National Science Foundation Annual Report

NSF 69-1

'68

NATIONAL SCIENCE FOUNDATION

National Science Foundation

Eighteenth Annual Report for the Fiscal Year Ended June 30, 1968

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $1.25

LETTER OF TRANSMITTAL

Washington, D.C.,
December 30, 1968.

DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1968 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.

CONTENTS

PREFACE

This 18th Annual Report of the National Science Foundation presents an account of major activities in support of scientific research and education in the sciences during fiscal year 1968. In accordance with the format established with the report for fiscal year 1967, discussion of direct support for research is arranged, insofar as possible, by major fields of science rather than in correspondence with the administrative structure of the Foundation. Other programs, however, which cut across scientific disciplines and provide support for science education and institutional development, are presented individually as program elements having multiple objectives. One example of this type of program (among a number of others) is found in Foundation support for computing activities in research and education, which assumes separate organizational status for the first time in fiscal year 1968.

As an additional convenience for the reader, the report this year contains an index which is intended to facilitate a better understanding of the relationship between program activities and the broader objectives of the Foundation as a whole.

The financial statement for the year is presented as appendix B, and various component or supporting data are included where appropriate in the description of activities. Data on prior years are also presented where such information may be useful for purposes of comparison.

A listing of grants, contracts, and fellowship and traineeship awards is published as a separate volume entitled "National Science Foundation Grants and Awards, Fiscal Year 1968" (NSF 69–2).

DIRECTOR'S STATEMENT

Albert Einstein once observed: "To raise new questions, new possibilities, to regard old problems from a new angle requires creative imagination and marks real advances in science." This 18th Annual Report of the National Science Foundation (NSF) is the story of men who have advanced science, during the past fiscal year, by hard work and "creative imagination." The highlights of this story are in the introductory chapter of this Report, and are followed by detailed accounts of some of the activities supported for creating and validating scientific knowledge; transferring and using this knowledge; and maintaining and improving the means for accomplishing these ends.

I realize that the proposition that science serves man while simultaneously pursuing knowledge for its own sake is not new. But in these times when so many judgments must be tentative and uncertain; and when "ignorance is bold, and knowledge reserved" it is important not to lose sight of and to observe again the economic and social content with which science is invested. By so doing, we testify in a concrete manner to the humanity of science.

Testimony to this effect is found throughout the Report, and so I will select but one example to illustrate the point. For many years NSF has supported the research by George Wald of Harvard University in the chemistry of visual pigments and the molecular changes associated with the absorption of light by these pigments.[1] From these studies have come inproved understanding of the way in which light is converted to a nerve impulse in the retinal rods and cones of the eye, and the causes of color blindness.

The scientific value of Dr. Wald's work merited recognition by his sharing in the award of the Nobel Prize in Medicine or Physiology in late 1967. In his address on receiving the Nobel Prize, Dr. Wald remarked that experimentation was "like a quiet conversation with Nature. One asks a question and gets an answer; then one asks the next question and gets the next answer. An experiment is a device to make Nature speak intelligibly. After that one has only to listen.[2]

[1] *National Science Foundation 18th Annual Report for the Fiscal Year ended June 30, 1968* (hereinafter referred to as Report), pp. 83–84.

[2] George Wald, "Molecular Basis of Visual Excitation," *Science*, vol. 162, No. 3850, October 11, 1968, pp. 230–239.

There are many ways of having "conversations with nature." Sometimes questions deal with the atomic or molecular states, at other times with broad, environmental systems. Thus, at the molecular state in biology, interrogations have established the general features of chemical reactions which yield the energy and chemical structures required by living organisms. Now our questions are directed to the regulatory processes which confer upon biological systems their unique characteristics of organization, replication, and self-correction.[3] A major achievement in the past year has been the successful replication, outside of the living cell, of a viral DNA molecule with biological activity. In the words of President Johnson:

> These men have unlocked a fundamental secret of life. It is an awesome accomplishment. It opens a wide door to new discoveries in fighting disease and building much healthier lives for all human beings.[4]

Increasingly, we have come to recognize the interdependence of the components of the natural systems about us, and the problems which man is creating as he modifies his environment. Our questions in these areas are as broad as the oceans [5] and the atmosphere [6] and the total biological community.[7]

In contrasting molecular and microscopic methods to environmental and macroscopic approaches to scientific research, one should keep in mind that the comparison represents a perspective and a mode of investigation rather than some hard and fast constraint on a scientist. Also, environmental studies are grounded in the basic knowledge and understanding that we have of the atomic or molecular states. Perhaps the best illustration of this point is to be found in research in astronomy which is concerned with the greatest system of them all—the universe. But in studying the environment of space, nuclear and molecular interactions as revealed by spectral phenomena provide indispensable clues to the astronomer.

Whether we ask questions of nature at the smallest or the largest levels, recurring patterns in problem solving may also be noted regardless of the scientific discipline involved. Two recurring tactics of investigation include mathematical model-building and testing; and tracing of the pathways taken by natural processes in order to see how they operate.

Mathematical models have been used in extraordinarily diverse problems. For example, in the case of a ground fire burning through compacted leaves and debris or a brush fire, models have been derived

---

[3] Report, pp. 84–85.

[4] *Weekly Compilation of Presidential Documents*, vol. 3, No. 50, December 18, 1967, p. 1714.

[5] Report, pp. 116–126.

[6] Report, pp. 92–116.

[7] Report, pp. 82–83.

which relate wind velocity and fuel moisture content in a way which makes possible more accurate predictions concerning the effect of these variables on fire spread.[8] This particular example of model-building is of special importance because only a small fraction of the substantial sums spent on fire research in the United States each year is devoted to fundamental studies of this type. And yet, it is such an approach which experience tells us will have the best chance of success in reducing the large annual fire losses experienced in this country and around the world.

The tracing of pathways as another way of answering questions has both large- and small-scale dimensions. At the atomic level, techniques have been perfected which permit the isolation of ions and electrons for comparatively long times.[9] With this new capability, subtle differences in electronic energies can be measured to phenomenal accuracy—even as high as one part in a billion. As a result, the road is opened to improvements in atomic theory, as well as laser technology.

Tracing of pathways is not limited only to the making of more precise or refined measurements. Pathways may also be traced, on a broader scale, through studies of chemical interactions between marine organisms, and the dynamics of the marine food chain.

Whatever the value may be of the answers we receive to our questions, there is another more subtle benefit which is relevant to this discussion. We live in a time when tradition and knowledge are subject to attack, from those who, in challenging conventional and transmitted wisdom, prefer to rely on subjective reactions and stress visual and personal rather than intellectual images. This attack has contributed much toward the disequilibrium and anxiety we see in our society. As a counterbalance, the methodology of science is relevant because it builds towards orderly sequences, coherent theories, and values. It has demonstrated how to question tradition and yet draw on past insights; it relies on intuition while demanding objective verification and testing. The very thought processes and procedures of science, in effect, become a model on which society can draw to help chart its future course.

The patterns of NSF activities in support of research and education in the sciences described in this Annual Report do not take place in isolation. They are profoundly affected by the ambient legislative and financial environments—both of which were marked by important developments in fiscal year 1968.

NSF Legislative Environment

To turn to a seemingly different, but nevertheless closely related subject, a major legislative revision of the NSF organic statute was

---

[8] Report, pp. 137–139.

[9] Report, pp. 48–49.

passed by Congress and signed into law on July 18, 1968. Congressman Emilio Q. Daddario of Connecticut introduced the original bill in the House of Representatives in 1966. In the Senate, the Special Subcommittee on Science under the chairmanship of Senator Edward M. Kennedy, added to the long work carried out by the Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics, and introduced several important amendments incorporated into the final act. A full evaluation of the significance of the new legislation can come only with the passage of time. However, it is evident that this new act represents one of the most significant legislative changes in the functions and organization of the National Science Foundation.

It is important to realize that the revised act not only makes changes in the NSF charter and operations, but that it represents a clear congressional endorsement of the importance of the central functions of the Foundation, namely, the advancement of science and science education. In the words of Senator Harris, "No past investment America has made in any field has brought returns which exceed those it has received from its investment in scientific research. American affluence and our standard of living are in large measure attestations of this fact." The new legislation encompasses not only important changes in the charter and operations of NSF but it represents a clear congressional reaffirmation of the role of the NSF in the promotion of national science. I believe that the NSF can take much satisfaction in knowing that during the debate on its legislation, Senator Edward Kennedy expressed a sense of the Congress by stating that "The National Science Foundation is charged with supporting the development of American scientific expertise. This is a very broad charge. It is also a very great challenge. The record of the National Science Foundation in carrying out the charge and meeting the challenge is a proud one."

As for changes in NSF activities, the Congress assigned new areas of responsibility to the Foundation and explicitly emphasized the importance of some of the previously authorized endeavors.

One important extension of NSF responsibility is the authorization to initiate and support applied research activities in academic and other nonprofit institutions. This new authority undoubtedly will affect a number of programs of the Foundation. It will also make it possible for the Foundation to support efforts at academic institutions aimed at providing the knowledge base required to deal with the contemporary problems of our modern science-oriented society. However, it is not the intent of the Foundation to support applied research at the expense of the important fundamental science activities which it now supports.

The new act specifically emphasizes the importance of social science research, which is mentioned explicitly in the new law as one of the areas in which the research potential of the Nation should be strengthened. In view of these recently authorized NSF responsibilities, it is the intent of the Foundation to provide active leadership in the development and support of research programs pertinent to contemporary societal problems. Only through such research efforts can we expect to provide the necessary knowledge and methodology required for the solutions of these problems.

In this connection, the NSF has steadily increased its support of social science research and related activities as part of its effort to assist in advancing the body of scientific knowledge and techniques which are fundamental to any later use of them in real world problem solving. The social sciences are growing, yet they remain comparatively underdeveloped and their body of expertise is comparatively limited. Although the research techniques may not be as precise as in the natural sciences and the methods not as easy to control as in laboratory settings, the potential contribution to problem solving is nevertheless more than enough to justify the risk. We foresee a demand for resources to use on these problems which will be on a substantially larger scale than has been typical for social science research grants in the past. Meaningful research, be it basic or applied, that is related to environmental and population problems for instance, requires multidisciplinary groups of social scientists and others working in collaboration through augmented or new academic research centers or institutes.

There are enough examples of positive contributions from the techniques that have been developed and the knowledge which has already been acquired to warrant continued and increased support of further efforts to advance the social sciences. It is recognized that money alone will not assure major advances or instant solutions in this area or any other. But with increased resources, social science research can be strengthened in quality and increased in rate of productivity by providing stable, broad-gauged support for highly qualified investigators. The results will not only add to our general fund of knowledge about human beings and their institutions, but often may provide information which will assist in the resolution of pressing problems of society. In some cases, the information to resolve at least part of the problems is available, or essentially so, but economic, social, and political hurdles prevent appropriate action. In other cases, where many "social" factors are involved, e.g., racial issues, the solution depends not so much on science as in the attitudes of people. In such circumstances, it is important to realize that science may help but should not be expected to be decisive in the policy decisions that must be made.

It seems only proper that the Foundation, which has developed such close relationships with the academic community, was authorized to help provide the means to stimulate our universities to put their intellectual resources to the task of augmenting knowledge that will assist in the solution of some of these most important problems of our times. In selecting programs for development, the Foundation will concentrate on research areas which are not of focal interest to other agencies and which deal primarily with the interaction of man and the physical world and man with man himself.

In the course of the next year, NSF will give thorough consideration to the development of these new programs. This will include: formulation of criteria for support; determination, with the aid of various advisory groups, of the areas of research on which we will concentrate; and establishment of the most effective mechanisms by which creative energies can be brought to bear on the successful implementation of this new congressional mandate.

Another important mandate assigned to the NSF by the new legislation is to initiate and support scientific activities relating to international cooperation and in furtherance of national objectives abroad. Now, NSF may support scientific activities in pursuit of objectives of greater scope than the promotion of science and science education per se, provided such activities coincide with national policies. This new mandate will considerably enhance the Foundation's role in regard to science in the international area. At the present time, we are assessing the implications to international science activities of the new legislation in order to determine how best to pursue the goals of stimulating science not only at home but abroad, of encouraging increased cooperation between American and foreign scientists, and, finally, of supporting American and foreign scientists in advancement of U.S. national interests and objectives abroad.

The new act also assigns a major new responsibility to the National Science Board. The Board is required to provide Congress with an annual report on the status and health of science and its various disciplines. This report, which is not intended to be comprehensive every time, will provide an excellent opportunity to provide the Congress with information on specific timely and significant developments and to identify noteworthy achievements and problem areas for consideration by the Congress in its deliberations on policy matters related to science and technology. Another pathway of communication has been opened up by the establishment of a new requirement for annual congressional authorizations for appropriations. Because of the growth of the NSF programs, it was felt by the Congress that the permanent authorization of the original NSF Act of 1950 should be replaced by annual authorization reviews. Arrangements are currently underway to prepare for such hearings, and it is hoped that the ensuing dialogue will not only provide a better information channel but will develop a better understanding of common problems.

The act redefines the activities of the Foundation's director and the National Science Board. It reaffirms the responsibility of the NSB to establish the overall policies of the Foundation, while at the same time relieving it of some of its responsibilities for the operation of the Foundation. In addition, the act includes language intended to assure that the Board will have a strong advisory voice in national science policies as promulgated by the administration.

Earlier in this statement, we noted the linkage in scientific research between molecular and microscopic methods, and broader microscopic approaches to environmental systems. In a similar way, the new mandates from Congress may be viewed as being aimed at how the individual fruits of science, and the wisdom of scientists can be integrated into the system of government and society including international systems.

NSF Financial Environment

Dollars are another form of legislative guidance, and there has been much concern that the current budget stringencies will hamper, if not harm, the Nation's science effort. Looking back over the 5-year span, fiscal years 1964–1968, we find that funds available to the Foundation have increased. Unfortunately, the increase has not kept pace with the ever growing demand for support of high quality projects in scientific research and education. As a result of the cuts made from recent NSF budget requests, the Foundation has been compelled to limit its support for new projects and to reduce the funds for its programs, especially graduate facilities, specialized equipment (e.g., chemistry research instruments), fellowships and traineeships.

It is not possible, as of the writing of this statement, to assess fully the impact of fiscal year 1969 budget cuts on the various programs of the Foundation. It seems clear, however, that the limited funds that will be made available will again require reductions in support for new investigators, for facilities, for specialized equipment, for development of additional strong academic science centers, and for science education projects, including traineeships. It is our intention to use the funds that are made available for preserving the continuity of the scientific enterprise to the fullest extent possible. It is primarily for this reason that we feel it desirable to limit our available funds for hardware-oriented porgrams so as to maintain as much as we can of those programs where continuity of the scientific careers of people is involved.

The National Science Foundation has the primary responsibility for assuring that the scientific base of the Nation is maintained and strengthened through the totality of Federal programs involving science, particularly at academic institutions. Other Federal agencies are also concerned with this goal, but they are more directly concerned with specific and immediate mission-related objectives involving the ultimate use of science and technology. In pursuing their goals, the mission-oriented agencies quite properly support basic as well as applied research in relevant areas. Thus, various aspects of the mission-related scientific porgrams of the Federal Government contribute to the long-range goal of strengthening science in the United States, but this is not their main purpose, and the expansion and contraction of such programs must be determined on the basis of immediate mission requirements. Government-wide, therefore, the Foundation's role as a major source of support for all scientific research and science education is of critical importance in developing and sustaining a superior U.S. capability in science.

In fulfilling this responsibility, the National Science Foundation seeks to determine national needs for particular kinds of scientific research by assessing both internal considerations (those generated on intellectual grounds) and external considerations (those suggested by problems of society such as air and water pollution, overpopulation, etc.). The Foundation is committed to administer its overall support of scientific research programs in such a way as to avoid, insofar as possible, sharp fluctuations in the total national level of activity in each broad area of science.

As long as we were in a period when Federal support for R&D was rising, it was possible for the NSF to carry out this commitment to balanced opportunities for progress in all fields of science. We, and other principal Federal agencies supporting research, now find ourselves in a period when expenditures must be limited, and our obligational authority to budget for research and education in the sciences has been reduced. At the same time, faced with rising costs, an apparent decrease of public support and interest, and increased needs, the NSF finds itself at the point of converging pressures which seriously impair its aim of supporting the stability and progress of the scientific and academic communities.

Conclusion

In this statement, I have tried to synthesize some general ideas and conclusions from a review of the past year's activities by the NSF and changes in its environment. It has been said that every country gets the science it deserves. In the light of the intellectual and social ferment around us, certainly we cannot afford to be without the very best science.

I believe that this report presents a record of noteworthy accomplishment. Under the new charter established by Congress, we look forward to the new challenges and opportunities of the future.

PROGRAM ACTIVITIES
of the
NATIONAL SCIENCE FOUNDATION

322-215 O—68——2

INTRODUCTION AND SUMMARY

This chapter summarizes important National Science Foundation (NSF) activities of fiscal year 1968, including major policy considerations, the Foundation's financial picture for the year, significant program changes and accomplishments, and other noteworthy developments.

MAJOR POLICY CONSIDERATIONS

In fiscal year 1965, the Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics, under the chairmanship of Congressman Emilio Q. Daddario, undertook a comprehensive review of Foundation operations. As a result, legislative recommendations were introduced to amend the Act of 1950 so as to broaden and more clearly define the scope and nature of Foundation responsibilities.

Action by both Houses of Congress was completed in the final week of fiscal year 1968 and with the signature of the President on July 18, 1968, the new legislation became law.

The principal changes to the Act of 1950 effected by the legislation of 1968 (Public Law 90–407) include:

1. **Applied Research.** The Foundation is now permitted, at its discretion, to initiate and support scientific research, including applied research, at academic and other nonprofit institutions. In addition, when directed by the President, the Foundation is authorized to support applied scientific research through other appropriate organizations when the research is relevant to national problems involving the public interest. In expectation of the passage of Public Law 90–407, considerable effort was directed toward the development of plans on how the National Science Foundation would effectively extend its activities into appropriate areas of applied research.

2. **The Social Sciences.** The social sciences have been specifically added to the list of scientific disciplines eligible for Foundation support. The authority for such support already existed under the original legislation, but in less specific terms, and over the years the social sciences have in fact been receiving increasing support. The new law adds emphasis to the need for continuing a strong program in the social sciences.

3. **Additional Responsibilities of the National Science Board.** The new legislation has redefined the composition, characteristics, and areas of responsibility of both the National Science Board and the Office of

the Director. The National Science Board continues to be responsible for establishing the policies of the Foundation; it is to be consulted by the Director in the formulation of new programs and is expected to review NSF programs on a selective basis. The act specifically provides that "the Board and the Director shall recommend and encourage the pursuit of national policies for the promotion of basic research and education in the sciences." The Board has been given a major new responsibility—that of rendering an annual report to the Congress through the President on the status and health of American science and its various disciplines.

4. International Cooperation. The Foundation is authorized, at its discretion, to initiate and support specific scientific activities in connection with matters related to international cooperation. The new legislation allows for support of a broad range of scientific programs in these areas.

5. Computers and Other Scientific Methods and Techniques. The National Science Foundation has been instructed to foster and support the development and use of computer and other scientific methods and techniques primarily for research and education in the sciences. This is a new provision to make explicit the authority for such activities and to allow some support for those which may not be directly related to science education or research.

6. Data Collection. The data collection functions of the Foundation have been expanded somewhat with specific direction given to the Foundation to provide a central clearinghouse for the collection, interpretation, and analysis of data on the availability of, and the current and projected need for, scientific and technical resources in the United States, and to provide a source of information for policy formulation by other agencies of the Federal Government. The National Science Foundation has carried out such analyses for many years, but the new law reemphasizes the importance of this function. The Foundation is also instructed to report annually to the Congress on the total amount of Federal funds being received from each agency by each academic and other nonprofit institutions for research activity.

7. Weather Modification Program. The law removes the statutory basis for the Foundation's focal activities in the area of weather modification. However, as part of its new authority to fund applied research undertakings, the Foundation can continue its support of applied as well as basic research for programs in weather modification.

8. Annual Appropriations. The permanent authorization provision of the Act of 1950 is replaced by the requirement that, beginning with fiscal year 1970, only such amounts may be appropriated for the National Science Foundation as the Congress may hereafter authorize by law.

SUMMARY OF FINANCIAL, PROPOSAL, AND AWARD ACTIVITIES

The Congressional appropriation for fiscal year 1968 operating expenses for the National Science Foundation totaled $495 million, a small increase of 3 percent over the fiscal year 1967 appropriation of $480 million. Funds available for obligation in fiscal year 1968 amounted to $552.8 million. Of this total availability, which consisted of the fiscal year 1968 appropriation of $495 million plus the unobligated balance of prior years of $36.7 million and the recovery of $21 million from termination of the Mohole Project, an amount of $505.2 million was actually obligated in fiscal year 1968. An amount of $46.5 million of the NSF total available funds for fiscal year 1968 was placed in reserve by the Bureau of the Budget in compliance with provisions of Public Law 90–218.

