19, 1966; Chairmen: John D. Fox and D. Robson, Florida State University; Sponsors: Air Force Office of Scientific Research, Atomic Energy Commission, and Florida State University.

Symposium on Singular Integrals.—Chicago, Ill.; Apr. 21–23, 1966; Chairman: Alberto P. Calderon, American Mathematical Society; Sponsor: American Mathematical Society.

Conference on High Energy Two-Body Reactions.—Stony Brook, N.Y.; Apr. 22–23, 1966; Chairman: Max Dresden, State University of New York, Stony Brook; Sponsor: State University of New York, Stony Brook.

The 1966 Midwest Conference on Theoretical Physics.—Bloomington, Ind.; May 20–21, 1966; Chairman: D. B. Lichtenberg, Indiana University; Sponsor: Indiana University.

Otto Struve Memorial Symposium.—Marfa and Mount Locke, Tex.; May 27–28, 1966; Chairman: David S. Evans, University of Texas; Sponsor: University of Texas.

Gordon Research Conference on Nuclear Structure Physics.—Andover, N.H.; June 13–17, 1966; Chairman: Harry E. Gove, University of Rochester; Sponsor: Gordon Research Conferences.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE SOCIAL SCIENCES

Research Conference on Political Data.—Ann Arbor, Mich.; July 26–Aug. 13, 1965; Chairman: Warren E. Miller, University of Michigan; Sponsor: Interuniversity Consortium for Political Research.

Conference on the Sociology of the Intellectual.—Rochester, Mich.; May 5–8, 1966; Chairman: Jesse R. Pitts, Oakland University; Sponsor: Oakland University.

Conference on the Prehistoric Ceramics of the Maya Lowlands.—Guatemala City, Guatemala; Aug. 6–14, 1965; Chairman: Gordon R. Willey, Harvard University; Sponsor: University of Arizona.

Conference on Indo-European Linguistics and the Indo-Europeans.—Philadelphia, Pa.; Nov. 29–Dec. 1, 1965; Chairman: Henry M. Hoenigswald, University of Pennsylvania; Sponsor: University of Pennsylvania.

Conference on Neurophysiology in the 17th Century.—Copenhagen, Denmark; Aug. 18–19, 1965; Chairman: G. Scherz; Sponsor: Brain History Committee of the International Brain Research Organization.

ADVANCED SCIENCE SEMINARS

International Field Institute.—Brazil; June 18–Aug. 1, 1966; Director: J. Van N. Dorr II, U.S. Geological Survey, Washington, D.C.; Grantee: American Geological Institute.

Seminar on Relativity Theory and Astrophysics.—Ithaca, N.Y.; July 25–Aug. 30, 1965; Director: G. L. Walker, American Mathematical Society, Providence, R.I.; Grantee: American Mathematical Society.

Symposium on Recent Advances in the Analysis of Differentiation.—Urbana, Ill.; Aug. 18, 1965; Director: C. S. Thornton, Michigan State University; Grantee: American Society of Zoologists.

Advanced Seminar in Algebra: Algebraic Number and Class Field Theory.—Brunswick, Maine; June 21–Aug. 11, 1966; Director: D. E. Christie, Bowdoin College; Grantee: Bowdoin College.

A Summer Field Program in Anthropology.—Trinidad; June 15–Sept. 15, 1966; Director: R. A. Manners, Brandeis University; Grantee: Brandeis University.

Summer Seminar in Theoretical Physics.—Waltham, Mass.; June 20–July 29, 1966; Director: M. Chretien, Brandeis University; Grantee: Brandeis University.

Institute of Glaciological Sciences.—Juneau Icefield, Alaska; July 24–Sept. 4, 1965; Director: M. M. Miller, Michigan State University; Grantee: Michigan State University.

Seminar Series in Quantitative Geography.—Sept. 1, 1965–Aug. 30, 1968; Director: M. F. Dacey, Northwestern University; Grantee: Northwestern University.

Advanced Science Seminar on Forest Hydrology.—University Park, Pa.; Aug. 29–Sept. 10, 1965; Director: P. W. Fletcher, Pennsylvania State University; Grantee: Pennsylvania State University.