The distribution of Foundation obligations in terms of major program category is summarized below in table 1 for both fiscal year 1967 and 1968. (The Financial Summary, in Appendix B, presents a more detailed breakdown of Foundation obligations for fiscal year 1968.)

Table 1.—*Obligations of the National Science Foundation, Fiscal Years 1967 and 1968*

[Dollar amounts in millions]

	Fiscal year 1967		Fiscal year 1968	
	Amount	Percent	Amount	Percent
Scientific Research	$220.9	47.6	$236.5	46.9
Science Education	123.4	26.5	124.8	24.7
Institutional Support of Science	79.7	17.1	83.2	16.4
Computer Activities in Education and Research	12.7	2.7	22.0	4.3
Sea Grant Programs			5.0	1.0
Planning and Policy Studies	2.4	.5	2.4	.5
Science Information Activities	10.0	2.2	14.4	2.9
International Science Activities	2.0	.4	1.4	.3
Program Development and Management	14.0	3.0	15.4	3.0
Total obligations	465.1	100.0	505.2	100.0

As can be seen from the table, the relative emphasis on various Foundation programs was generally the same in fiscal year 1968 as in 1967. However, a number of changes may be noted. As seen in Table 1, computer activities received substantially more support in fiscal year 1968 than during the previous year, rising by 73 percent, from $12.7 million in fiscal year 1967 to $22.0 million in fiscal year 1968.[1] Obligations for science information activities also increased substantially over the period. This rise is largely associated with additional Foundation support for the development of a national chemistry information system. This additional support was provided during fiscal year 1968 to fill the gap created when the Department of Defense and the National Institutes of Health, originally cooperating with the Foundation in this venture, were unable to continue their support and withdrew from the undertaking. The table also reflects some absolute increases in funding for scientific research, science education, and institutional support programs, but these increases are relatively minor (7 percent, 1 percent, and 4 percent respectively).

Table 2, pages 8 and 9, shows Foundation obligations for fiscal years 1967 and 1968 according to field of science. Annual variations in the support of different disciplines by individual Foundation programs can result from a number of interrelated factors: shifts in program emphasis to meet changing or new needs; fluctuations in the amount of funds necessary for the support of long-range, continuing activities as they move from one stage of the activity to the next; and the influence of budgetary considerations. Except for the scientific research program of the Foundation, which is organized along disciplinary lines, Foundation programs do not allocate funds to the various fields of science on a predetermined basis; awards are made to meet overall institutional support, science education, or other activity requirements, and the disciplinary beneficiaries do not influence these awards except insofar as a particular field might be ripe for special exploitation.

With the exception of engineering all major science fields received a higher level of support in fiscal year 1968 than during the previous year. The environmental sciences showed the greatest growth over the period (an increase of $13.8 million or approximately 20 percent) with increases in obligations for both the earth sciences and oceanography; obligations for the atmospheric sciences remained about the same. The increase in oceanography was concentrated primarily in the Foundation's scientific research support program and stemmed largely from the obligation of funds in fiscal year 1968 for the National Research Program in Ocean Sediment Coring, a long-term Foundation commitment for which no obligation of funds had been required in fiscal year 1967, and from the obligation of funds in fiscal year 1968 for oceanographic facilities originally to have been supported in the previous year. The additional fiscal year 1968 support for the earth sciences was contributed chiefly by the Foundation's institutional support program.

As a group the physical sciences increased by less than 10 percent between 1967 and 1968. The field of astronomy, however, showed a

[1] In February 1967, the President specifically instructed the Foundation and the Office of Education to develop effective methods for utilizing computers at all levels of education; this increase represents, in large part, a response to that assignment.

gain of 40 percent over this period, and much of this gain is the result of a 1968 obligation, deferred from 1967, for the construction of the 150-inch telescope at Kitt Peak National Observatory. Obligations for physics also increased, by 13 percent, but those for chemistry declined. The drop in chemistry occurred mainly in the institutional support program; scientific research support for chemistry rose.

The overall decrease in engineering obligations between fiscal year 1967 and fiscal year 1968 may not be attributed to any single Foundation program; the reduction was spread across several program areas, chiefly the science education and institutional support programs. Engineering obligations in the scientific research program remained essentially the same for the 2-year period.

Of the total $505 million obligated by the Foundation in fiscal year 1968 approximately four-fifths was utilized for support of academic science activities (basic research projects, R&D plant, science education, science information programs and other science efforts at colleges and universities). Fiscal year 1968 academic science support by the Foundation represents an increase of 3.5 percent over fiscal year 1967, approximately the same as the increase in total Federal support for academic science over the period. In fiscal year 1967, however, Foundation support for academic science activities had increased by about 6 percent and total Federal support by close to 8 percent. The decline in fiscal year 1968 in the growth rate of Federal funds for academic science is largely due to major decreases in support on the part of the Department of Defense and the National Aeronautics and Space Administration, and somewhat smaller decreases in the Department of Agriculture and the Atomic Energy Commission. In both fiscal years 1967 and 1968 Foundation obligations for academic science represented about 17 percent of all Federal support for this purpose.

Support for academic science includes a variety of science-oriented activities at the nation's colleges and universities. In terms of only its basic research support at these institutions, the Foundation obligated $208 million during fiscal year 1968, an increase of 5.5 percent over the previous fiscal year's total. It should be recognized, however, that this increase did not compensate for the decreases in obligations for basic research made by other Federal agencies at colleges and universities over the period which resulted in a reduction of total Federal obligations for this purpose. Because of these decreases, once again primarily in the Department of Defense and the National Aeronautics and Space Administration, in fiscal year 1968 the Foundation accounted for 26.5 percent of all Federal obligations to colleges and universities for basic research, slightly higher than the comparable proportion for fiscal year 1967 (25 percent) and the highest proportion since fiscal year 1958, the first year for which data on Federal basic research obligations are available.

A total of 8,748 grants and contracts were awarded by the National Science Foundation in fiscal year 1968. In fiscal year 1967 the number

Table 2.—National Science Foundation Net Obligations, by Discipline, Fiscal Years 1967 and 1968

[Dollars in thousands]

FISCAL YEAR 1967

	Total	Scientific research	Science education	Institutional support of science	Computing activities	Sea grant program	Planning and policy studies	Science information activities	International science activities	Program development and management
Physical sciences	$134,313	$69,696	$29,337	$33,051				$2,017	$212	
Astronomy	21,281	19,902	666	637					76	
Chemistry	54,547	20,327	14,798	18,222				1,114	86	
Physics	58,485	29,467	13,873	14,192				903	50	
Environmental sciences	70,635	58,811	7,737	2,531				1,366	190	
Atmospheric sciences	27,672	25,740	348	1,365				161	58	
Earth sciences	18,562	9,840	6,703	710				1,205	104	
Oceanography	24,401	23,231	686	456					28	
Mathematical sciences	48,794	13,053	25,969	8,050	$1,396			292	34	
Life sciences	76,999	44,395	18,953	11,743				1,053	855	
Social sciences	35,376	14,724	11,198	8,131			$922	362	39	
Engineering	51,249	20,188	20,560	9,556				893	52	
All other [1]	47,738		9,606	6,661	11,295		1,471	4,042	619	$14,044
Total	465,104	220,867	123,360	79,723	12,691		2,393	10,025	2,001	14,044

FISCAL YEAR 1968

Physical sciences	$144,865	$79,182	$28,524	$31,144	$170	$19		$5,698	$128	
Astronomy	29,734	26,520	811	2,387				9	7	
Chemistry	49,074	22,064	13,694	8,691	170	19		4,392	44	
Physics	66,057	30,598	14,019	20,066				1,297	77	
Environmental sciences	84,425	64,337	9,627	8,704	79	364		1,079	235	
Atmospheric sciences	27,467	25,044	387	1,715				158	163	
Earth sciences	23,498	9,415	7,727	5,480	79	20		720	57	
Oceanography	33,460	29,878	1,513	1,509		344		201	15	
Mathematical sciences	53,915	12,700	27,825	7,647	5,220			461	62	
Life sciences	85,783	44,144	19,686	19,397		1,831		432	293	
Social sciences	36,968	15,671	13,644	5,072	503	252	$1,052	734	40	
Engineering	44,624	20,470	15,791	6,536		1,254		516	57	
All other [1]	54,648		9,736	4,746	16,026	1,280	1,394	5,476	612	$15,378
Total	505,228	236,504	124,833	83,246	21,998	5,000	2,446	14,396	1,427	15,378

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

awarded was somewhat higher (9,311), and this difference may be accounted for in large part by a change in education program award procedures and also by some change in education program emphasis.[2] and a reduction, by about one-fifth, in the number of international travel grants. Based on the total number of proposals on which final action was taken by the Foundation (14,374), the awards made in fiscal year 1968 reflect an acceptance rate of 61 percent, the same rate of acceptance as in 1967.

In terms of dollar support, grants and contracts awarded during fiscal year 1968 amounted to $483 million.[3] The comparable figure for fiscal year 1967 was $441 million and thus 1968 obligations for grants and contracts represent an increase of about ten percent over the previous year. Adjustment of the dollar amounts for the Foundation's "operational" programs[4] to an annual rate basis to eliminate the influence of the duration of the award shows a rate of $250 million per year in fiscal year 1968. This annual rate was 9 percent higher than the comparable 1967 rate of $229 million per year.

The distribution of Foundation awards made during fiscal years 1967 and 1968 for contracts, grants and fellowships is presented in table 3. The pattern varies among the different programs. In general, although the number of awards declined slightly among the Foundation's "operational" programs, the amount awarded increased over the period. On the other hand, facilities support decreased in both number of awards and dollar obligations while the awards for institutional support varied only slightly between 1967 and 1968.

Reflected in the education program totals in table 3 are traineeship and fellowship awards for fiscal years 1967 and 1968. The Foundation's traineeship awards are not made directly to the students but to academic institutions which in turn select qualified individuals as graduate trainees. In fiscal year 1968 traineeships awarded to colleges and universities supported 6,621 graduate students while in fiscal year 1967 such awards supported 5,973 students.

The Foundation's fellowship program is designed to provide support to outstanding graduate students; this program also makes available a limited number of fellowships to scientists who have already received a doctorate. In contrast to traineeship support, fellowship awards are made directly to the selected individual. In fiscal year 1968 a total of 2,963 fellowships were awarded by the Foundation.

---

[2] During fiscal year 1968 the Foundation's Science Education unit changed and improved the grant management practices in its traineeship program; whereas previously a new traineeship award and its continuation constituted separate actions, they are now combined into a single action or award. The education program also reduced its awards for scientific instructional equipment during the year.

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

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

Table 3.—Summary of Grants, Contracts, and Fellowships Awarded, by Program Category, Fiscal Years 1967 and 1968[1]

[Dollars in thousands]

	Fiscal year 1967[2]			Fiscal year 1968		
	Number awarded	Total amount awarded	Total annual rate awarded	Number awarded	Total amount awarded	Total annual rate awarded
Scientific research	4,204	$200,793	$122,895	4,126	[3] $214,817	[3] $131,495
Science education	6,471	129,869	114,820	5,942	141,580	108,968
Science information activities	142	10,710	[4] 7,691	152	15,400	[4] 13,293
Computing activities[5]	(5)	(5)	(5)	165	22,000	10,736
Planning and policy studies	55	2,410	2,689	65	2,651	2,589
Subtotal—"Operational" Programs	10,872	343,782	248,095	10,450	396,448	267,081
Facilities support	330	61,800		282	47,279	
Institutional support of science	532	52,711		528	55,792	
Subtotal	862	114,511		810	103,071	
International travel	548	971		451	783	
Total—All programs	12,282	459,264	248,095	11,711	500,302	267,081

[1] These data do not match the obligation figures shown in tables 1 and 2 which include funds for the administration of Foundation programs and which reflect net obligations; gross obligations are shown in this table.

[2] For purposes of comparison with the information for fiscal year 1968, the fiscal year 1967 data are not presented in exactly the same form in which they appeared in the NSF Annual Report for fiscal year 1967.

[3] Includes awards made for the newly initiated sea grant program for which no awards were made in fiscal year 1967.

[4] The considerable difference in annual rate awarded between fiscal year 1967 and 1968 may be attributed to a great extent to large grants awarded in fiscal year 1968 to professional societies for the development of discipline-oriented information systems.

[5] Awards for computing activities were not separately identified in fiscal year 1967 but were included under other program categories. Thus, comparisons between fiscal year 1967 and 1968 on an individual program basis may not be entirely accurate.

SIGNIFICANT PROGRAM CHANGES

New Programs

Sea Grant Programs

Toward the end of fiscal year 1967 the Foundation formally established a National Sea Grant Program, in response to the requirements of the National Sea Grant College and Program Act of 1966, which authorizes the Foundation to initiate and support activities to foster the development and utilization of the nation's marine resources. This program, in accordance with the distinction drawn in the legislation between "sea grant colleges" and "sea grant programs," provides for two major types of support, Sea Grant Institutional Support and Sea Grant Project Support. The Sea Grant Institutional Support program is designed to create major centers for marine training and education, applied research, and advisory services at institutions of higher education. It is principally geared toward the support of those academic institutions that have current programs in basic marine science education and research and that are capable of extending their present competence into the practical aspects of marine resource development. The Sea Grant Project Support program provides funds for specific sea grant projects in applied research, education and training, and advisory services.

First awards in the Foundation's National Sea Grant Program were made during fiscal year 1968. Six institutions were awarded $2.5 million as part of the Sea Grant Institutional Support activity, and 27 Sea Grant Project Support awards were made totaling $2.4 million.

University Science Planning and Policy Program

During fiscal year 1968 the Foundation inaugurated a program to strengthen capability in science planning and policy activities at university centers throughout the country. The prime objective of the program is to develop intellectual resources which can contribute to solutions of problems relating to planning and policy issues. Areas of interest include both the administration and support of scientific activities and the manner in which these activities relate to the social, economic, and legal structure of the nation. In fiscal year 1968 four colleges and universities received awards for the development or maintenance of science planning and policy centers.

State Science Activity

During the past fiscal year the Foundation also launched a modest program to help develop capability in regional, State, and local groups for the assessment and use of local scientific and technical resources. This program is designed to support planning and project activities related to the solution of long-range scientific and technological regional problems.

As a first step the Foundation joined with the Southern Interstate Nuclear Board in the support of a study-conference project aimed at exploring the advancement and utilization of science and technology at the State and local levels. The Foundation also provided partial support, in conjunction with the Economic Development Administration of the Department of Commerce, for a nine-State project aimed at determining how State and local governments obtain advice and reach decisions involving scientific and technical matters.

OTHER PROGRAM CHANGES

In addition to the initiation of the above new programs, the Foundation also increased its emphasis of or strengthened its support of a number of ongoing activities over the past year.

Research

International Biological Program

Increased Foundation support for the International Biological Program (IBP) was provided during fiscal year 1968. This program represents a multination effort to better understand some of the world's pressing biological problems. At the request of the Office of Science and Technology, the National Science Foundation accepted the role of coordinating agency for the United States effort. The Foundation, in carrying out this responsibility, formed an Interagency Coordinating Committee to channel Federal support for IBP projects of interest to many agencies and provided both the chairman and the executive secretary of the group.

Interest in the IBP program within Congress has been evidenced through the introduction of two concurrent resolutions expressing support for the program and through a series of hearings held by the Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics.

Increased Foundation support for this activity over the past year stems from the progress of the program from its initial phase to a more fully operational stage. Foundation support for the program may be divided into two types. One represents the Foundation's principal thrust in IBP and is specifically designed for the support of major integrated research programs. An example of this is the analysis of ecosystems project, a group of related studies designed to provide intensive comparative analyses of six ecological systems—tundra, desert, coniferous forest, deciduous forest, tropical forest, and grasslands. The first of these studies, of a Colorado grasslands area, was announced during fiscal year 1968. The second type of IBP support is provided through individual, Foundation-funded projects which relate to IBP. In the latter effort, although prime support is provided through funding of basic research projects in the biological sciences, other Foundation organizational units such as the Office of Science Information Service, the Office of Sea Grant Programs and the Division of Social Sciences, also participate through IBP-related support programs.

Chemistry

As part of the implementation of the recommendations of the National Academy of Sciences' report, "Chemistry: Opportunities and Needs" (the Westheimer Report), during fiscal year 1968 the Foundation continued to increase its support for acquisition of instruments used in chemical research. Examples of the complex and costly instrumentation now required for research in chemistry include mass spectrometers, X-ray crystallographic equipment, nuclear magnetic resonance spectrometers, and optical rotary dispersion equipment.

An award to the California Institute of Technology was announced during the year for a powerful chemistry research instrument, an ultrahigh nuclear magnetic resonance spectrometer, for use by chemists in the southern California region. The instrument will be used to analyze the structure, bonding, and conformation of molecules and is expected to help scientists understand more about the environment of individual atoms in large molecules. This installation is the first of its kind at an academic institution in the United States, and the award marks the first use, by the Foundation's chemical instrumentation program, of the concept of the regional center for very expensive instrumentation.

Oceanography

Another area which received some additional Foundation support during the year was the oceanographic phase of the U.S. Antarctic Research Program. Additional funds were made available to this program in part to support the inauguration of the Foundation's participation in the International Weddell Sea Oceanographic Expedition. The principal objective of the expedition is to obtain information on the origin of the Antarctic Bottom Waters, a high-salinity, low-temperature water mass occurring at the bottom of all oceans and reaching well north of the equator. This northward-moving water represents a major source of heat exchange between the Antarctic and the lower latitudes. The effort is international in scope, and seven United States universities and a Coast Guard oceanographic unit carried out various marine programs in the Weddell Sea as part of the first phase of the undertaking.

Global Atmospheric Research Program

Foundation participation in the Global Atmospheric Research Program (GARP) assumed increased importance during fiscal year 1968. Originated as a preliminary to the World Weather Watch, an international program designed to further scientific research on the atmosphere, GARP received formal endorsement during fiscal year 1968 from a number of international scientific organizations such as the World Meteorological Organization, the International Union of Geodesy and Geophysics, and the Executive Committee of the International Council of Scientific Unions. Further endorsement for the World Weather Program was given both by the United States Congress through a concurrent resolution and, early in fiscal year 1969, by the President, through a memorandum urging Federal agency cooperation in the program. By formal agreement among Federal agencies, the Foundation is the primary agency for non-Federal research in this area, particularly at universities, and the Department of Commerce is the primary agency for Federal activities.

Social Sciences

In fiscal year 1968, responding to the increasing need to strengthen education and research in the social sciences and to make practical use of the knowledge gained in the growing research activity in the behavioral and social sciences, the National Science Board appointed a Special Commission on the Social Sciences consisting of 11 eminent individuals in science and public affairs. The commission, which is responsible to the Board, will address itself to the following:

1. "A statement and analysis of the mechanisms and institutions, societal and governmental, that are needed so that the understanding and knowledge gained by the social sciences may be drawn upon and used effectively when they are relevant to understanding and dealing with significant problems in our society.
2. "An analysis of what forms of collaboration may be necessary among the social and natural sciences, and engineering, and among their practitioners in addressing these problems; and recommendations concerning how such collaboration might be brought about.
3. "A statement of what measures and programs, to be administered by Federal agencies including the National Science Foundation, are required so that the social sciences may be more effective both in generating new knowledge and in its utilization, and so that our society can gain maximum benefit from the growing knowledge derived from fundamental research in social sciences."

Appendix A provides a list of the members of the Special Commission on the Social Sciences.

Institutional Support Programs

The Foundation conducts three institutional science development programs designed to assist colleges and universities in improving their activities and capabilities in scientific research and education, and also aimed at broadening the base of the Nation's total science effort. Under these programs—the University Science Development Program, the Departmental Science Development Program, and the College Science Improvement Program—the Foundation provides support for those institutions which have not yet reached the forefront of scientific excellence but have existing strength in the sciences and potential for additional development. The Departmental Science Development and the College Science Improvement programs were formally established in fiscal year 1967, and with these programs in their infancy during that period only very few awards were made. In fiscal year 1968, however, the two programs became fully operational, and thus were able to provide a significantly greater amount of support to eligible institutions. A total of 22 Departmental Science Development Program awards and 55 College Science Improvement Program awards were made during the past fiscal year for a total of $12.0 million and $9.6 million in obligations respectively.

It should be noted that the Graduate Science Facilities Program, another Foundation institutional support activity, was sharply curtailed during the year as part of an overall Federal agency reduction in facilities support programs due to budgetary restrictions and a resultant reassessment of funding priorities.

Education

Cooperative College-School Science Program

In accordance with a decision made during fiscal year 1967 to strengthen and expand the Cooperative College-School Science Program, in fiscal year 1968 this activity received increased financial backing. The purpose of the Cooperative College-School Science Program is to provide a mechanism whereby administrators in a school system (or systems) can receive assistance from subject matter experts at nearby colleges and universities in updating the system's instructional programs in science. Awards may be made to colleges for projects designed to assist elementary or secondary schools or both, and recommendations to school systems may relate to curriculum changes or to teacher training. By creating collaborative arrangements between school administrators and the science faculties of neighboring colleges this program allows local educational authorities to be fully involved in educational reform in their systems. Fiscal year 1968 expansion in the Cooperative College-School Science Program resulted in large part from increasing interest among school systems and concentrated to a great extent on teacher training activities related to the improvement of science curricula in school systems.

Special Projects Program

During the year the Foundation's program to provide support for special undergraduate science education projects was also expanded. The

Special Projects Program supports projects of an unusual nature which show promise of developing new approaches for the improvement of undergraduate science education. It is hoped that the results of these efforts will become successful pilot models of activities that could enhance the programs of colleges and universities. Increased attention during fiscal year 1968 was focused on two prime areas of interest, one aimed at funding experimental projects to upgrade curricula at teacher training institutions, the other designed to increase the competence of junior college teachers, particularly in view of the fact that junior colleges are playing an increasingly important role in the training of undergraduates.

Computing Activities in Education and Research

In line with the growing emphasis on the use of computers as an important educational and research tool, Foundation financial support for computer programs was considerably larger in fiscal year 1968 than in fiscal year 1967. In addition, during the past year the Foundation established a separate organizational unit to administer and strengthen its computer support activities. The decision to organize computer-related support programs under one office, the Office of Computing Activities, was based on Foundation recognition of the magnitude of the future requirements for computers in research and education and the need to respond as effectively as possible to these requirements.

The Office of Computing Activities administers new computer-related programs covering education and training, computer science research, and support of computer activities at the institutional level. Examples of activities in the support of computer programs for education and training include the sponsorship of efforts to make use of computers in course work; experimental projects in the techniques of computer-aided instruction; and aid for the initiation and expansion of academic computer science programs, including support for students and faculty, highly specialized computing facilities, and cooperative computer science curricular projects. Computer science research project support concentrates on the encouragement of research activity in such areas as time-shared use of equipment, software developments, computer-assisted design, hybrid computers, and computers for education and training. Finally, Foundation computer support at the institutional level assists colleges and universities in the introduction, expansion, or modernization of computer systems which are primarily intended for use in education and unsponsored research. Support under this program may be for individual academic institutions or for groups of institutions.

Science Information Activities

The Foundation has continued to increase its emphasis on the establishment of discipline-oriented science information systems. Under this

322-215 O—68——3

program the Foundation supports scientific professional societies and associations in their efforts to develop comprehensive information systems for their disciplines. During fiscal year 1968 the Foundation granted funds to the American Institute of Physics, the American Psychological Association, and the Center for Applied Linguistics for the initiation of national information systems. The first such award, for chemistry, was made to the American Chemical Society in fiscal year 1965 and, as previously indicated, was originally a cooperative venture, with funds provided by the Department of Defense and the National Institutes of Health as well as by the Foundation.

SIGNIFICANT PROGRAM ACCOMPLISHMENTS

Described below are some of the more important achievements of the past year resulting from programs and activities supported by the National Science Foundation.

Research in Vision

George Wald of Harvard University, whose research over a number of years has been supported by the National Science Foundation, was a joint recipient of the 1967 Nobel Prize in Medicine or Physiology with Haldan Keffer Hartline of Rockefeller University and Ragnar Ganit of Sweden. This recognition was accorded to the three scientists for their outstanding contributions to the understanding of how light is transformed into a nerve impulse in the eye. Dr. Wald's work has dealt with the chemistry of visual pigments and the molecular changes associated with the absorption of light by these pigments. An early and particularly notable achievement by Dr. Wald was his elucidation of the role of Vitamin A in vision, one of the first identifications of the biochemical function of a vitamin.

As one result of his investigations, which are dependent upon the use of animal material, Dr. Wald has provided additional information on the way in which animals may respond to light. His research has also contributed to the development of nondestructive methods of examining visual pigments in living animals and has permitted the testing of theories relating pigments to human vision.

Replication in Biology

Culminating nearly 11 years of work, made possible by grants from the National Science Foundation and the National Institutes of Health, a team of biochemists at the Stanford University School of Medicine successfully manufactured, for the first time, a synthetic DNA. DNA (deoxyribonucleic acid) is the material that controls the heredity of all living substances. The ability to create a fully infectious artificial DNA virus is viewed as an extremely important step forward in the understanding of how viruses are duplicated and has significant implications for future progress in the study of genetics. Potential practical applications in the control of virus-related infections are also foreseen. Members of the successful team include Mehran Goulian, now on the faculty of the University of Chicago but formerly an NSF-postdoctoral fellow at Stanford University; Arthur Kornberg of Stanford University, winner of the Nobel Prize in 1959; and Robert L. Sinsheimer of the California Institute of Technology.

Important progress has also been made in relation to the synthetic replication of RNA (ribonucleic acid). At the University of Illinois, Sol Spiegelman, who 2 years ago synthesized the single-stranded RNA contained in a virus which attacks bacteria, has made significant strides in understanding the mechanism whereby this occurs. With this RNA molecule, he has been able to obtain something in the test tube which mimics the postulated natural selection of the evolutionary process. The accomplishment marks the first time evolution has been observed under artificial conditions and constitutes a significant contribution toward the understanding of the basic chemical mechanisms of heredity. In addition, the non-infective shortened piece of RNA can act as a blocking agent for virus growth in a cell. This achievement may permit the development of a new approach to the cure of viral diseases. Dr. Spiegelman's work has been supported by grants from the National Science Foundation and the National Institutes of Health.

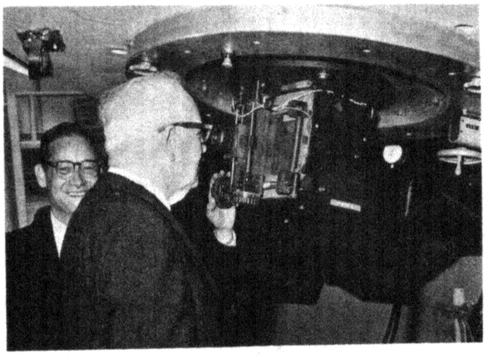
Time-Resolved Spectroscopy

In the metals industry, such as steel, aluminum, and copper production, almost every manufacturer controls the composition of alloys and the refining of pure metals by studies of the emission spectra from vaporized metal samples. Such spectra are produced when samples are vaporized, absorb energy, and then emit radiation which is passed through a spectrograph producing a series of lines on a sensitized plate. These lines differ for every substance, and the intensity of the lines is used to determine the concentration of the alloying elements or impurities.

In the past, observations of spectral line intensities have been gross measurements for as long as the film was exposed—on the order of seconds. As a result of research by John P. Walters of the University of Wisconsin, spectroscopists now will be able to measure spectral line intensities over as short a time interval as one-hundredth of a millionth of a second from the time excitation begins to the time of observation of the spectral lines on the plate. With this enormously increased detection ability, it is possible to observe clearly the detailed formation of spectral lines and to study the supersonic movement of microgram-size plugs of vaporized material away from the electrode surface as the metal electrode absorbs the energy of the vaporizing spark.

With the information available about the excitation processes in the spark, the University of Wisconsin Chemistry Laboratory is developing new analytical spectroscopic methods for metals as well as for the determination of fractional part-per-million metal impurities in tissue and other biological samples, and the determination of gaseous isotopes of molecules.

Cerro Tololo Inter-American Observatory



Representative George P. Miller inspects the 60-inch telescope at Cerro Tololo Inter-American Observatory.

The new Cerro Tololo Inter-American Observatory located near La Serena, Chile, was formally dedicated in November 1967. The observatory is fully supported by the Foundation and operated through the Association of Universities for Research in Astronomy, Inc. The new facility will permit research in astronomical phenomena in Southern Hemisphere skies, not previously possible due to the lack of sufficiently modern telescopic equipment. Among those attending the ceremonies atop the Andes mountain site were President Eduardo Frei of Chile; the Honorable Edward M. Korry, U.S. Ambassador to Chile, a delegation of U.S. Congressmen, including Representatives George P. Miller of California, Chairman of the House Committee on Science and Astronautics, Jerry L. Pettis of California, and Olin E. Teague of Texas; and Dr. Philip Handler, Chairman of the National Science Board who delivered a message of greeting from President Johnson. A number of other representatives of the United States and Chile were present.

Progress was also made toward the construction of the 150-inch optical telescope at Cerro Tololo, which is being jointly funded by the Ford Foundation and the National Science Foundation. Initial work was begun during the year with plans calling for completion of the telescope in 1973. The new telescope is intended to be used as a Southern Hemisphere counterpart of the 150-inch telescope planned for Kitt Peak National Observatory in Arizona. Construction of the Kitt Peak instrument was also initiated during the past fiscal year with completion scheduled for 1972.

New Pulsar Discovered

During the past year, working under a National Science Foundation grant, J. H. Taylor in collaboration with G. R. Huguenin of the Harvard College Observatory, detected a previously unnoticed pulsating radio source in space. This pulsar, the fifth to be discovered, was detected during observations at the NSF National Radio Astronomy Observatory, and was the first such discovery by American astronomers.

The physical nature of pulsars, which are celestial sources of energy emitting rhythmic radio pulses, is not yet understood. Several theories have been advanced in an effort to explain them, but none has been found completely satisfactory. It is possible, however, to calculate the approximate distances from the earth of these pulsars, and it is estimated that the new pulsar is roughly between 50 and 300 light years away.

Computer-Aided Building Design

Working with Foundation support, A. G. H. Dietz and Alan M. Hershdorfer, both of the Massachusetts Institute of Technology, made progress in the past year in applying computer technology to the solution of problems associated with the design and construction of buildings. A special language called "Build" is being formulated which a designer can use to communicate with a computer-based information system. The project has already produced the capability to work with four building systems (activities, space, surfaces, and structure), and with the use of the computer it is possible to define relations among these systems and perform calculations of areas, volumes, weights, and costs. It is anticipated that this study will contribute significantly to progress in the design of buildings from the point of economy as well as from the point of view of the construction of more satisfactory facilities.

Antarctic Fossil Find

A team of geologists from the Ohio State University Institute of Polar Studies uncovered the first land-vertebrate fossil to be found in Antarctica. The fossil bone, from an amphibian known as a labyrinthodont that lived about 200 million years ago, was discovered in an ancient sediment-filled stream bed in the central Transantarctic Mountains about 325 miles from the South Pole and may provide a clue to the origin of Southern Hemisphere continents. The find could play an important part in a current major scientific issue dealing with the geographical origins of the Southern Hemisphere continents and India. One theory supports the argument that at one time Africa, Antarctica, Australia, South America, and India were joined in a supercontinent, designated Gondwanaland, and slowly drifted apart to their present locations. The fossil discovery provides support for this theory because this was the first time that fossil remains had been found in Antarctica of an animal that could not have reached the present continent across salt water. This indicates that Antarctica was joined to the rest of Gondwanaland at the time the labyrinthodonts were evolving.

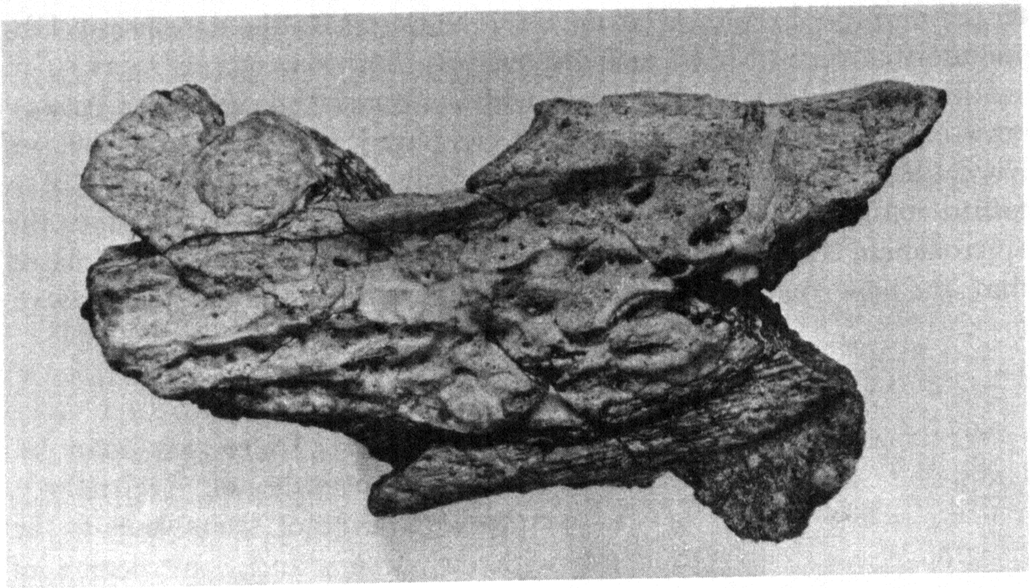


Photo American Museum of Natural History.

This fossil, the first of a land-vertebrate ever found in Antarctica, is part of the jawbone of an amphibian that lived about 200 million years ago. The find was made about 325 miles from the South Pole and may provide important clues concerning the origin of Southern Hemisphere continents and the "continental drift" theory.

Early Man in America

Human remains, believed to be the oldest found to date in the Western Hemisphere, were unearthed in the State of Washington by a group of scientists from Washington State University working with support of the National Science Foundation and the National Park Service. It is estimated that the bones are 11,000 to 13,000 years old and belonged to a young pre-Indian nomad, designated Marmes Man. Previous finds of this type in the Western Hemisphere have been judged to be about 10,000 years old. In addition to the discovery of human remains, a delicate bone needle of about the same age was unearthed. This may be the oldest artifact of its kind ever found in the United States.

Despite a century of intensive search by archaeologists, few discoveries of even fragmentary remains of the earliest inhabitants of the New World have been made, and previously these had been found under circumstances which made estimates of their age problematical. The find at the Marmes site, documented by 6 years of earlier archaeological and geological research at the site, can be dated on a firmer basis than any of the prior discoveries.

Farther north, excavations at the Onion Portage site in Alaska, conducted with Foundation support under the direction of Douglas D. Anderson of Brown University, have unearthed cultural remains, such as tools and weapons, which closely match stone artifacts previously found in Northeastern Asia. These remains provide substantial evidence of human habitation at the site at least 8,500 years ago.

Both finds, that in Washington State and that in Alaska, contribute toward a better understanding of the origin of man in the Americas. It is generally accepted that man migrated to the Western Hemisphere from Asia via the Arctic, and through the accumulation of evidence relating to the length of time man has lived in the Western Hemisphere and through discoveries relating to the physical and cultural characteristics of the hemisphere's early human inhabitants, it is hoped to establish a relationship between early man in the Americas and the people and regions of Asia.

Science Curriculum Improvement Program

As part of its science improvement curriculum activities, the National Science Foundation's Education Division and the Office of Computing Activities joined together in a grant to support the development and trial of computer-moderated remedial instruction in mathematics for inadequately trained freshmen at Tennessee Agricultural and Industrial State University. This institution, predominantly Negro in composition, has found its work seriously hampered because of the lack of proper mathematics training of some of its incoming freshmen. Extensive cooperation from Stanford University will undergird the software development, and computer services will be supplied during the trial by Stanford through a long-line remote access hookup.

SPECIAL ACTIVITIES

Report on U.S. Science Policy

A comprehensive review of the science policies of the United States, prepared by the National Science Foundation's Planning Organization under contract with the United Nations Educational, Scientific and Cultural Organization (UNESCO), was issued by UNESCO during the past year. This document, "National Science Policies of the U.S.A.," represents the U.S. contribution to a major study by UNESCO of the science policies of a number of its member nations. Prime responsibility for U.S. participation in the effort rested with the Foundation.

The report cites many of the changes in the organization and conduct of scientific and technological activities experienced in the United States over the past 25 years. Analysis of factors influencing national science policy and statistical data on funding and manpower are employed to portray the extent of pluralism found in U.S. science and technology. The rise of Government as the dominant supporter of research and development has occurred without Government also becoming the principal performer. The report describes a number of the mechanisms which have acted to preclude undue governmental restraint on the substance of scientific inquiry.

Public support for science and technology in the United States is now tempered by the urgent need for finding solutions to major domestic social problems, as distinct from the concern with national security which followed in the years after World War II. There is mounting interest in finding new ways whereby science can promote social and economic goals. Accordingly, the report notes among its conclusions, as science and technology become more closely interrelated with social and economic systems, it becomes increasingly important that national policy alternatives be developed in anticipation of both the scientific and social implications which future scientific developments may hold. This is regarded as one of the most significant challenges currently facing those responsible for the formulation of science policy.

United States Exhibit in Brazil

At the request of the Government of Brazil, and with the sanction of the U.S. Department of State, the National Science Foundation planned, organized, and assumed responsibility for operational management of the United States Exhibit at the First Biennial of the Sciences and Humanism held in São Paulo, Brazil, during the fall of 1967. The exhibit, presented with the cooperation of other Federal agencies and a number of universities and science-oriented industrial firms, was based on the theme "Progress Through Science" and afforded both the scientific community of Brazil and the Brazilian population at large an opportunity to gain some insight into the current state of scientific and technological progress in the United States. The exhibit proved highly successful, having been viewed by more than 40,000 visitors, and may serve as a prototype for future international science projects.

NSF Photo

Enthusiastic Brazilian schoolchildren were among the 40,000 visitors to the U.S. exhibit at São Paulo. Audiovisual displays proved to be of particular interest.

NATIONAL SCIENCE FOUNDATION PARTICIPATION IN GOVERNMENT-WIDE ACTIVITIES

Foundation participation in Government-wide activities has already been touched on earlier in this chapter. The Foundation has been designated coordinating agency for the International Biological Program and shares focal agency responsibility for the Global Atmospheric Research Program (with the Department of Commerce) and for computing activities for education (with the Office of Education).

Another interagency group in which the Foundation plays the key role is the Committee on Academic Science and Engineering (CASE) of the Federal Council for Science and Technology which was established to coordinate Federal agency science activities pertaining to universities and colleges. During fiscal year 1968, as part of the CASE operation, the Foundation published its second comprehensive annual report on Federal support of institutions of higher education, *Federal Support to Universities and Colleges, Fiscal Years 1963–66.* (The first such report, *Federal Support for Academic Science and Other Educational Activities in Universities and Colleges, Fiscal Year 1965,* was issued during fiscal year 1967.) A brief discussion of the more significant findings emerging from this second analysis may be found in a later chapter (see page 225).

Other CASE undertakings in fiscal year 1968 include development of specifications for the collection of manpower information from academic institutions receiving Federal agency support and the development of uniform criteria for defining what had been called Federal Contract Research Centers—those R&D organizations financed exclusively or principally by Federal funds but administered on a contractual basis by universities, other nonprofit institutions, or industrial firms. In the latter effort in addition to establishing definitional standards, which were approved by FCST and are now in current use, these institutions were formally redesignated as Federally Funded Research and Development Centers.

The Foundation is also active in a variety of other Government-wide endeavors through participation in interagency groups. The Foundation's Director and various senior staff serve on a number of governmental interagency committees, as illustrated below by those on which the Director serves:

Department of Defense
Defense Science Board (Member)

Federal Council on the Arts and the Humanities
(Member)

Federal Council for Science and Technology (Member)
Committee on Academic Science and Engineering (Chairman)
International Committee (Member)

Department of Housing and Urban Development
Interagency Working Committee on Science and Urban Problems (Member)

National Council on Marine Resources and Engineering Development (Member)

President's Committee on Manpower (Member)

President's Science Advisory Committee (Consultant)

Department of State
Interagency Council on International Educational and Cultural Affairs (Invited Guest)
Science Liaison Group (Member)
Agency for International Development Research Advisory Committee (Guest)

ORGANIZATIONAL DEVELOPMENTS

Foundation Personnel and Organizational Units

On July 18, 1968, President Johnson signed legislation amending the National Science Foundation Act. The Act provides that henceforth the Deputy Director of the Foundation shall be appointed by the President with the advice and consent of the Senate. As a result, the position of Deputy Director became vacant.

Dr. John T. Wilson, formerly Deputy Director of the Foundation, agreed to accept the position of Executive Associate Director and to discharge the responsibilities previously vested in the Deputy Director until his departure in August 1968 from the Foundation to become Vice President and Dean of Faculties at the University of Chicago. Following his departure, Dr. Louis Levin, Associate Director (Institutional Relations), assumed the position of Executive Associate Director pending appointment of a Deputy Director by the President.

During Dr. Levin's tenure as Executive Associate Director, Dr. Howard Page is serving as Acting Associate Director for Institutional Relations.

In addition to the resignation of Dr. John T. Wilson mentioned above, Dr. Geoffrey Keller, Deputy Planning Director, also resigned to become Dean of the College of Mathematics and Physical Sciences at Ohio State University.