Advanced Science Seminar in Dynamical Astronomy.—Stanford, Calif.; July 5–Aug. 13, 1965; Director: D. Brouwer, Yale University; Grantee: Stanford University.

Field Training for Anthropologists.—Oaxaca, Mexico; June 20–Aug. 26, 1966; Director: B. A. Gerow, Stanford University; Grantee: Stanford University.

Summer Program in Geophysical Fluid Dynamics.—Woods Hole, Mass.; June 27–Sept. 2, 1966; Director: W. V. R. Malkus, University of California, Los Angeles; Grantee: Woods Hole Oceanographic Institution.

Advanced Field Training Program in Archeology.—Grasshopper, Ariz.; June 10–Aug. 5, 1966; Director: R. H. Thompson, University of Arizona; Grantee: University of Arizona.

ADVANCED SCIENCE SEMINAR IN LINGUISTICS.—Los Angeles, Calif.; June 20–Aug. 13, 1966; Director: J. Puhvel, University of California, Los Angeles; Grantee: University of California, Los Angeles.

BIOLOGICAL ADAPTATIONS TO DESERT ENVIRONMENTS.—Riverside, Calif.; June 13–25, 1966; Director: E. B. Edney, University of California, Riverside; Grantee: University of California, Riverside.

ENERGY EXCHANGE IN MOLECULAR SYSTEMS.—Chicago, Ill.; May 12–13, 1966; Director: N. H. Nachtrieb, University of Chicago; Grantee: University of Chicago.

INSTITUTE FOR THEORETICAL PHYSICS.—Boulder, Colo.; June 20–Aug. 26, 1966; Director: W. E. Brittin, University of Colorado; Grantee: University of Colorado.

NONLINEAR PARTIAL DIFFERENTIAL EQUATIONS—A SYMPOSIUM ON METHODS OF SOLUTION.—Newark, Del.; Dec. 27–29, 1965; Director: W. F. Ames, University of Delaware; Grantee: University of Delaware.

ADVANCED SCIENCE SEMINAR ON ENERGETICS IN METALLURGICAL PHENOMENA.—Denver, Colo.; June 20–Aug. 12, 1966; Director: C. B. Magee, University of Denver; Grantee: University of Denver.

WINTER SEMINAR IN QUANTUM CHEMISTRY, SOLID-STATE PHYSICS, AND QUANTUM BIOLOGY.—Gainesvilla, Fla.; Dec. 13, 1965–Jan. 22, 1966; Director: P. O. Löwdin, University of Florida; Grantee: University of Florida.

STATISTICS AND STATISTICAL METHODS IN THE SOCIAL AND INDUSTRIAL SCIENCES.—Athens, Ga.; June 13–July 22, 1966; Director: A. C. Cohen, Jr., University of Georgia; Grantee: University of Georgia.

FIELD METHODS FOR SYSTEMATIC VERTEBRATE ZOOLOGISTS AND PALEONTOLOGISTS.—New Mexico, Montana, and Alberta, Canada; June 6–July 16, 1966; Director: E. R. Hall, University of Kansas; Grantee: University of Kansas.

LATIN AMERICAN SCHOOL OF PHYSICS.—Mexico City, Mexico; July 26–Aug. 28, 1965; Director: M. Moshinsky, National University of Mexico; Grantee: National University of Mexico.

ADVANCED SCIENCE SEMINARS ON QUANTITATIVE POLITICAL SCIENCE RESEARCH.—Ann Arbor, Mich.; June 15–Aug. 15, 1966; Director: W. E. Miller, University of Michigan; Grantee: University of Michigan.

CONFERENCE ON THE CRYSTAL STRUCTURE AND CRYSTAL CHEMISTRY OF ROCK-FORMING SILICATES.—Minneapolis, Minn.; Sept. 13–17, 1965; Director: T. Zoltai, University of Minnesota; Grantee: University of Minnesota.

SUMMER SEMINAR IN HIGHER MATHEMATICS.—Montreal, Canada; June 27–July 29, 1966; Director: L. F. S. Ritcey, Canadian Mathematical Congress, Montreal, Canada; Grantee: Canadian Mathematical Congress.