Other major staff changes during the year include the following appointments:

- Dr. Robert Fleischer, Head, Astronomy Section in the Division of Mathematical and Physical Sciences (reassignment)
- Dr. Ray Koppleman, Head, Science Liaison Staff, New Delhi, India
- Mr. Richard W. H. Lee, Deputy Head, Office of Data Management Systems
- Dr. Hugh J. McLellan, Head, Oceanography Section, Division of Environmental Sciences
- Dr. John W. Mehl, Deputy Division Director for Biological and Medical Sciences
- Dr. Clifford J. Murino, Program Coordinator, National Center for Atmospheric Sciences, Division of Environmental Sciences
- Dr. William H. Pell, Head, Mathematical Sciences Section, Division of Mathematical and Physical Sciences (reassignment)
- Dr. Louis O. Quam, Chief Scientist, Office of Antarctic Programs, Division of Environmental Sciences
- Mr. Irvin V. Voltin, Head, Office of Data Management Systems

In addition, Dr. Milton E. Rose was designated to serve as Head of the Office of Computing Activities. Along with the creation of the new unit, an Advisory Committee for Computing Activities was appointed to advise the Foundation in carrying out its responsibilities in this area.

An Advisory Committee for Planning was also formed during the past fiscal year to counsel the Foundation with regard to its science planning activities. A list of members of both the Advisory Committee for Planning and the Advisory Committee for Computing Activities will be found in Appendix A.

One program office was officially closed in fiscal year 1968. As of December 31, 1967, the Mohole Project Office and the Mohole Field Operations Office at Houston were closed. Project Mohole represented a 5-year effort to drill through the earth's crust to allow for observation and analysis of the mantle. Congressional action, based on a reordering of national priorities, terminated the program.

At the end of fiscal year 1968, 971 full-time personnel were employed by the National Science Foundation.

National Science Board Changes

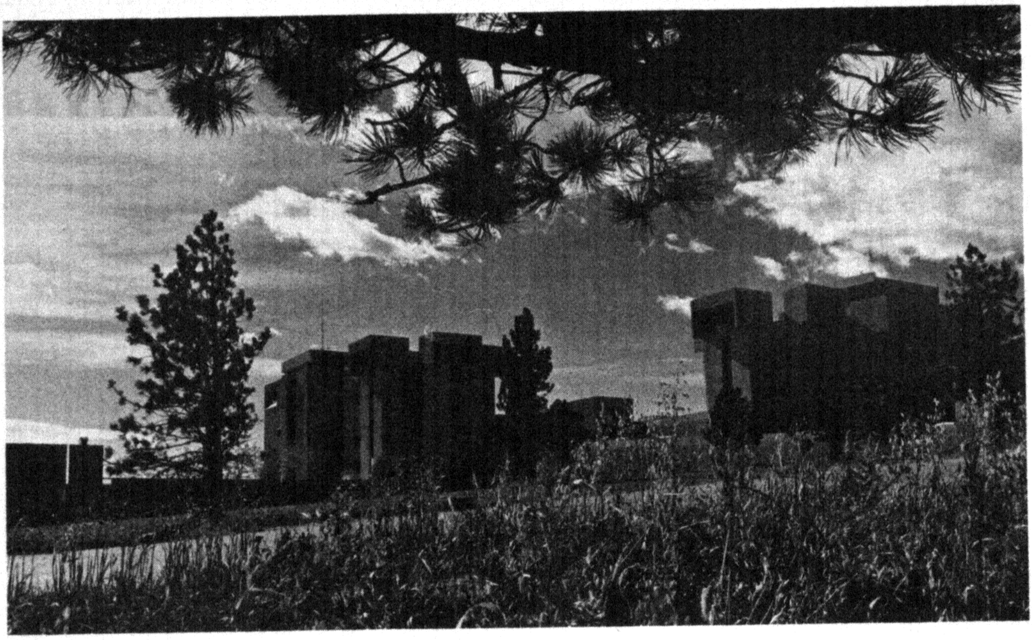
Significant changes in National Science Board membership took place in fiscal year 1968: Dr. Roger W. Heyns, Chancellor, University of California, Berkeley, replaced Dr. Julius A. Stratton, Chairman of the Board of the Ford Foundation, and a vacancy was created in Board membership with the death of Dr. Rufus E. Clement, President, Atlanta University, Atlanta, Ga., who had served with the Board since June 1960. This vacancy remained unfilled until late in the fiscal year when the President nominated eight distinguished scientists to fill 6-year terms expiring May 10, 1974. Renominated by the President were Dr. Philip Handler, James B. Duke Professor and Chairman, Department of Biochemistry, Duke University Medical Center, who had just completed 2 years as Chairman of the National Science Board, and Dr. Harvey Brooks, Gordon McKay Professor of Applied Physics and Dean of Engineering and Applied Physics, Harvard University. New nominations by the President to replace outgoing Board members are listed below:

- Dr. R. H. Bing, Research Professor of Mathematics, the University of Wisconsin
- Dr. William A. Fowler, Professor of Physics, California Institute of Technology
- Dr. Norman Hackerman, President, the University of Texas at Austin
- Dr. James G. March, Dean, School of Social Sciences, University of California at Irvine
- Dr. Grover Murray, President, Texas Technological College
- Dr. Frederick E. Smith, Chairman, Department of Wildlife and Fisheries, School of Natural Resources, University of Michigan

All eight nominees were confirmed by the Senate on June 17, 1968, and appointed by the President the following day.

Elections for National Science Board officers resulted in the reelection of Dr. Philip Handler as Chairman for an additional 2-year term expiring in May 1970, and the election of Dr. E. R. Piore, Vice President and Chief Scientist of International Business Machines Corp., as Vice Chairman for the same period.

A complete list of National Science Board members is presented in appendix A of this report.



NCAR Photo

Laboratory building at the National Center for Atmospheric Research, Boulder, Colo. NCAR is one of four national research centers maintained by the Foundation to provide scientific equipment and facilities that are not normally available at other institutions.

RESEARCH SUPPORT ACTIVITIES

The National Science Foundation statutory authority as amended through August 14, 1968, specifically authorizes the Foundation "to initiate and support basic scientific research and programs to strengthen scientific research potential." Support for such research activities can be divided into four major areas:

- Research project grants to institutions (primarily colleges and universities) for scientific investigations by individual scientists or groups of scientists.
- Grants to academic institutions for the acquisition of specialized research equipment and facilities.
- Support of cooperative National (and International) Research Programs.
- Support of National Research Centers, established and operated for the Foundation by associations of universities.

The major research programs are discussed in this chapter in connection with the related scientific disciplines, following a brief summary of overall fiscal data.

Basic Research Project Grants

In fiscal year 1968, the Foundation made 3,874 awards totaling $170.6 million.

Of all actions taken by the Foundation on research project proposals in fiscal year 1968, 56 percent were awards.

The total amount requested in the proposals receiving favorable action was $359.8 million; on the average, therefore, the awards provided 47 percent of the funds requested. Part of this reduction in funds is due to shortening the time for project support; for this shortened time span the percentage of funds provided was 75 percent of that requested. Table 4 gives the distribution, by number and amount, of awards according to the fields of science for fiscal years 1966, 1967, and 1968. Research grants were awarded to 403 institutions in 50 States, the District of Columbia, and Puerto Rico. More than 90 percent of the funds went to academic institutions in every State and the District of Columbia. Of these 216 received two or more research grants and 114 received at least $200,000.

Table 4.—National Science Foundation Basic Research Projects, Fiscal Years 1966, 1967, 1968

[Dollar amounts in millions]

	1966 awards		1967 awards		1968 awards	
	Number	Net Amount	Number	Net Amount	Number	Net Amount
Mathematical and Physical Sciences:						
Astronomy	94	$6.7	118	$5.8	118	$6.1
Chemistry	405	16.5	420	17.2	456	17.8
Mathematical Sciences [1]	368	12.9	422	14.2	406	12.8
Physics	253	20.1	269	23.7	235	25.9
Subtotal	1,120	56.2	1,229	61.0	1,215	62.6
Biological and Medical Sciences:						
Cellular Biology	297	10.2	239	10.9	236	10.5
Environmental and Systematic Biology	311	12.1	420	12.2	375	11.9
Molecular Biology	307	12.3	254	12.3	243	11.4
Physiological Processes	233	10.4	343	11.8	335	11.8
Psychobiology	141	5.2	118	4.8	117	4.7
Subtotal	1,289	50.1	1,374	52.1	1,306	50.3
Environmental Sciences:						
Atmospheric Sciences	81	6.4	90	7.2	99	7.4
Earth Sciences	227	7.5	224	7.9	213	7.9
Physical Oceanography	59	7.2	91	7.8	75	8.4
Subtotal	367	21.1	405	22.7	387	23.7

Engineering Sciences:						
Engineering Chemistry	67	3.0	78	2.9	69	2.8
Engineering Energetics	85	3.5	72	3.1	66	3.1
Engineering Materials	71	2.6	82	3.1	86	3.4
Engineering Mechanics	173	5.3	161	5.8	160	5.9
Engineering Systems	94	3.3	87	3.5	83	3.4
Special Engineering Projects	36	.4	30	.9	42	.6
Subtotal	526	18.1	510	19.2	506	19.4
Social Sciences:						
Anthropology	125	3.8	147	3.6	142	3.5
Economics	51	2.2	81	3.3	69	3.6
Economic and Social Geography	5	.2	15	.4	23	.6
History and Philosophy of Science	49	1.0	43	.8	47	.7
Political Science	17	.3	32	.8	39	.8
Sociology and Social Psychology	83	3.6	118	3.6	118	3.7
Special Projects	15	1.0	15	2.0	22	1.8
Subtotal	345	12.2	451	14.4	460	14.7
Total	3,647	157.6	3,969	169.4	3,874	170.6

[1] Figures for fiscal years 1966 and 1967 include computer science research projects which for 1968 are reported on page 194.

The program of Research Initiation Grants for young engineering faculty members, beginning independent investigations, has been continued. The Foundation received 695 such proposals requesting $10.3 million, and awarded 147 grants totaling $2.2 million.

Specialized Research Equipment and Facilities

Increasingly complex, expensive equipment and facilities are required for modern science as it continues to develop rapidly and become more and more interdisciplinary. The cost of funding such items cannot usually be provided out of normal resources of academic institutions. A limited amount of support, therefore, is provided by the Foundation to facilitate the acquisition of academic facilities needed for the advancement of research. The support given by the Foundation for this purpose for the past 3-year period is summarized in table 5.

Table 5.—*Specialized Research Equipment and Facilities, Fiscal Years 1966, 1967, and 1968*

[Dollars in millions]

	Fiscal year 1966		Fiscal year 1967		Fiscal year 1968	
	Number	Net Amount	Number	Net Amount	Number	Net Amount
Astronomy	7	$1.363	12	$1.860	4	$0.662
Atmospheric Sciences	19	.800	19	.954	11	.788
Biological and Medical Sciences	31	4.042	25	1.668	30	1.709
Chemistry	45	2.360	88	3.121	113	4.296
Engineering	45	1.175	44	.943	43	1.073
Oceanography	7	2.371	11	2.017	9	4.711
Physics	23	6.496	19	5.797	19	4.697
Social Sciences	7	.771	10	.309	3	1.006
Total	184	19.378	228	16.671	232	18.942

National Research Programs

The Foundation has been assigned responsibility by the President, or by the Congress, or by agreement within the Executive Branch, for a number of research programs that are so large or complex as to require coordinated planning and funding on a national basis, particularly if international cooperation is involved. The actual funding in these cases is largely in the form of grants to universities and colleges. These activities are discussed in more detail under the scientific discipline to which they are most closely related. The National Research Program grants and contracts for fiscal years 1966, 1967, and 1968 are listed in table 6.

Table 6.—National Research Programs

[Dollars in millions]

	Fiscal Year 1966		Fiscal Year 1967		Fiscal Year 1968	
	Number	Net Amount	Number	Net Amount	Number	Net Amount
U.S. Antarctic Research	178	$8.36	143	$7.58	149	$7.64
Arctic Ocean Research	0	0	1	.13	0	0
Weather Modification	32	1.85	41	2.91	32	2.90
International Indian Ocean Expedition	10	1.07	0	0	0	0
Deep Crustal Studies of the Earth (MOHOLE)	15	16.97	1	.06	0	0
International Years of the Quiet Sun	28	1.62	18	.72	0	0
International Biological Program [1]	0	0	(12)	(.50)	1	.70
Ocean Sediment Coring Program [2]	1	5.40	0	0	4	4.17
Global Atmospheric Research	0	0	0	0	1	.20
International Cooperative Scientific Activities	32	.71	25	1.05	59	.65
Total	296	35.98	229	12.46	246	16.25

[1] Funded from basic research in fiscal year 1967, not included in above total.

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

322-215 O—68——4

National Sea Grant Program

In addition to the above, the Foundation in fiscal year 1968 made its first grants under the National Sea Grant Program, a new field of responsibility defined and assigned to the Foundation by the National Sea Grant College and Program Act of 1966. Details of Sea Grant activities and awards will be found on page 197.

National Research Centers

In some instances, research needs cannot be met by mere expansion of programs at existing institutions. Accordingly, the Foundation has established four National Research Centers which are Government-owned facilities, operated in each case by a nonprofit corporation formed by a group of universities, but funded and supervised generally by the Foundation. Each center maintains close collaboration with the scientific community. Two optical astronomy observatories (Kitt Peak National Observatory near Tucson, Ariz., and Cerro Tololo Inter-American Observatory in Chile) and a radio astronomy observatory (National Radio Astronomy Observatory, Green Bank, W. Va.) maintain a limited staff of resident astronomers and support personnel. Most of the available telescope time is used by visiting astronomers and graduate students from the academic community at large. The National Center for Atmospheric Research, on the other hand, maintains a resident staff of highly qualified scientists representing the many disciplines involved in atmospheric science research. Here, too, however, there is considerable participation by visiting scientists who use its specialized equipment and who join in projects of a wider scope than those available at their own institutions.

MATHEMATICAL AND PHYSICAL SCIENCES

The mathematical and physical sciences are the common threads binding together the entire structure of science. National Science Foundation support of research in the physical sciences is sectioned into astronomy, chemistry, and physics, even though with time the lines separating the areas become less and less distinct. All three disciplines are concerned with the matter of which the universe is made and it is the differences in viewpoint and approach which are the bases for the classification by discipline. As knowledge expands, workers in the various fields find their interests increasingly overlapping and the solutions to their problems more and more interdependent.

In the following paragraphs, the reader will find examples which are representative of Foundation-sponsored activities in advancing the mathematical and physical sciences.

Chemistry

Chemistry, concerned with the properties and transformation of matter, leans more and more heavily on concepts and instrumentation

Table 7.—*National Research Centers Funds—Fiscal Years 1966, 1967, and 1968*

	Fiscal year 1966			Fiscal year 1967			Fiscal year 1968		
	Capital obligations	Research operations and support services	Total	Capital obligations	Research operations and support services	Total	Capital obligations	Research operations and support services	Total
Cerro Tololo Inter-American Observatory	$735, 900	$690, 000	$1, 425, 900	$1, 020, 000	$693, 000	$1, 713, 000	$1, 502, 000	$823, 000	$2, 325, 000
Kitt Peak National Observatory	2, 983, 280	3, 202, 990	6, 186, 270	2, 058, 400	3, 446, 600	5, 505, 000	8, 331, 176	4, 144, 192	12, 475, 368
National Radio Astronomy Observatory	2, 017, 639	2, 916, 091	4, 933, 730	1, 392, 538	3, 592, 462	4, 985, 000	874, 300	3, 989, 700	4, 864, 000
National Center for Atmospheric Research	2, 182, 000	8, 289, 905	10, 471, 905	3, 060, 656	9, 240, 000	12, 300, 656	2, 041, 100	9, 758, 612	11, 799, 712
Total	7, 918, 819	15, 098, 986	23, 017, 805	7, 531, 594	16, 972, 062	24, 503, 656	12, 748, 576	18, 715, 504	31, 464, 080

once considered entirely the province of physics. Time-resolved spectroscopy illustrates how new instrumental techniques operating for extremely short time periods lead to both increased scientific understanding and technological advances. Technology that proceeds from basic chemical research has made modern transportation possible through synthetic rubber, high-energy fuels, and super alloys; increased longevity by producing chemotherapeutic agents; and made life easier by providing detergents, pesticides, lubricants, plastics and thousands of other products produced by the chemical industry.

Laboratory Synthesis of Antibiotics

In September 1968, Hans H. Muxfeldt of Cornell University announced the successful laboratory synthesis of the *d,l* form of the antibiotic oxytetracycline, thus marking a historic achievement in organic chemistry following 10 years of research. The accomplishment provides new basic knowledge about one of the most complex and widely used antibiotics and could lead the way to more effective attacks against presently incurable illnesses.

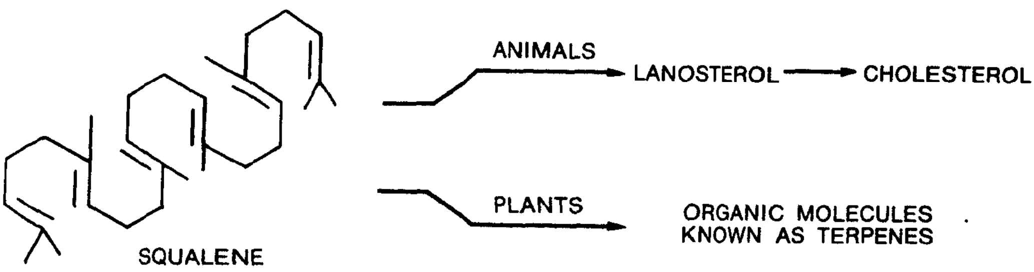
Oxytetracycline, generally familiar as terramycin, is one of the more important compounds in a family of antibiotics known as tetracyclines which are superior to penicillin in combating a variety of bacteria, including the larger viruses. The tetracyclines are produced naturally as products of microbiological fermentation.

The molecule of oxytetracycline is notable for its overall structural complexity. It has six asymmetric centers and is remarkable for its inherent chemical instability. In attempting to synthesize this complicated structure, Dr. Muxfeldt started with a base molecule of juglone, a relatively simple compound derived from walnuts. From this a key aldehyde, a highly reactive compound, was synthesized, and chemical changes in 16 successive steps were introduced. Atoms and pieces of other molecules were added and subtracted until there emerged a molecule with a formula of $C_{22}H_{24}O_9N_2$. This is identical in content and form, but it has only one-half of the biological activity of the *d,l* form of the antibiotic as produced by the natural fermentation process.

It is at present unlikely that artificial synthesis will replace the natural production of oxytetracycline, or terramycin. However, Dr. Muxfeldt plans to apply his newfound synthetic technique to the preparation of tetracyclines not now available in nature. This means that eventually it may be possible to construct a molecule of a compound not found in nature and match it with a specific disease for which no known remedy exists. One might now also be able to synthesize compounds that might be active against bacteria that have become resistant against antibiotics from the fermentation sources. This work has attracted international recognition because of its potential medical importance.

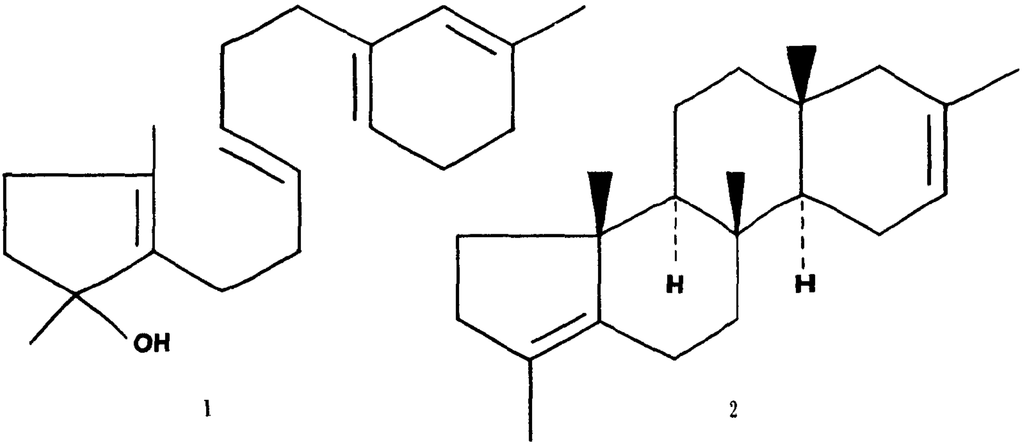
Cholesterol is an extremely important material which is broadly distributed in the animal kingdom. In man, it has been implicated as a factor in arteriosclerosis. The unraveling of its biological origin (biogenesis) is one of the most fascinating chapters in modern chemistry and has led to an understanding of how cholesterol is formed in the cell.

Of all the steps used by the cell in the biogenesis of cholesterol, there is one which is most intriguing from the point of view of the organic chemist. This involves the conversion of squalene, a polyolefinic molecule found in quantity in shark liver oil. The molecule resembles a long chain and has 30 carbon atoms in it. In nature, this long, open chain molecule is converted by enzymes into lanosterol, a new molecule having four rings (tetracyclic). The lines in the diagram represent bonds between carbon atoms which are represented by angles.



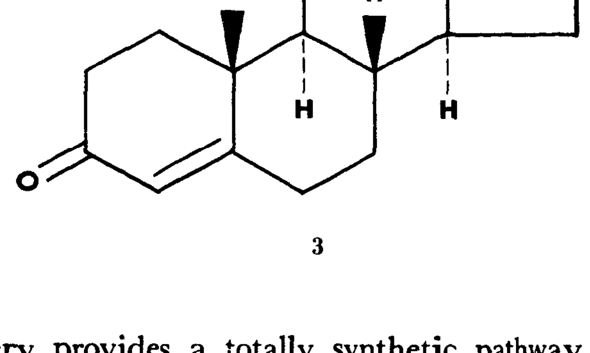
The manner in which nature changes the squalene molecule into the tetracyclic lanosterol is particularly intriguing. Squalene has no center of asymmetry and is symmetric. A molecule that has a center of asymmetry can exist in either a left or a right handed form. In this reaction, symmetric squalene is converted into the molecule lanosterol which has seven centers of asymmetry. In the lanosterol, each of the seven possible centers of assymetry has only one form, so that of the 128 possible ways of putting together the centers, only one structural combination is formed. It is nature's virtuosity in forming only the one correct form that has stimulated the organic chemist to learn how to mimic this in the test tube.

William S. Johnson of Stanford University, with Foundation support, has been studying this process in order to try to duplicate it. He has been making a detailed study of the cyclization of open chain polyolefins (similar to squalene) to convert them, without the use of enzymes, into polycyclic molecules. The chemicals that are being used to bring about the ring formation are acids, chosen on the basis of a theory of how the enzymes function. As a result of these studies, he has been able to demonstrate that extremely complex molecules can be made from relatively simple, open-chain starting materials. Recently this work has led to a completely novel total synthesis of a steroid. The steroids are a class of complex polycyclic molecules that have very important functions in running of the cell. The key step in this synthesis is the cyclization of the chain-like polyolefinic compound, *1*, into the tetracyclic compound, *2*, as shown below, by a nonenzymatic reaction which mimics the biogenetic process.



1 2

The reaction caused the formation of only the correct handedness (left or right) at each of the five centers of assymmetry so that new polycyclic molecules have the characteristic structural features of the steroid family. The intermediate tetracyclic olefin, *2*, is then converted in two further chemical reactions into the hormone-like molecule, *3*, which resembles progesterone. The elegance of the entire work lies in the ease in which the entire backbone of the tetracyclic steroids is formed.



3

This discovery provides a totally synthetic pathway which can be employed in the production of medicinally useful hormones. The utility of the method lies in its complete generality and flexibility which allows it to be used in the total synthesis of the steroid family of hormones. These represent a very broad class of hormones such as estradiol, estrone and progesterone which are extremely important female hormones, and testosterone and androsterone which are male hormones. Some of these hormones are important in maintaing the body's metabolism. Also, the female hormone progesterone is involved in the preparation and the maintenance of the menstrual cycle which makes it extremely important in fertility and birth control problems. The new process, after a great deal of development, has the possible potential of being economically competitive.

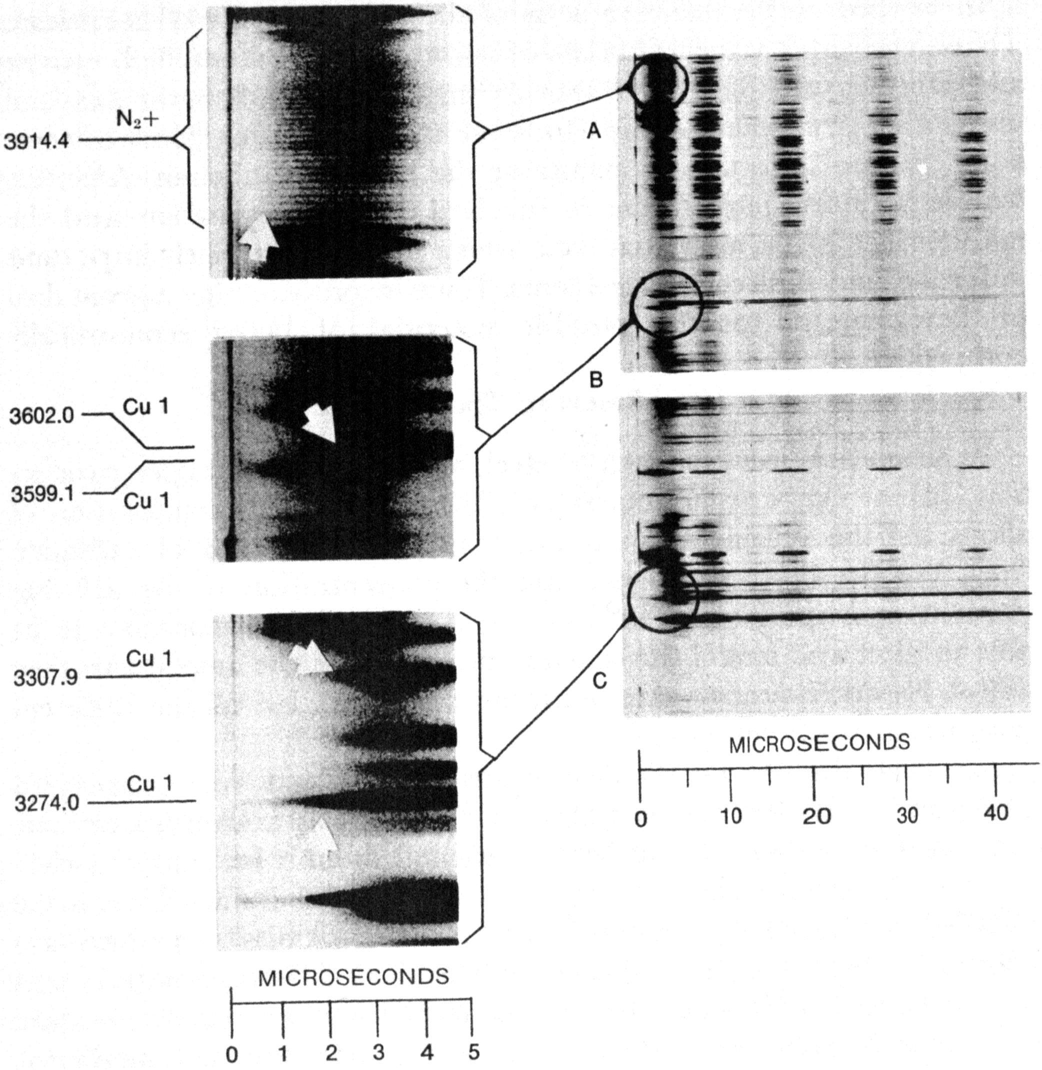
Time-Resolved Spectroscopy

In the metals industry, such as steel, aluminum, and copper production, almost every manufacturer controls the chemical composition of alloys and the refining of pure metals using the emission of radiation from vaporized samples to measure the concentration of the alloying elements or impurities. In an analysis, it is extremely important to be able to select and control the emission process, since the analyst can then adjust his instrumentation to optimum conditions for all the different samples and problems at hand.

Although the general physical principles involved when vaporized atoms emit radiation are well known, much less is known about how the atoms are vaporized and become excited to emit radiation in electrical discharges or other sources, such as arcs and flames. Unless the detailed mechanisms involved in the radiation emission process are known, the best that can be done is to fit and try different combinations of instruments and vaporizing sources until some acceptable measure of success is achieved. Although this is a frustrating and inefficient approach, it is remarkable that for the millions of analyses that are done in the steel industry alone each year using emitted radiation, almost all of them are developed and executed empirically.

A high-voltage spark discharge is an effective and popular device for vaporizing metal samples and causing the vapor to emit radiation that can be used for an analysis of the composition of the sample. John P. Walters, chemist at the University of Wisconsin, with National Science Foundation support, has developed instrumentation and methods that allow the photography of the emission spectrum within 0.05 millimeter of the surface of copper, steel, and aluminum samples; and within 0.07 microsecond (millionths of a second) of the time they are sparked.

Large segments of the emitted spectrum were photographed with this high time resolution for either long or short times during the life of the spark. Using these techniques, it was possible to clearly observe and study the supersonic movement of microgram-size plugs of vaporized material away from the electrode surface as the metal electrode absorbed the energy of the spark. It was possible to watch the atoms composing the vapor first be excited, then ionized, then ionized again, and finally emit



A composite photograph of a time-resolved emission spectrum of a spark between two copper electrodes in a pure nitrogen atmosphere is shown in the above figure. The photographs on the right display the spectrum lines occurring in the first 40 microseconds (millionths of a second) after the beginning of the spark. Some important features are magnified in the insets to the left which show the history of the spark during its first 5 microseconds. Inset A shows the conditions in the hot spark core before the copper vapor arrives. The arrow in inset A shows a closely spaced series of lines of the nitrogen molecule ion, indicating the appearance of nitrogen at the time that the spark core has violently snapped into a filament. Insets B and C show the arrival of copper vapor in this violent environment; the three arrows point to key spectral lines of copper within the moving mass of vapor.

radiation in times much less than a microsecond. The plugs or jets of vapor could be followed through space until they struck the surface of the other electrode in the spark and plated out there. Because of the very short times and small distances that were measured, the actual atomic excitation process could be followed in small steps, and entirely new facts about how the radiation was emitted were established. This new information is of great value in an analysis because it is based on the physical properties of the individual atoms composing the vaporized sample, and is not empirical.

With the information available about the excitation process in the spark, the Wisconsin laboratory is developing new analytical spectroscopic methods for the determination of carbon and other impurities in steel, the determination of fractional part-per-million metal impurities in tissue and other biological samples, and the determination of gaseous isotopes of molecules. The new methods are promising in terms of high sensitivity and precision, as well as experimental control of the emitted light. With continued support from the National Science Foundation, more information is now being gathered about excitation mechanisms in other electrical discharges and plasmas, and new instrumentation is being developed for basic research in time-resolved emission spectroscopy.

Reactions in Micelles

Everyone knows about detergents; they are the substances that pry grease off clothes, dishes or skin and float it down the drain with the water. They do this by forming a "capsule" of detergent, called a micelle, around each particle of grease. Chemists have made surprisingly little use of detergents in chemical processes, yet they can have dramatic effects on simple chemical reactions. One example was recently discovered by a Foundation grantee, R. L. Letsinger of Northwestern University.

Dr. Letsinger's work was not concerned with micelles at all; instead, he was studying some interesting reactions which happen only under the influence of light. They involved substances like hydroxide (the "caustic" in lye) or cyanide reacting with aromatic compounds, which are related to the materials used in mothballs. He kept having trouble because the aromatic compounds would not dissolve in water; he could get them to dissolve in a mixture of alcohol and water, but then the reactions went very slowly. In one case, cyanide would not react at all. But if he put that same aromatic compound in water with the right kind of detergent, it dissolved and cyanide reacted rapidly. Apparently, the micelle helped the cyanide and the aromatic compound to react. This was confirmed by the fact that a different kind of detergent had no effect in making the reaction go, even though it formed a micelle around the aromatic compound.

There have been a few other reports of reactions which were either speeded up or slowed down by detergents, but no one has really studied these effects in detail. Yet it is not hard to imagine great practical value from this behavior, both in getting incompatible materials like water and oil to react, and also in controlling the various reactions which might occur. Further, it is known that micelles are important in biological systems. In fact, it has been learned recently that some enzymes are proteins folded up much like a micelle, with the "fatty" part inside.

Thus studies of reactions in the presence of detergents may make an important contribution to the understanding of enzyme-controlled reactions.

Xenon Fluorides—Their Properties and Uses

The discovery of xenon and krypton compounds in the early sixties came as a great surprise to the majority of chemists, including the experts in chemical theory. Of course the noble gases, a group of unreactive elements including xenon and krypton, have, since their discovery, featured in chemistry as the epitome of inertness and they have served as a key and a prop to chemical theory.

The work which led to the first compounds in xenon in 1962 by Neil Bartlett, at that time at the University of British Columbia but now at Princeton University, was not undertaken with a practical end in view nor indeed were the experiments which led up to the discovery relevant to noble gas chemistry. The prediction that xenon should be capable of entering into chemical combination to form solid compounds under ordinary temperatures and pressures was based on experimental findings in a related system. The reasonable hypothesis framed to account for the other experimental observations admitted the possibility of xenon compounds and thus by the usual scientific method a prediction bore fruit and a hypothesis received further support.

The compounds which xenon forms with fluorine (XeF_2, XeF_4, and XeF_6) are colorless solids at room temperature. They may be distilled in a vacuum and in inert containers can be kept indefinitely. Despite the considerable effort invested in their examination immediately after their first synthesis, they continue to be of great importance for two reasons: (1) although the efforts of theorists have thrown considerable light on the bonding of the atoms in these compounds, several crucial points remain to be settled and (2) very little has been done systematically to explore these compounds as chemical reagents in spite of their promise as reagents in synthesis requiring oxidizing conditions. With Foundation support, Dr. Bartlett's efforts in xenon fluoride chemistry have been aimed at fulfilling both of these objectives.

Although the xenon fluorides are thermochemically stable compounds, the binding energy of each fluorine atom to the central xenon atom is less than in all other fluorides except other noble gas fluorides. The xenon fluorides are therefore potentially valuable sources of fluorine and are (at least on the basis of thermochemical predictions) capable of producing fluorides of other elements or compounds in oxidative fluorinations. An attractive feature of them as reagents both in the laboratory and possibly in industrial processes is that in their reactions, xenon gas is the only reagent side-product and in most foreseeable applications this will not enter into chemical combination with the desired product. Of course the xenon can easily be recovered and used again.

Xenon difluoride (XeF_2) is the easiest xenon fluoride to make and is the safest. It can be made in Pyrex bulbs from xenon and fluorine gas, simply by exposure of that mixture to sunlight. Surprisingly, this fluoride proved to be resistant to chemical interaction. For example, the fluoride can be recovered from solution in water (in which it is readily soluble) but on thermodynamic grounds alone it would have been expected to yield xenon, oxygen, and hydrogen fluoride. For some unknown reason, the xenon difluoride molecule (in the absence of a catalyst) is unable to interact with water molecules. In other situations, where xenon difluoride was expected to yield xenon and a fluoride, a similar chemical inertness was noted. Dr. Bartlett set out to discover the catalyst which would realize the chemical potential of XeF_2. He discovered that the key to xenon difluoride reactivity is any reagent which will give rise to the hitherto unknown species XeF^+ (the monofluoroxenon cation). This cation is evidently an extremely effective oxidative fluorinator. These findings confirm the utility of XeF_2 as a reagent in synthesis, particularly in cases where oxidative syntheses are required without side reactions. The reagent will undoubtedly have application in organic as well as inorganic synthesis.

The findings just referred to stimulated a search for salts of the XeF^+ cation and these have been made and characterized. An unexpected finding was that salts containing a cation $(Xe_2F_3)^+$ could also be easily prepared. An X-ray crystal structure determination of one of these salts revealed that the cation has one fluorine atom bridging two XeF groups. Bridging fluorine atoms have been noted many times before but because of the central place of the noble gases in chemical theory, this has special significance.

Infrared Intensities in Liquids

Of the three common states of matter—vapor, solid, and liquid—the latter is understood least. In the vapor state, the individual molecules are well separated and do not interact strongly with each other. In the case of crystalline solids, the individual molecules or atoms are close together and do interact strongly with each other, but they are arranged in an orderly and rigid manner, which permits very accurate descriptions. The liquid state presents a more complicated situation because the molecules in liquids are very close to their neighbors and interact strongly with each other but lack the orderly arrangement which aids understanding of crystals.

The strong molecular interactions which occur in liquids alter many molecular properties. One such property is the molecule's infrared absorption spectrum. Even in an isolated molecule, the constituent atoms may vibrate and cause absorption of electromagnetic radiation, e.g., visible light. It so happens that the absorption of radiation due to the vibration of the atoms of a molecule occurs most commonly in the infrared region of the spectrum. This infrared spectrum has been likened to a molecular fingerprint, since each chemical compound has a unique set of molecular vibrations, and by studying the bands in an infrared absorption spectrum of an unknown molecule, scientists can deduce valuable information about its structure and composition.

The intensity of the infrared absorption band, i.e., how effectively it absorbs the electromagnetic radiation, is dependent upon subtle changes in the distribution of electrons as the atoms vibrate. Accordingly, changes in the electronic charge distribution of a molecule, due to the influence of external forces, such as the near presence of another molecule, can result in changes in the intensity of its absorption bands. By comparing absorption strengths for the vapor phase, where molecules are essentially isolated, with those for liquid phases, extremely important information about the nature of intermolecular forces can be obtained.

Progress in this area in the past has been hampered by the lack of reliable data on liquid phase-band intensities, but recent work at the University of Minnesota, under the direction of Bryce Crawford, Jr., has gone a long way toward removing this handicap. The key to reliable liquid state intensity measurements is the use of a method known as attenuated total reflectance (ATR) which was first suggested by the Dutch scientist, J. Fahrenfort. Dr. Crawford and his students, with NSF support, have developed the ATR method to a high degree of sophistication.

In order to determine band intensities of a material accurately, it is necessary to know its infrared absorption spectrum and refractive index, which is a measure of how much light is slowed down when it passes through the material. Previously, infrared intensities were determined either by direct measurement or were calculated from refractive index data. The great advantage of the ATR method is that it permits the measurement of both these properties simultaneously. As a result of applying this advanced method, the experimental error of the data may be reduced by a factor of five to tenfold.

As mentioned earlier, the intensity of an infrared absorption band may be influenced by specific molecular interactions. In addition, the intensity also depends upon bulk dielectric effects (i.e., the action of the material in conducting or hindering the passage of electricity), which in turn are related to the refractive index of the material. The ATR approach, as developed by Dr. Crawford, enables one to separate dielectric and molecular interaction effects with considerable confidence. After eliminating bulk dielectric effects by means of suitable corrections, one can progress to the chemically more interesting effects due to specific interactions.

For example, it has been hypothesized that the unusual width of certain infrared absorption bands is due to the persistence of molecular rotation in the liquid phase. The ATR approach has provided strong evidence that this hypothesis is indeed correct, and has permitted a quantitative characterization of rotational motion in liquids.

The comparison of integrated intensities of absorption bands in the vapor and liquid phases has occupied the attention of numerous molecular spectroscopists during the past two decades. However, in spite of this considerable effort, a completely satisfactory theoretical explanation has not been advanced. Preliminary progress in this area by Crawford's group has been encouraging. By studying molecular systems, notably perfluorobenzene, where specific interactions are virtually absent, it has been shown that the gas-phase data and the liquid-phase data are essentially identical, provided the latter are appropriately corrected for the dielectric field effects.

These, and other related studies, have helped make it possible to achieve some satisfactory understanding of band shapes, of the rotational motion of molecules in liquids, of the relation of integrated intensities between gas and liquid phases, and of the localized effects of intermolecular forces. Ultimately, the information gained from these studies should shed light on that structural enigma, the liquid state.

Chemical Instrumentation

Modern instrumentation for chemists is crucial for both teaching and research in universities today. Decisive results which require less equivocation in their interpretation are possible through the application of electronic, optical, magnetic and mechanical devices to the solution of the vexing problems now facing chemists. A central problem for university departments of chemistry is that of the acquisition and maintenance of large expensive items of instrumentation so vital to the educational process.

During fiscal year 1968, the National Science Foundation contributed to the purchase of $7.3 million worth of general purpose instrumentation for use by a large number of chemists and other scientists at 113 institutions. Foundation grants for this purpose totalled $4.3 million, the balance being provided by the institutions. This significant participation by the universities in providing improved capabilities for students and faculty is evidence that institutions of higher learning recognize the great importance of complex instrumentation in modern chemistry. For the first time the Foundation introduced the concept of the regional center for ultraexpensive chemical instrumentation. A grant to the California Institute of Technology provided for a 220 MHz (million cycles per second) nuclear magnetic resonance spectrometer for use by chemists in the southern California region. If this proves to be a viable way to solve the problems of ultraexpensive instrumentation, the regional concept of support will be continued.

Physics

Physics, already noted for its innovation of equipment and experimental techniques, is experiencing further acceleration in its development through the increasing interplay between its various subfields. The methods of data handling and theories of particle scattering developed in nuclear and elementary particle studies are increasingly valuable in atomic, molecular, and solid-state physics. Alternatively some of the most sophisticated experiments in high-energy physics are being performed by solid-state and atomic physicists using techniques they developed for work in their own fields. Solid-state, atomic, and molecular physics and quantum electronics are becoming of increasing utility. Perhaps even more important are new areas such as plasma physics, the physics of fluids and the general area termed "many body" physics (which refers to problems of many particles interacting). These fields bear an intimate connection with life sciences, atmospheric phenomena and oceanography, and sufficient understanding has been gained to begin examining other problems of very practical significance in these areas.