FIELD TRAINING FOR ANTHROPOLOGISTS.—Flagstaff, Ariz.; June 13–Sept. 2, 1966; Director: W. L. d'Azevedo, University of Nevada; Grantee: University of Nevada.

FIELD TRAINING IN ANTHROPOLOGY.—Puebla, Mexico; June 20–Aug. 26, 1966; Director: D. Landy, University of Pittsburgh; Grantee: University of Pittsburgh.

MOLECULAR THEORIES OF RATE PROCESSES.—Rochester, N.Y.; Jan. 17–19, 1966; Director: S. A. Miller, University of Rochester; Grantee: University of Rochester.

SUMMER INSTITUTE FOR THEORETICAL PHYSICS.—Seattle, Wash.; June 27–Aug. 31, 1966; Director: E. M. Henley, University of Washington; Grantee: University of Washington.

ADVANCED SCIENCE SEMINAR IN INTERSTELLAR GAS DYNAMICS.—Madison, Wis.; June 20–July 15, 1966; Director: D. E. Osterbrock, University of Wisconsin; Grantee: University of Wisconsin.

APPENDIX E

Publications of the National Science Foundation

This listing includes publications issued by the National Science Foundation during fiscal year 1966. A complete listing of available Foundation publications may be obtained upon request from the Foundation.

The publications marked with a price may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. Other publications are available from the Foundation.

ANNUAL REPORTS

1. Fifteenth Annual NSF Report, for fiscal year ending June 30, 1965: NSF 66–1, $.75.
2. National Science Foundation Grants and Awards, fiscal year 1965: NSF 66–2, $.70.
3. Seventh Annual Weather Modification Report, for fiscal year ending June 30, 1965: NSF 66–4, $.40.

DESCRIPTIVE BROCHURES

1. Grants for Graduate Science Facilities: NSF 66–14.
2. United States-Japan Cooperative Science Program: NSF 66–19.

SCIENCE RESOURCE BULLETINS

1. Reviews of Data on Science Resources:

   Vol. I, No. 4: Research Funds Used in the Nation's Scientific Endeavor, 1963: NSF 65–11, $.10.

   Vol. I, No. 5: Scientists and Engineers From Abroad, Fiscal Years 1962 and 1963: NSF 65–17, $.05.

   Vol. I, No. 6: Geographic Distribution of Funds for Industrial Research and Development, 1963: NSF 65–21, $.10.

   Vol. I, No. 7: Basic Research, Applied Research and Development in Industry, 1964: NSF 66–6, $.15.

   Vol. I, No. 8: Faculty Consulting: College and University Policies, Practices, and Problems: NSF 66–9, $.10.

MANPOWER AND EDUCATION STUDIES

1. Scientists and Engineers in College and Universities, 1961: NSF 65–8, $.65.
2. Scientific and Engineering Manpower in Communist China, 1949–1963: NSF 65–14, $2.00.

RESEARCH AND DEVELOPMENT ECONOMIC STUDIES

1. Federal Funds for Research, Development, and Other Scientific Activities:
   Vol. XIII: Fiscal Years 1963, 1964, and 1965: NSF 65–13, $1.25. $1.25.
   Vol. XIV: Fiscal Years 1964, 1965, and 1966: NSF 65–19, $1.00.
2. Current Projects on Economic and Social Implications of Science and Technology, 1964: NSF 65–16, $.55.
3. Basic Research, Applied Research, and Development in Industry, 1962: NSF 65–18, $1.00.

SCIENCE INFORMATION REPORTS

1. Scientific Information Notes (Bimonthly periodical reporting national and international developments in scientific and technical information dissemination): Single copy, $.25; subscription, $1.25 per year.
2. Scientific Information Activities of Federal Agencies (A series of pamphlets describing the policies and practices of Federal Agencies relative to their scientific and technical information activities):
   No. 31. U.S. Army—Part II: Army Materiel Command: NSF 65–22, $.35.

SPECIAL WEATHER COMMISSION REPORTS

1. Weather and Climate Modification: NSF 66–3.
2. Weather Modification: Law, Controls, Operations: NSF 66–7.

ANTARCTIC REPORT

1. Antarctic Journal of the United States (Bimonthly periodical reporting developments in the Antarctic).

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