Electronic and Atomic Scattering

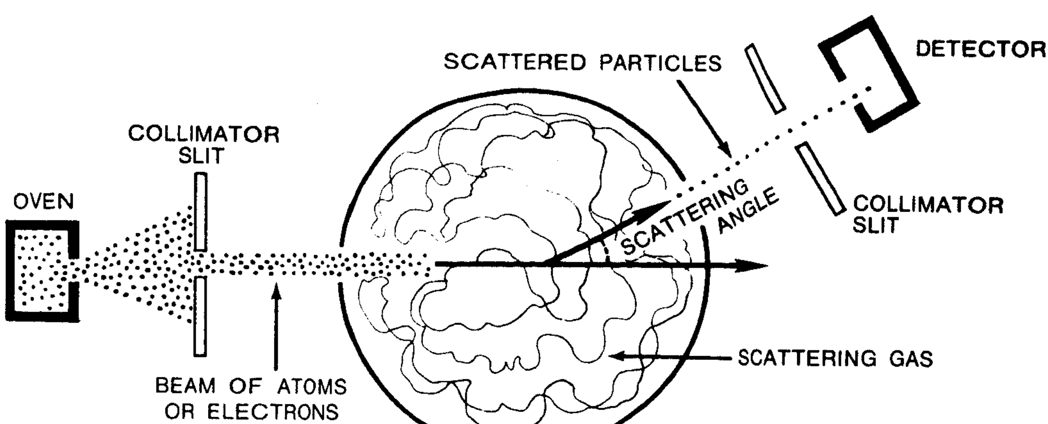
Recent significant advances have been made in understanding how atoms, ions, and electrons in a gas interact with each other. This is not only important because several predictions and calculational techniques of quantum mechanics can now be tested for the first time, but is of extreme practical importance in learning how chemical reactions proceed and how energy is transferred in gases or in the highly ionized gases called plasmas.

Scientists have known for many years that it is the electrons lying between the atoms in a molecule that hold the molecule together. Using various methods of optical and radio frequency spectroscopy they could even determine what orbits these "bonding" electrons occupy for various molecules. However, there has been no way of following the process from beginning to end—taking two or more individual atoms and watching what happens to their electrons as they are brought together to form a molecule. The consequence was that there was no sure way to predict why some sets of atoms combine readily and why others seem reluctant to combine to form molecules.

When the atoms of a gas or the ions in a plasma collide with each other, which occurs many millions of times a second at standard temperatures and pressures, the electronic states of the atoms or ions shift to new values as they come closer together. (See discussion on Infrared Intensities in Liquids, page 43.) If two atoms merely pass close to each other, there may only be a slight distortion of the electrons on each atom while the two are near each other. But if they really "hit" each other, that is if they come so close that the electron cloud about one atom penetrates that of the other atom, then the collision may have more lasting effects. The simplest of these consequences is that one atom may actually transfer energy to the other by forcing one or more of its electrons into an "excited state" in which its energy is higher than before. With a little more violent collision an electron may actually be stripped from one atom or the other, and sometimes the two atoms actually combine to form a molecule, even though that molecule may be so unstable that its lifetime is extremely short. All of these events occur when thermal energy is transmitted by a gas, and these processes are important to all problems involving a gas, including that of our weather.

In atomic scattering experiments a beam of atoms or ions of known energy is directed at a cloud of gas atoms, so that the individual atoms of the beam are scattered by collisions with the gas atoms. By studying the directions in which the beam atoms are scattered, and the energies of these atoms after the collision has occurred, it is possible to calculate in detail what happened to the two atoms during the collision. The reason that these experiments have not been possible long ago is that it is extremely difficult to create beams of atoms having precisely the desired energies as well as to detect these particles with accuracy. In order to measure the angle of scattering precisely it is necessary to make a very narrow incoming beam. This is done by passing the atoms through a narrow slit as shown in the diagram, and the narrower the slit the fewer atoms get through. Those that do get through are scattered into all possi-

SCATTERING OF ELECTRONS AND ATOMS



ble directions, so that even fewer wind up traveling in any particular final direction. The device used to detect the scattered atoms must also be made small if it is to detect only those atoms being scattered at a particular angle. And finally, it is essential to maintain tremendous purity in the gas in the scattering chamber, for a very few atoms of the wrong type can totally upset the results. In addition, it has taken a very long time to develop proper methods of interpreting the data of these experiments. So many very different kinds of events can occur when two atoms collide that it took years of careful experimental and theoretical work to learn to distinguish between the most important types of processes. Only a small number of scientists have pioneered this new area. NSF grantees

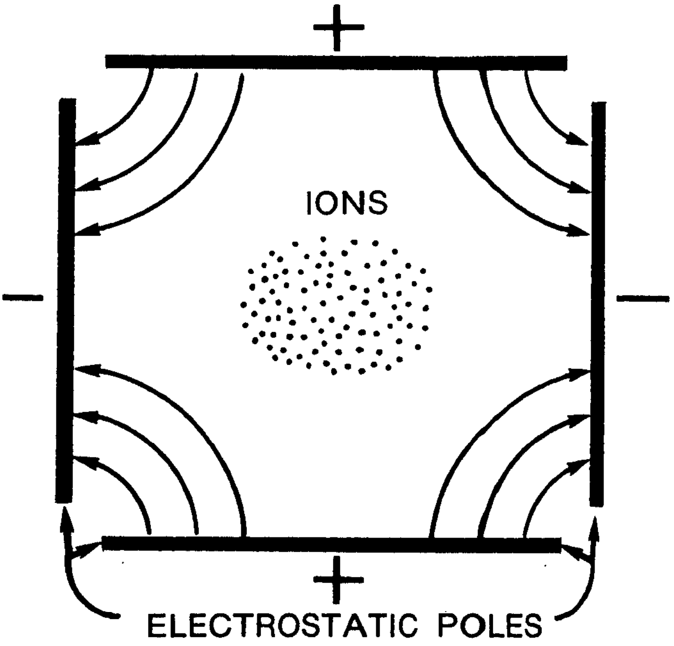
Wade Fite at the University of Pittsburgh, Felix Smith at Stanford Research Institute, Eugene Rudd at the University of Nebraska and George Schulz of Yale University have each played an important role in developing different aspects of this field, which has just begun to stimulate much broader interest as a result of the very interesting new information being produced.

Ion and Electron Isolation

Professor Hans Dehmelt at the University of Washington has recently perfected a technique originally attempted in Germany about 10 years ago to isolate ions and electrons for extremely long periods of time. The scientific importance of this is fairly easy to understand. As mentioned in the previous section, when atoms interact with each other their electrons are shifted in energy, and scientists are naturally interested in measuring the energies of the electrons in a collection of supposedly identical atoms that are interacting with each other by having frequent collisions. If the atoms were isolated, similarly placed electrons on each atom would each have the same identical energy. But because of the collisions, at any instant of time these single energy values will be spread over a variety of values, so that a measurement of electron energies shows a range of energy values for each supposedly identical energy state. Thus, in a non-isolated situation it is impossible to determine the energy states of atoms accurately.

The technique used in this isolation procedure consists of trapping the ions or electrons at very low densities and extremely high vacuum in an

ISOLATION OF IONS



electrical field whose symmetry is said to be quadrupolar, to indicate the four charged electrical poles as shown in the figure. The polarity is changed rapidly back and forth, alternately forcing the electrically charged ions first in one direction and then in the other. The switching frequency is so rapid, however, that the ions do not have time to travel very far before the field is reversed, with the result that they do not reach the walls of the container. Of course, after sufficient time, each of the ions is bound to suffer some sort of collision or other mishap which will allow it to diffuse to the container walls, but on the average this does not happen for about an hour. Considering that these ions would normally reach the walls in about one millionth of a second without the containment technique, this storage time is extremely long. With this new technique, subtle difference in electronic energies can now be measured to phenomenal accuracy, even as high as one part in a billion. This precision will be important not only for further improvement of atomic theory but also for the possible development of radically new types of infrared lasers that will not be affected by temperature fluctuations, a problem that seriously limits the long-term stability of current lasers.

Electrical Dipole Moments of the Electron and Neutron

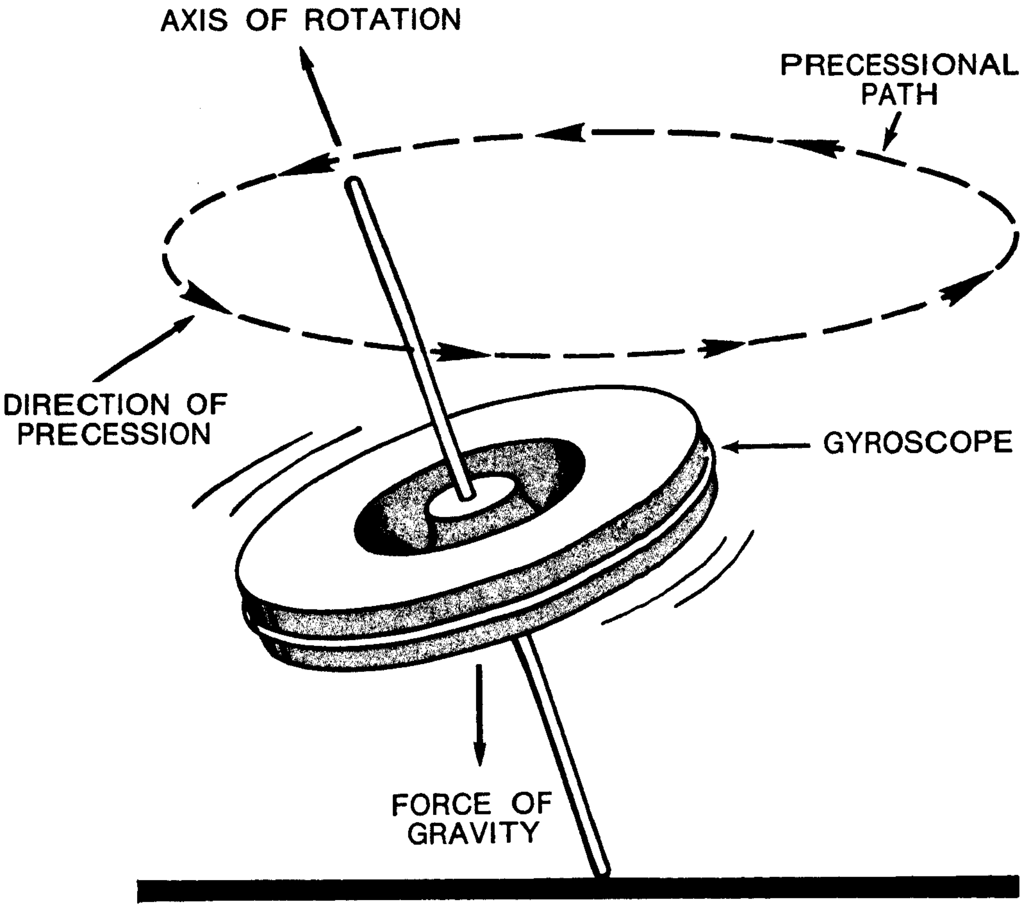
Recent experiments show that the shape of the electrical charge in the electron and neutron is almost perfectly spherical and may be absolutely spherical. This is a most important finding because the electron and neutron are, with a few other particles, the fundamental building blocks of all matter. If they are not perfectly spherical, as was generally assumed for years but is now open to question, the implications to elementary particle theory and nuclear structure theory are profound. For example, certain nuclear reactions can be possible which are expressly forbidden under current theories, and the findings to date have already eliminated some avenues of approach that once seemed promising.

The shape of the charge distribution of these particles is measured by examining how the particles behave in an electrostatic field. The electron and neutron each possess a small magnetic moment, that is, they generate magnetic fields similar to those of little bar magnets as a result of the fact that they are made up of electrical charges which are rotating about an axis. The application of a magnetic field will therefore make the particles turn so that their magnetic moments point in the direction of the field, just as a compass needle does.

But anyone who has observed a gyroscope knows that rapidly rotating bodies behave in an unusual manner. As indicated in the diagram below, the force of gravity causes the axis of a gyroscope to rotate or precess in a circular fashion. A somewhat similar process can occur within an atom.

In addition to a magnetic dipole moment, a particle can have an electric dipole moment if the electric charge on the particle is nonspheri-

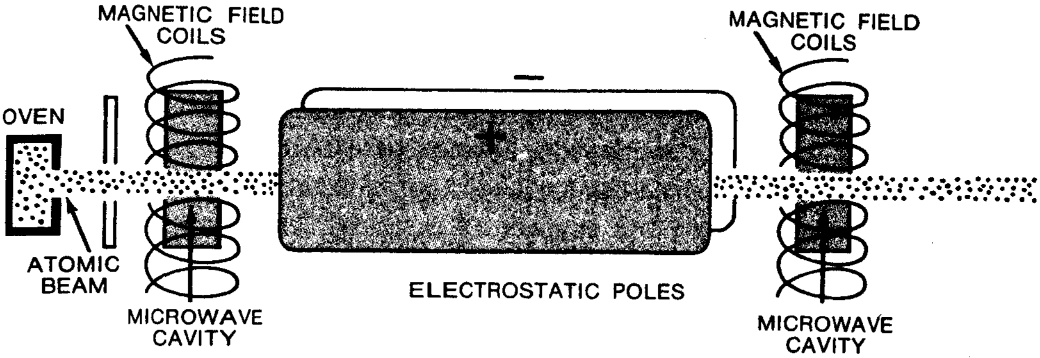
322-215 O—68——5



cal. This moment will make the particle appear to be composed of two opposite electrical charges separated by a distance, and would cause the particle to precess in an electrostatic field just as the magnetic moment causes precession in a magnetic field. If the charge is spherical, i.e., equally distributed in all directions from the center, then there is no moment and precession will not take place. Thus, by measuring precession the presence or absence of this electric dipole moment can be measured and the shape of the charge determined.

In the "atomic beam" technique used in these experiments, the particles being examined are formed into a beam and sent through two microwave resonance cavities, each of which is in a strong magnetic field. These two cavities are separated in distance by several feet over which an electrostatic field is applied, as shown in the diagram. The microwave field of the first cavity both orients the magnetic moments of the atoms and causes their rotation axes to start moving in *phase* (i.e., "in step") with each other. After traversing the first cavity, the atom enters the electrostatic field region. It will precess about the direction of that field as it travels toward the second microwave cavity if it has an electric dipole moment.

ATOMIC BEAM APPARATUS



When the particle arrives in the second cavity, a signal will be detected if the axis of the atom or neutron has precessed far enough to be pointing in the direction opposite to the magnetic field in the cavity. Thus the experiment is performed by slowly varying the electrostatic field from zero to the highest possible value and noting whether a signal is found in the second cavity, meaning that the electrostatic field has caused the axis of the particle to precess. At the highest possible field value, the apparatus is tuned to measure the smallest sized dipole movement capable of being detected.

Unfortunately, it is difficult to produce high electrostatic fields because sparks occur after a sufficiently high intensity is reached. As a result, the failure to detect any dipole moment does not prove that the moment is zero (i.e., that the charge on the electron or neutron is perfectly spherical), but rather that it must be smaller than the smallest moment capable of being detected with the field that can be produced. Of course an acceptable theory of elementary particles would predict the magnitude of such moments, and in that case an experiment might be designed to look for a moment of the appropriate size. Because such a theory is not yet available, these measurements are intended to give some of the information necessary to formulate such a theory, and the experiments are designed to detect the smallest moment that is reasonable to search for considering the current state of knowledge, and the costs involved.

The electric dipole moment of the electron is currently being measured by NSF grantee Edgar Lipworth at Brandeis University. In his experiment, he measures the electric dipole moment of cesium atoms, from which the size of the electric dipole moment of the electron can be calculated. The fact that no dipole moment has been detected by this experiment means that the electron's electric dipole moment must be less than 2×10^{-24} centimeters times the electric charge on the electron, which is the smallest value Dr. Lipworth's apparatus could detect. This is an exceedingly small value and shows that the charge on the electron is almost perfectly spherical. However, in the next few months Dr. Lipworth intends to test for even smaller values, hopefully by a factor of 40.

Identification of Impurities in Solids

Erwin Müller of Pennsylvania State University, an NSF grantee, has recently developed an important new instrument capable of determining the identity of a single atom among many thousands of other atoms on the surface of a metal. This device, known as an Atom Probe Field Ion Microscope, enables an investigator to magnify the image projected onto a fluorescent screen from the surface of a metal whisker-tip to such a degree that the individual atoms comprising the surface appear as single luminous dots. A unique feature of the new apparatus is that an individual atom can be selected, stripped from the surface, and its chemical identity determined. This is accomplished by moving the viewing screen until a small hole in the screen lies at the position of the image of the atom to be studied and then applying such a strong electrical field pulse between the metal surface and the screen that the atom is literally pulled out of the surface and propelled out through the hole. The atom is then identified by measuring its mass in another apparatus called a mass spectrometer.

This ability to identify a single atom is a major advance which is exceedingly important to solid state physicists, chemists and biologists. The properties of semiconductors are actually determined by the presence of a few carefully chosen impurity atoms among billions of atoms of silicon or germanium, and metallurgists have found that modern refractory alloys actually require the addition of very small amounts of impurities to have the desired characteristics. Chemists can now study surface catalysis. Biologists may be able to use suitable modifications of this technique for analyzing the structure of biological molecules.

Mountain Experiment in High Energy Physics

An experiment featuring the paradoxical combination of very small particles and a very large and unusual instrument has led to one of the most intriguing developments in fundamental physics. The particles are muons, intermediate in size between the electrons that form the outer structure of atoms, and the nuclei that form the atoms' core. The instrument used was, in part, the Wasatch mountain range in Utah.

For several years the research group of Jack W. Keuffel of the University of Utah has been watching for cosmic ray muons in a mine under the Wasatch mountains. By arranging an array of cylindrical spark counters, the group "looks" for muons and records their number and direction. Since, in order to reach the detector, the muons must pass through the mountain rock which tends to absorb them, only the more energetic muons reach the detector. However the mountain range is very rugged, and the distance traversed through the rock by a particular muon depends strongly on the direction from which it comes. Particles that reach the detector from different directions will usually thus have different energies since greater thicknesses of rock can absorb higher energy muons.

The thicknesses of rock that correspond to each direction can be measured, so that the mountain range performs the function of sorting the particles according to energy. The depths of rock involved correspond to muons in the energy range between 1000 and 10,000 Bev (billion electron volts), corresponding to collisions between primary protons with energies between 2×10^{12} and 2×10^{14} eV, almost three orders of magnitude greater than the highest energies available in the laboratory using present day particle accelerators.

This ingenious approach of using natural topography to do ultra high energy physics has now led to a most surprising result. Although the muon intensity varies with depth of rock in good agreement with expectations, an expected variation of the number of muons with the angle from the vertical is not present. The expected variation of the numbers of muons with the angle arises because of the two-step nature usually assumed for the production process of cosmic ray muons. The muons are thought to be produced by high energy protons bombarding the atmosphere, but muons are weakly interacting particles and thus cannot be produced directly by primary cosmic rays. Rather the primaries are thought to produce pions and kaons, which then can further decay to muons. Pions and kaons, both lighter than nuclei but heavier than muons, are strongly interacting particles that can decay into muons. But their existence may be very transient since they can also interact strongly with nuclei in the atmosphere, and the theory describing the flight and subsequent decay of these pions and kaons requires a very strong variation of intensity, depending on angle from the vertical.

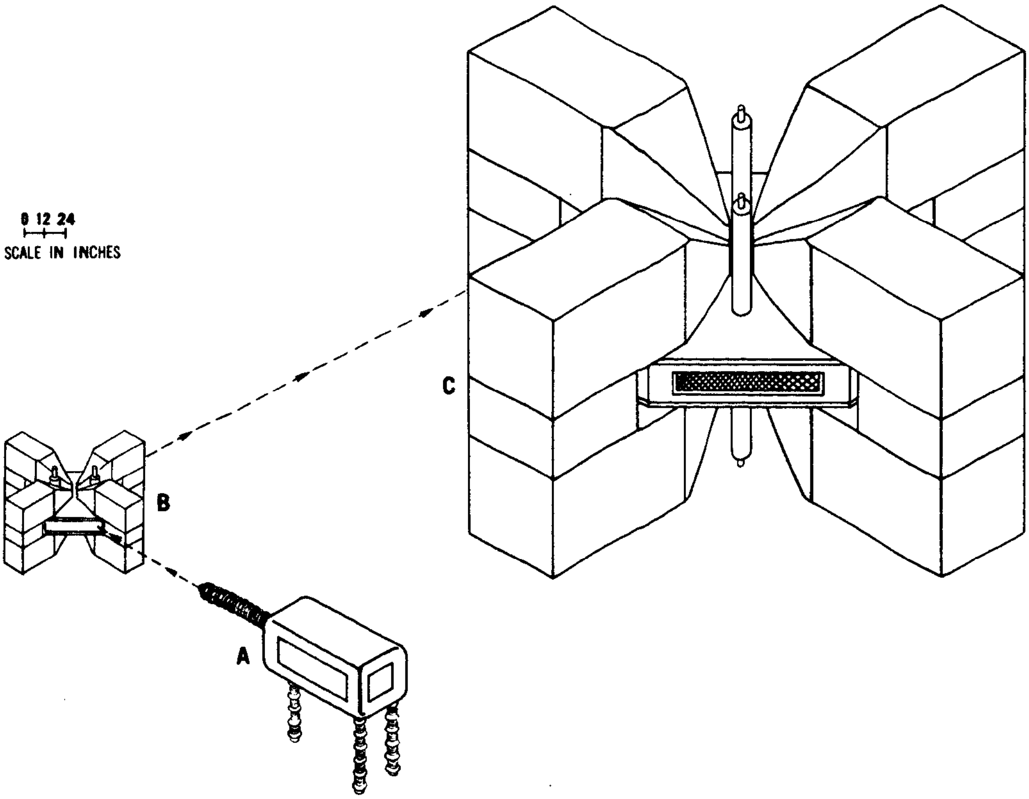
Dr. Keuffel and co-workers were forced to the conclusion that, since the expected angle dependence was *not* present, many of the ultra high energy cosmic ray muons must arise not from pions and kaons, but from some other production mechanism. No such alternative mechanism has yet been observed using the lower energies presently available in the laboratory.

One possibility is the production of a new particle, called an intermediate boson, that has long been conjectured to exist, but has never been observed. Other mechanisms, however, may also be possible and the question is still considered open. What is certain so far is that the use of topography by physicists has initiated work in an area of high-energy physics far beyond the capabilities of present accelerators and has produced significant new results.

Major Physics Research Facilities

The progress of nuclear and elementary particle physics has been closely tied to the development of new and unique accelerators. Projects undertaken at Indiana University and the University of Illinois will assure that the most modern and innovative accelerators are available for further research.

At Indiana, the design of a new type circular accelerator has been completed and construction has been authorized. This accelerator has a novel configuration which greatly simplifies many of the most troublesome problems of conventional cyclotrons such as the location of the ion source inside the machine, the large magnetic gap to accommodate the accelerating cavity, and the difficulty in placing the extraction unit in the magnetic field.



This drawing illustrates the novel configuration of a new type of accelerator now under construction at the University of Indiana. The design simplifies many of the troublesome problems associated with conventional accelerators. A. is the electrostatic injector; B., stage 1 accelerator. Particles are injected through one field-free region and extracted in another. This accelerator serves as an injector for the main accelerator; C., the main accelerator consisting of four wedge-shaped magnets separated by four field-free regions instead of the usual large circular structure.

The main magnet consists of four wedge-shaped magnets separated by four field-free regions instead of the usual large circular structure. The accelerating cavities are placed in two of these field-free regions thus permitting higher voltages to be used. Since there are no accelerating components in the magnetic field, the poles can be much closer together. The particles to be accelerated are injected into the accelerator through one field-free region and extracted in another.

The energy of the resulting proton beam will be at least 200 million electron volts with a beam current of 10 to 50 microamperes. The particles will have an energy spread of 0.1 to 0.01 percent, and the particle energy can easily be varied over a wide range. This excellent homogeneity will allow very precise measurements of nuclear energy levels. Also, many low-yield nuclear reactions can be investigated owing to the high intensity of the particle beam. Since the ion source is outside the accelerator, different ions can easily be introduced and calculations indicate that even the very heavy nuclei can be accelerated.

A superconducting electron linear accelerator (linac) is being constructed at the University of Illinois. This accelerator, which will replace two obsolescent circular machines, will incorporate a variety of major new technological advances in low-temperature physics and accelerator physics. An energy of at least 30 million electron volts is planned for the 15-foot-long device. The superconducting mode of operation will essentially eliminate one of the major disadvantages of conventional room-temperature linear accelerators, namely a high rate of power dissipation in the walls of the accelerating cavities. The low heating losses in the superconducting cavities will enable the accelerator to produce an essentially continuous electron beam instead of the pulsed beam of conventional linacs. The energy homogeneity of the particle beam will also be greatly improved in the superconducting linac. Both of these features are extremely important for the physics experiments which will be done with the accelerator.

The cryogenic (low temperature) technology being developed for accelerator projects at Illinois, Stanford, and other laboratories may play a major role in both the construction of future very large accelerators and other areas of great economic importance, such as power transmission and communications.

The Cornell 10 Bev (billion electron volts) electron synchrotron, initially funded by the Foundation in 1965 and discussed in previous annual reports, reached its design energy on March 2, 1968. The first experiments at this accelerator began in November 1967 at reduced energy, and the first scientific report on research using this synchrotron was given at a meeting of the American Physical Society in February 1968. Since the beginning of March 1968, most of the time has been devoted to experiments at energies up to 10 Bev, although some time is still being used for tuning up the various subsystems and for minor improvements. Six experiments are in progress, including two which involve collaboration between members of the Cornell staff and staff members at the University of Rochester, Harvard University, and Ithaca College. Usage by non-Cornell scientists is expected to increase in the future.

Among the experiments that will be carried out with this accelerator is a series of experiments which will test the theory of quantum electrodynamics in ways that, until now, have not been possible at energies approaching 10 Bev. Since this is the basic theory describing the interaction between electromagnetic radiation and matter, verifying its correctness is of great importance. The first experiment of this series at Cornell has been completed. It measured the rate at which an electron interacting with the electric field of a nucleus would be deflected through a large angle and emit a photon. Good agreement with the theory was found. Another experiment in this series, a study of the photoproduction of mu-meson pairs has been started.

Astronomy

During the year there was a strong surge of interest following the discovery of an unexpected astronomical phenomenon. In the interplay of observational results in the two broad areas of optical astronomy and radio astronomy, radio astronomers this year have uncovered a new major mystery in a group of cosmic radio sources which undergo a rhythmic pulsation of short period and of remarkable pulse regularity.

The first discoveries in the series caught the attention of layman and scientist alike because of the implication that a radio signal of such regularity might require assistance for its production from some kind of intelligent being. However, this theory was discarded when it was later realized that the energy output of these objects, soon named pulsars, was so large that it required some natural phenomenon on a stellar rather than man-sized scale for its production. Scientists are responding to the challenge of finding an explanation for the pulsars by further observations, which have served to locate more of these objects in the sky, and which have provided more detail on the character of the pulses.

Observers have been aided by theorists in both astronomy and physics, who are attempting to explain the several puzzling characteristics of the pulsars. More detail about the pulsars and about the support by the Foundation for efforts to uncover and understand them is found in the section on projects in basic research below. Optical astronomers have checked these pulsating objects in the visible range of wavelengths. They have adapted their telescopes in the hope of confirming the radio pulses by the detection of related pulses in the optical region. The results to date are equivocal, but it is already certain that these pulsating objects are at best weak emitters of the relatively short-wavelength optical radiation. It will be necessary to use the largest aperture telescopes available, combined with very sophisticated detection equipment, to settle the question of pulsar behavior in the optical range.

Meantime the unexpected discovery of the pulsars enhances interest in possibly uncovering other cosmic phenomena of similar exciting character. An area currently being explored with high potential for such discoveries is the infrared region of the electromagnetic spectrum. Infrared waves are intermediate in length between the familiar optical region and the radio region, and are generally familiar as radiant heat.

The development of new and more sensitive detectors for infrared radiation and of techniques for their use with astronomical telescopes now permits astronomers to see the cosmic realm more clearly in this newly opening region of the spectrum. Since certain constituents of the earth's atmosphere strongly absorb the infrared energy as it passes down to the ground-based observer, there have been attempts to carry such detectors to great heights in the atmosphere by balloons, or outside the atmosphere aboard rockets and satellites, to avoid this absorption.

Unfortunately the infrared detectors require complex auxiliary apparatus to cool them to very low temperature before they become efficient. The necessary equipment is both heavy and bulky, and thus makes difficult the lofting of infrared telescopes to high levels of the atmosphere. But preliminary results of partial surveys of the sky are already exciting and have attracted the attention of both observers and theorists to the many questions raised. For example, there is the strong infrared radiation found in the near vicinity of some of the highly energetic quasi-stellar objects, or quasars, which had been expected to emit almost entirely in the violet and ultraviolet, shortwave part of the spectrum; or the previously unseen totally infrared sources which may well be representatives of the very earliest phases of stellar evolution, as the star born by condensation out of the dust and gas of interstellar space. (Here the star starts a long career of shining out in the galaxy as a new sun, subject to the laws of nature which are now sufficiently understood to permit astronomers to predict many of the later stages of evolution toward a possible "giant" phase followed by a later "dwarf" phase and an inconspicuous but lengthy old age. This is punctuated for some stars by possible catastrophic readjustments of size and character of sufficient energy to attract the further attention of earthbound astronomers.)

Recognition of the importance of the development of infrared astronomy occurred during the year with the award of the Helen B. Warner Prize for Astronomy of the American Astronomical Society, "for a significant contribution to astronomy during the previous 5 years," to Frank J. Low of the University of Arizona and Rice University. Dr. Low has been a leader both in the development of infrared detectors for astronomy and in their use through fundamental observations of the planets, infrared stars, and the quasi-stellar objects. His work has been assisted by the Foundation.

During the past fiscal year, an Advisory Panel for Large Radio Astronomy Facilities, which had been convened by the National Science Foundation to make recommendations regarding such facilities, submitted a most significant report which will be of great value in developing national policy concerning large radio astronomy facilities. The panel recommended that the proposal of the California Institute of Technology for an array of eight radio antennas (dishes) be funded, and that the 1,000-foot spherical dish in Arecibo, Puerto Rico, be upgraded.

The proposal from the National Radio Astronomy Observatory for a Very Large Array of 36 antennas in a Y configuration received much favorable comment but the panel recommended that some aspects of its design be carried further through continuing studies before a final decision for construction is made. They also recommended further study of the proposal from the Northeast Radio Observatory Corporation (NEROC) for a large steerable 440-foot antenna in a radome. The panel felt that this study should be continued, looking toward even larger instruments, and in addition that a comparative study between this type of antenna and the Arecibo type should be made. This study should examine both, not only in their proposed or existing sizes, but extrapolated to much larger dimensions. Such a comparative study has been completed by the NEROC group and is being reviewed by panel members and others in the scientific community.

Although specific reference to various activities of the Foundation in support of astronomy will be made on later pages, it may be mentioned that the Foundation is now the largest source of Federal support for ground-based astronomy. Its several programs include support of basic research projects at universities, the development and operational support of the national observatories in optical and radio astronomy, and the support, for the most part on a matching basis, of the construction of astronomical facilities at universities. Present Foundation support for ground-based astronomy is approximately one-half of the total Federal effort.

Kitt Peak National Observatory

Facilities

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

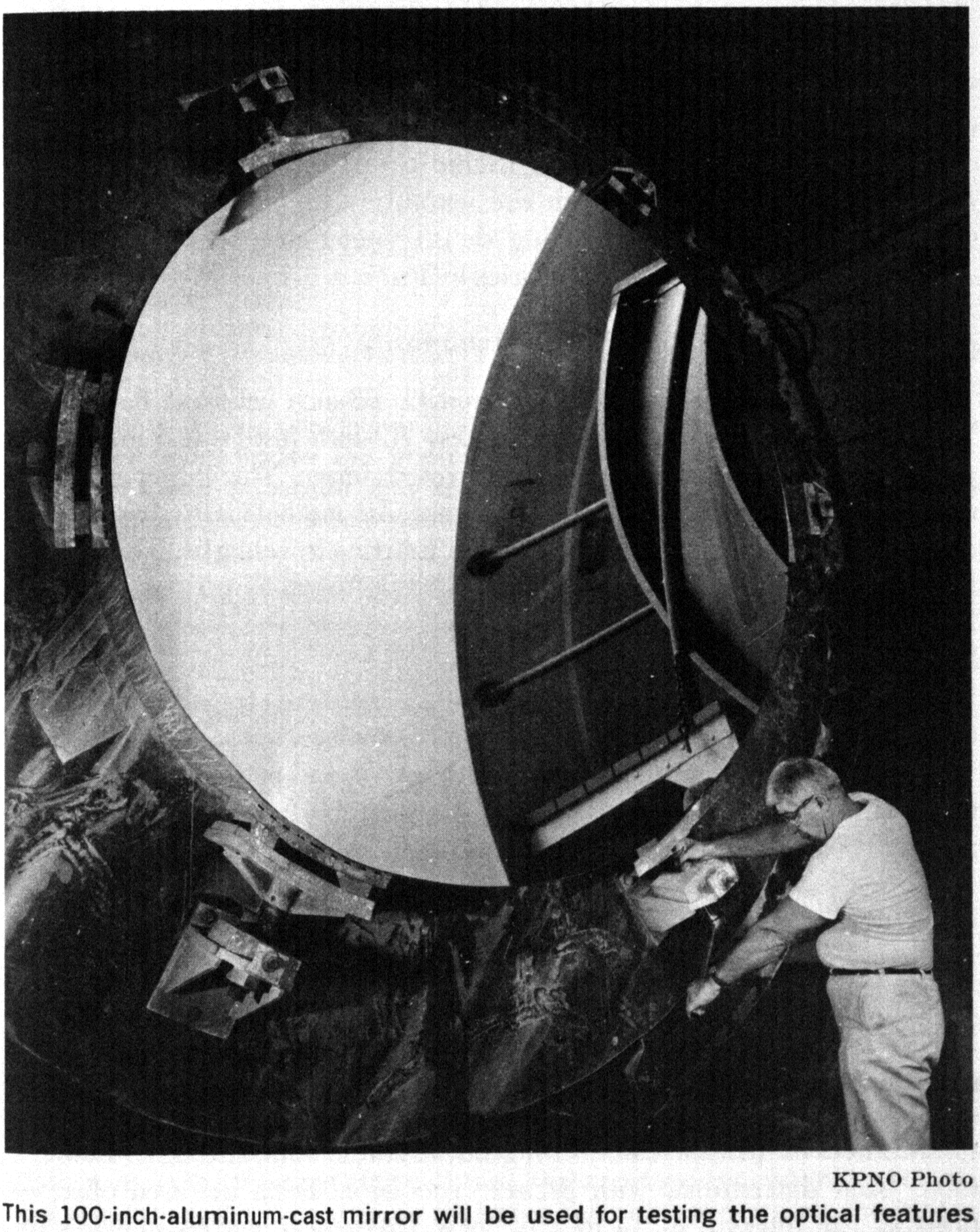
Research at the observatory is organized into three principal fields—stellar, solar, and space astronomy. In addition, engineering design and construction of instrumentation for telescopes and space experiments comprise a significant portion of the activities conducted by the observatory. The observatory also provides the astronomical community with design drawings of instruments and telescopes. In fiscal year 1968, 20 institutions were furnished with 1,326 prints, which represented 89,600 manhours for engineering, design, and drafting.

Construction of the addition to the Tucson headquarters building was completed in November 1967. This construction increased the previous useful square footage area of 73,500 by 23,000, which includes 6,500 square feet for new office space and 16,500 for new laboratory space.

Arrangements were completed in fiscal year 1968 for effecting a significant increase in observatory computer capability through purchase of an advanced computer to replace a rented computer previously in use more than 500 hours monthly. The new equipment is expected to provide three times the former capability.

Stellar Astronomy

A total of 99 visiting astronomers and graduate students used the 84-, two 36-, and two 16-inch stellar telescopes for 60 percent of the avail-



KPNO Photo

This 100-inch-aluminum-cast mirror will be used for testing the optical features of secondary mirrors on the new 150-inch telescope at KPNO. The 158-inch quartz mirror for the new 150-inch telescope will be finished on this same grinding and polishing machine at the observatory optical shop.

able scheduled time during fiscal year 1968. These visitors came from 38 astronomy departments and research organizations in the United States and from six foreign countries.

The 84-inch reflector, which was extensively redeveloped during a 3-week shutdown period in August 1967, continues to be in great demand. A fourth coudé spectrograph camera, a photoelectrically guided camera, and improved image-tube spectrographic equipment have been brought into operation. Visitors and staff alike have used the latter instrumentation for threshold observations of faint objects ranging from faint, highly reddened stars in the Milky Way to quasars, possibly the most distant objects known.

All major construction contracts for the building and mounting of the Kitt Peak 150-inch reflector have been let, and the associated optical work and instrumentation design is underway.

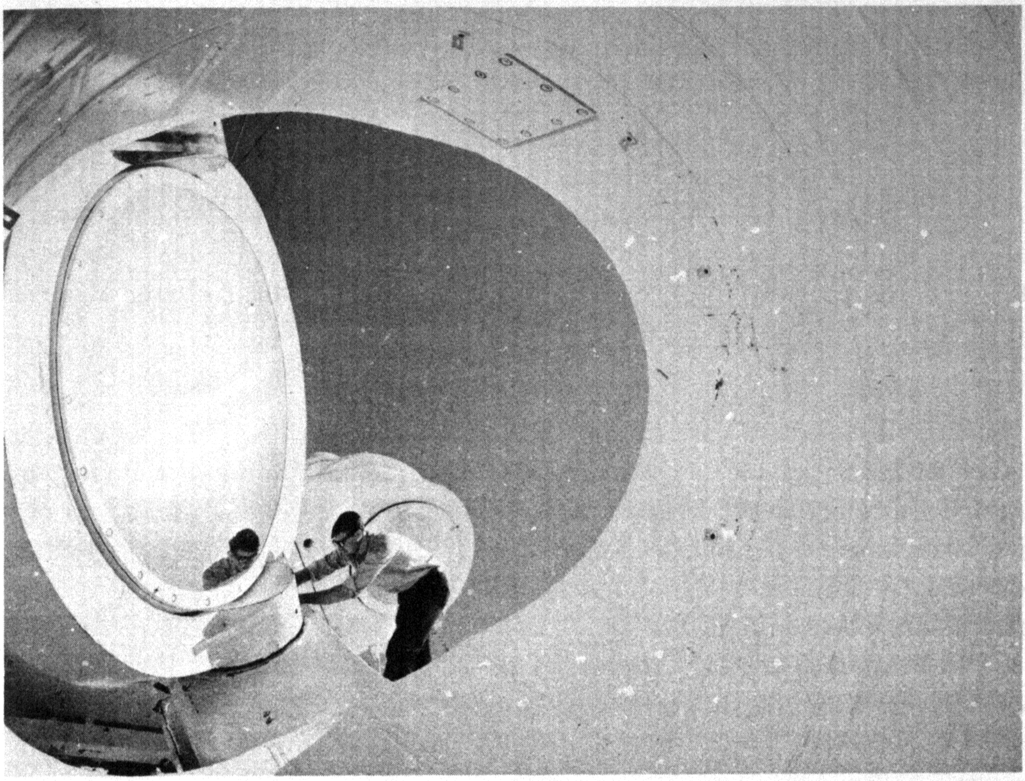
A number of new instruments, including photoelectric spectrum scanners, are nearing completion for use with the telescopes, and a new spectrum comparator and a recording densitometer have been acquired for visitor and staff use in the laboratories in Tucson.

Solar Astronomy

Replacement of the temporary quartz 63-inch heliostat flat on the McMath Solar Telescope with the new 82-inch fused silica mirror has produced a much brighter and improved image. The larger mirror is mounted in a special cell, so that it may be mechanically deformed to counteract the thermal distortion from heating by sunlight. This system, now under test, gives less vignetting, or softening of outline, over the large solar image, and sharper, more contrasty fine detail because of much less scattering by the heliostat flat.

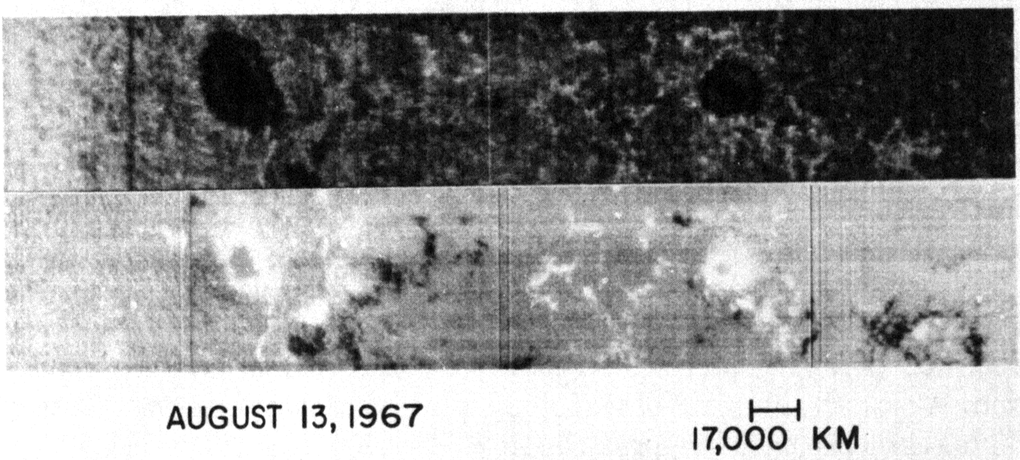
With the continuing and vigorous instrumentation research and development program it has been possible to exploit the great advances in infrared technology, computers, digital control, and optics to keep the instrumentation up to date and eminently suitable for research. Examples are: a versatile improved magnetograph, which measures solar magnetic fields down to $1/5$ gauss, and a large infrared spectrometer, under construction, to explore the unknown spectra of sunspots in the region from 1 to 5μ (microns).

One visitor each from Switzerland, Norway, and Belgium, and three from France, along with 12 astronomers and seven students from the United States used the McMath Solar Telescope during fiscal year 1968. The spectroscopic studies of the solar chemical composition, the abundances of lithium, cadmium, gold, silver, indium, and other elements have been determined with greater precision. From infrared observations in the interval of 1μ to 25μ, new theoretical models showing the distribution of temperatures and pressures in the solar atmosphere have been obtained. Detailed studies of solar magnetic fields have formed a



KPNO Photo

The new 82-inch fused silica mirror now installed on the McMath Solar Telescope produces a much brighter and improved image than its 63-inch predecessor. The larger mirror is mounted in a special cell so that it may be mechanically deformed to counteract the thermal distortion from heating by sunlight.



KPNO Photo

Detailed studies of solar magnetic fields have formed a large fraction of research activity using the McMath Solar Telescope. These photographs compare the appearance of a region of the solar atmosphere, as seen in the light from neutral iron atoms (upper part), with the distribution of magnetism in the same region (lower part). In the lower part of the picture, regions of opposite magnetic polarity appear as light and dark features. In the upper part of the photograph, the lighter-than-average features around the darker sunspots, and over the solar disk, correspond to the regions of stronger-than-average magnetism in the lower photograph.

large fraction of the research activity, because of their importance in solar-terrestrial phenomena such as flares, solar wind, sunspots, aurorae, radio communication, and climate.

The night work at the McMath Solar Telescope by staff members of the Observatory Space Division, and by research workers from NASA's Ames Research Center, Sunnyvale, Calif., has been directed toward studies of the atmospheres of Venus, Mars, and Jupiter. These investigations have contributed much new information about their chemical compositions, pressures, and densities.

Space Astronomy

In order to avoid or overcome the absorption of most of the electromagnetic spectrum by the earth's atmosphere, efforts are made to get instrumentation to high levels or outside the atmosphere, using satellites or rockets. The Space Division at KPNO is concerned with the utilization of such techniques.

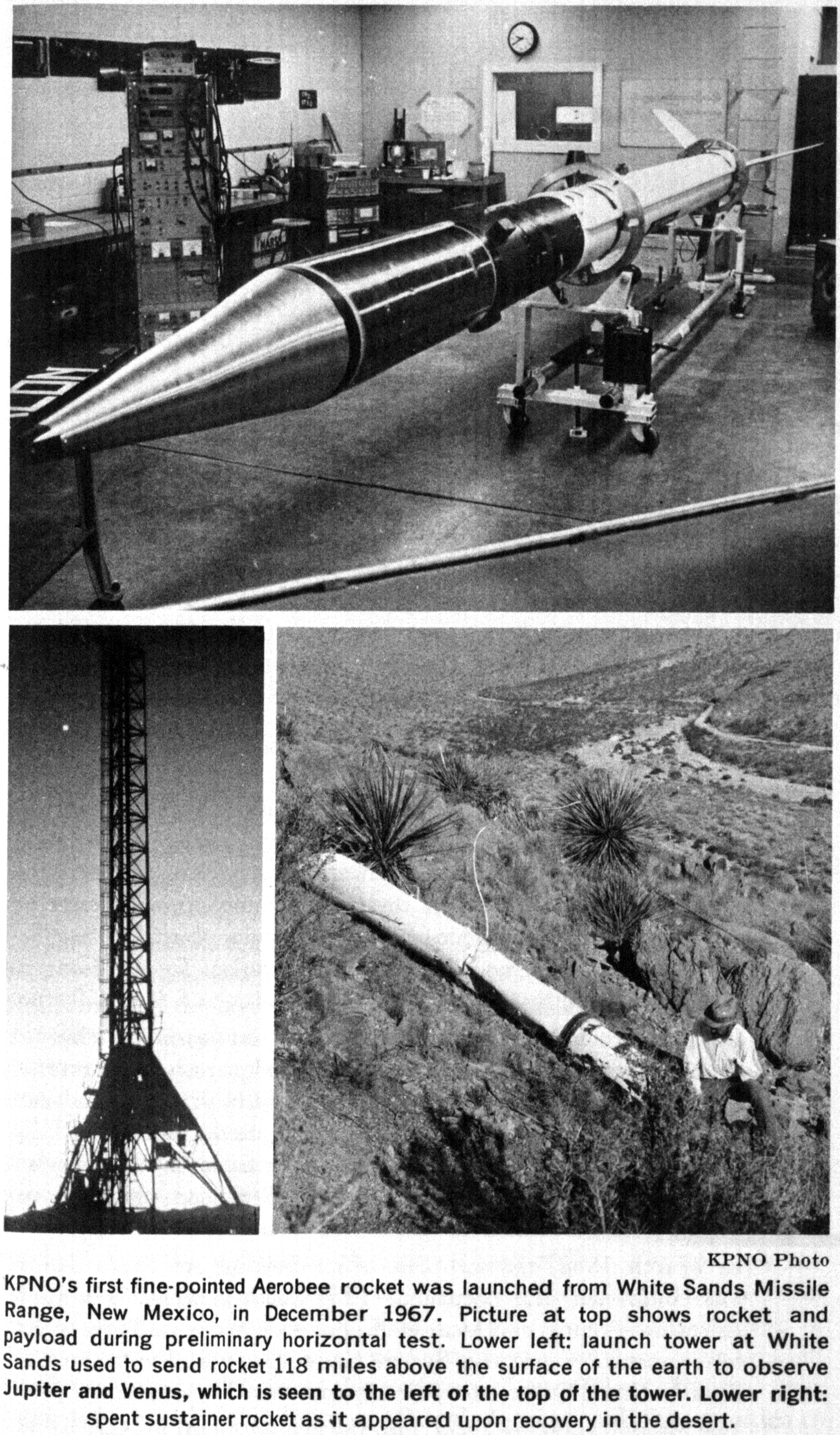
Experimental studies conducted by NASA's Mariner V, provided an opportunity for highly successful observations in its encounter with Venus on October 19, 1967. The hydrogen emission around Venus was observed to be similar to that observed near the Earth, but appears to require a different interpretation.

Sounding Rocket Program

The observatory's first fine-pointed Aerobee rocket was successfully launched from White Sands Missile Range, N. Mex., on December 4, 1967. The rocket carried the first Separable Payload Orientation System (SPOS), which was used as the primary pointing system to gather observations of the ultraviolet spectrum of Venus. Six very good scans of the Venus spectrum between 1600 Å and 3200 Å were obtained. The data reduction so far accomplished indicates a flight successful in all respects.

The same planetary telescope-spectrometer was reflown on May 16, 1968, to observe Jupiter. Excellent spectra were obtained, all subsystems operated perfectly, and the payload was recovered in excellent condition. Again, the data are of very good quality. Manuscripts on these two flights are in preparation for publication.

An Aerobee rocket instrumented by the observatory to investigate the ultraviolet spectra of stars in the constellation Orion was launched February 16, 1968. Operationally, the flight was extremely successful, although the ultraviolet (UV) background radiation was higher than expected. The instrument scanned its complete pattern, covering a sky area of approximately 20 x 20 degrees. Spectral scans were made on 21 stars, only two of which were so cool as to yield no useful UV signal. The data from the brighter hot stars give indications of line structure,



KPNO Photo

KPNO's first fine-pointed Aerobee rocket was launched from White Sands Missile Range, New Mexico, in December 1967. Picture at top shows rocket and payload during preliminary horizontal test. Lower left: launch tower at White Sands used to send rocket 118 miles above the surface of the earth to observe Jupiter and Venus, which is seen to the left of the top of the tower. Lower right: spent sustainer rocket as it appeared upon recovery in the desert.

and also indicate considerable UV flux down to the short wavelength limit of the instrument at 1050 Ångstrom units (one hundred millionth of a centimeter).

Theoretical Programs

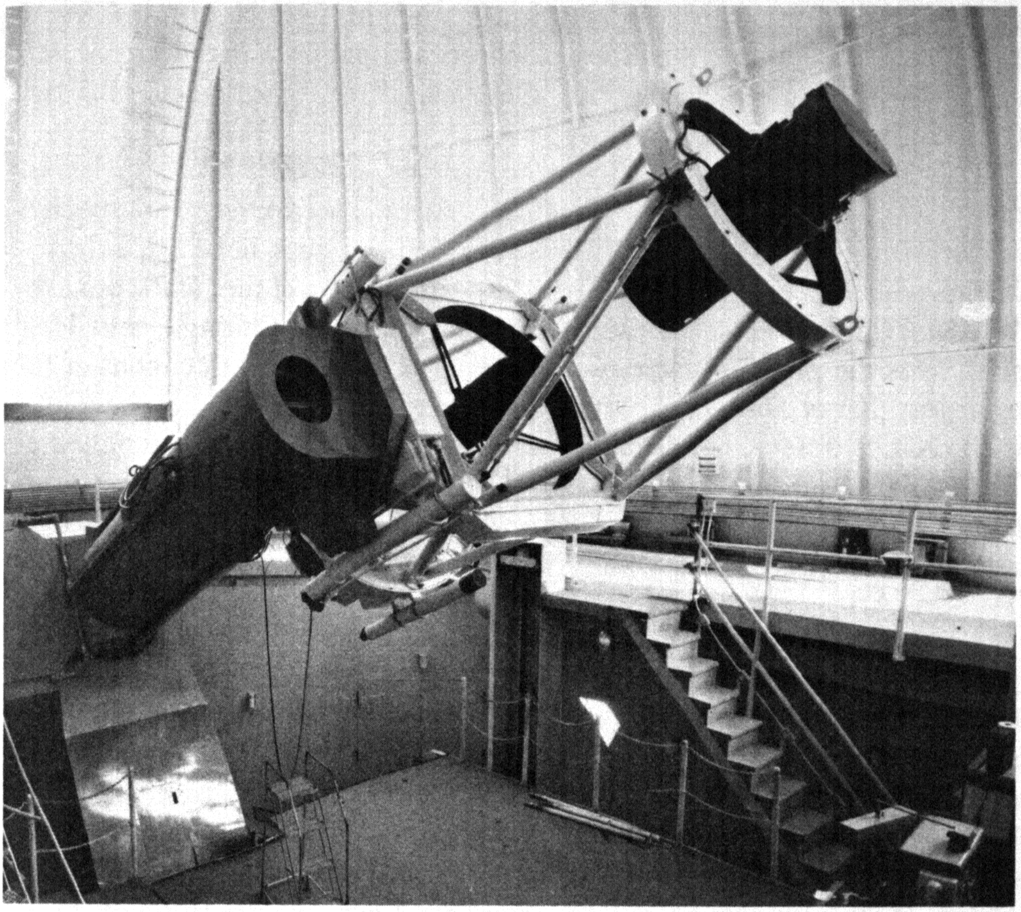
Planetary observations from the ground have revealed a possible trace of oxygen on Mars, and no sign of it on Venus. Other observations have been made, and corresponding laboratory work is in progress. Theoretical studies of planetary atmospheres have included the heat and ionization balance for Venus, as well as the interpretation of a wide range of observations, fundamental atomic quantities, stellar atmospheres, and cosmology.

Cerro Tololo Inter-American Observatory

The Cerro Tololo Inter-American Observatory is situated in the foothills of the Andean Cordillera in Chile, at an elevation of 7,200 feet and 30° south latitude. Observatory headquarters are located about 40 miles away in La Serena, 300 miles north of the capital city, Santiago. The observatory is operated by AURA under a National Science Foundation contract.

During fiscal year 1968, the following important events in the development of the Cerro Tololo Inter-American Observatory took place:

- Following the April 13, 1967, joint announcement at Punta del Este by the Presidents of the United States and of Chile, the project of constructing a 150-inch telescope and its housing was initiated with joint funding by the National Science Foundation and the Ford Foundation. Contracts for acquisition of the large mirror optical blank and of the telescope mechanical mounting were negotiated. Architectural and structural plans for the telescope housing were completed and excavations for the foundations of the building were dug on the summit of Cerro Tololo.
- On November 6, 1967, the observatory was formally dedicated in ceremonies held at the observatory's headquarters in La Serena, and at the telescope site on Cerro Tololo, with the attendance of various United States and Chilean dignitaries, including U.S. Congressmen George Miller, Jerry L. Pettis, and Olin Teague. The President of Chile, Sr. Eduardo Frei, also visited Cerro Tololo on this occasion.
- In March 1968, the scientific office building on Cerro Tololo was completed and occupied. This building houses a library, offices for visiting and local staff scientists, and a radio room for communications with La Serena headquarters and with the Kitt Peak National Observatory headquarters in Tucson, Ariz.
- The 60-inch telescope came into regular operation in April 1968.



KPNO Photo

The 60-inch telescope which came into operation at Cerro Tololo Inter-American Observatory in April 1968. The five telescopes now in use at Cerro Tololo play a unique role in observing a number of important astronomical objects which cannot be effectively studied from sites in the Northern Hemisphere.

The atmospheric conditions at Cerro Tololo are excellent, in regard to both cloudlessness and the exceptionally small stellar scintillation. These conditions and the southern latitude make possible the detailed study of a number of important astronomical objects that are not effectively observable, or are unobservable, from the Northern Hemisphere, such as the center of the Milky Way stellar system (the Galaxy), the Magellanic Clouds, the nearest and brightest globular star clusters, the majority of cosmic X-ray sources that are concentrated in the galactic center region, and many radio sources of unknown optical nature.

The five telescopes now operating at Cerro Tololo are playing a unique role in the exploration of many of these objects. For instance, the optical identifications of several new X-ray sources have been accomplished during the past year at Cerro Tololo. In addition, surveys of highly luminous stars, and analytical studies of such stars, have yielded much new information about the structure of our Galaxy. In fiscal year 1968, the Cerro Tololo telescopes offered observational opportunities to

322-215 O—68——6

professional astronomers and graduate students from North and South America. Altogether, 54 different observational programs were undertaken by 31 United States, five Chilean, three Argentinean, and two Canadian astronomers.

These programs, using all five telescopes, covered a wide variety of observational investigations. Included were photometric and spectroscopic studies of many individual stars, stellar groups, nebulae, galaxies, X-ray sources, and quasars. An interesting aspect of the work done by W. A. Hiltner, Yerkes Observatory, University of Chicago, and local staff, was the photometric optical observation on several occasions of the brightest X-ray source (in the constellation of Scorpius) concurrently with X-ray observations made from balloons and rockets launched in Texas, Hawaii, and Johnston Island in the Pacific Ocean. To facilitate these observations, radio links were established between the telescopes and the launching sites, usually via the radio communication system at Tucson, Ariz.

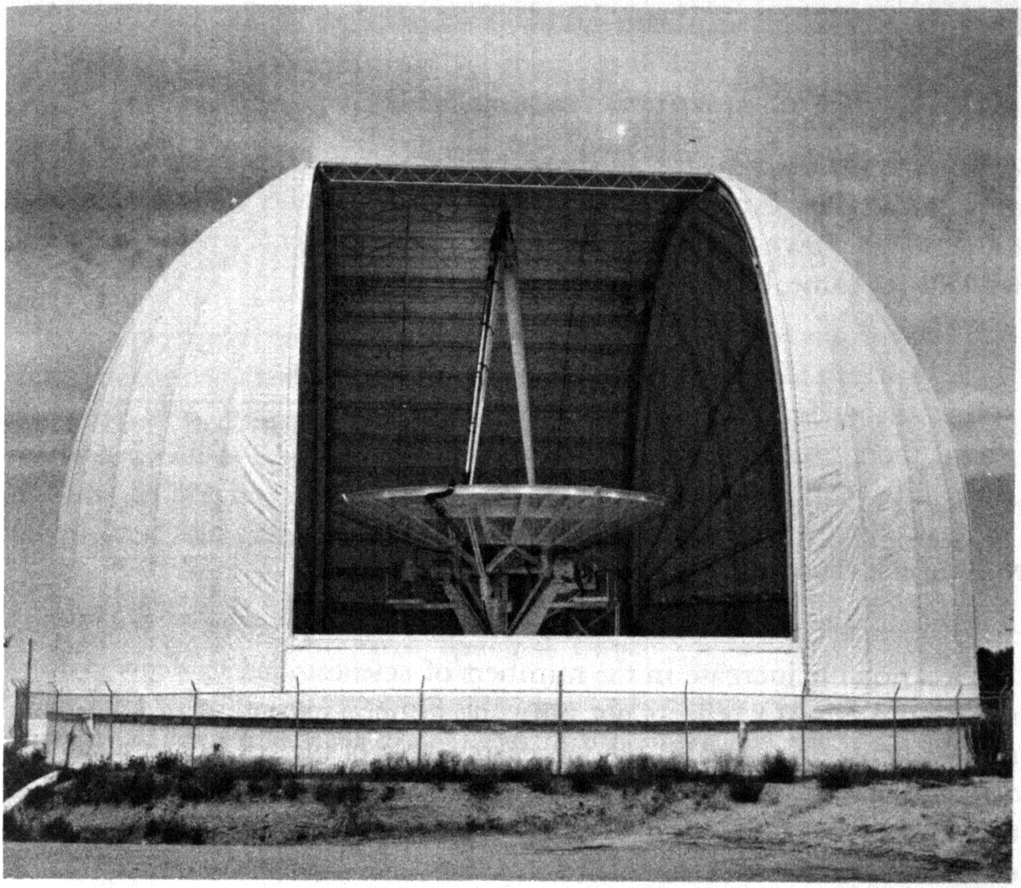
Another important series of observations was the pioneering Southern Hemisphere observations in the far-infrared spectral region carried out by G. Neugebauer and J. Westphal of the California Institute of Technology, Pasadena, Calif. These astronomers found on Cerro Tololo the most favorable noise-free conditions for infrared observations that they have experienced. Another survey of major importance, seeking the discovery of highly luminous stars and peculiar objects in the Southern Milky Way, was carried out by observers from Case Institute of Technology, Cleveland, Ohio. This survey has already resulted in the identification of many new and unique objects.

National Radio Astronomy Observatory

The National Radio Astronomy Observatory is managed by Associated Universities, Inc., under contract with the National Science Foundation for the purpose of providing radio telescopes and other specialized equipment for basic research in radio astronomy for use by qualified visitors from colleges, universities, and other institutions throughout the United States. The principal observing site is located at Green Bank, W. Va., with the computer laboratory and other support facilities at nearby Charlottesville, Va. A second NRAO observing site is now established at Kitt Peak National Observatory near Tucson, Ariz., with the completion in fiscal year 1968 of a new high-precision, 36-foot telescope.

Facilities

The new 36-foot radio telescope, housed in a dome at Kitt Peak National Observatory, became available for routine operations in January 1968. This telescope with its high-precision surface is designed for observations at millimeter wavelengths, thus extending research activities into a segment of the radio spectrum that cannot be reached by the



KPNO Photo

A second NRAO observing site was established at Kitt Peak National Observatory in 1968 when this high-precision, 36-inch radio telescope became operational. Addition of this instrument extends research activities into a segment of the radio spectrum that cannot be reached by the larger telescopes.

larger telescopes. Receivers at wavelengths of 9.5 mm. and 3.5 mm. are now in operation. Final processing of data is accomplished at Tucson, where time is made available on the Kitt Peak National Observatory computer through the courtesy of the KPNO staff.

For the first time in fiscal year 1968 the 42-foot portable telescope was used at Green Bank, W. Va., as a component of a two-antenna interferometer (in conjunction with an 85-foot telescope), thus providing better resolution than would be possible with a single telescope. A cooled, very-low-noise, parametric amplifier operating at 6 cm. was used on the 140-foot telescope in 1968, facilitating a marked advance in research programs in the ionized hydrogen (HII) regions.

The NRAO has a trained, professional telescope operator at all times at each telescope to assist with visitor and staff programs. Final processing of magnetic tape output is accomplished in Charlottesville, Va., on an IBM 360/50 computer. Use of these facilities is provided without charge to visiting observers who also have available a well-equipped library, drafting assistance and the services of a photographic department.

Visitors, Students, and Staff

The NRAO is playing an increasingly important role in U.S. radio astronomy. The table below shows the total number of scientists and students who have used NRAO facilities and number of institutions from which they came, by calendar year since 1960.

	Calendar Years							
	1960	1961	1962	1963	1964	1965	1966	1967
Number of scientists and students	30	30	39	50	65	82	96	141
Number of institutions	13	14	17	20	28	33	40	46

This notable increase in the numbers of scientists and students making use of the NRAO reflects not only the general expansion of interest in radio astronomy but also the increasing role of the NRAO as a visitor-oriented national research center. Also, the NRAO participates in the training of scientists and engineers through various programs which complement the more formal educational programs at the U.S. universities.

Within the past 5 years more than two-thirds of all present radio astronomy graduate students in the United States and more than two-thirds of all active post-Ph. D. radio astronomers who have received their degrees during this interval have participated in one or more of the programs outlined above.

At the end of fiscal year 1968, the scientific staff consisted of 12 scientists on the permanent staff, 8 on temporary appointments and 24 structural, mechanical, and electronic engineers. The total permanent NRAO staff was 219.

Antenna and Telescope Design Projects

In accordance with the recommendations of an NSF-appointed ad hoc panel for large radio astronomy facilities, NRAO is continuing work on the detailed design of a Very Large Antenna Array (VLA). This project, as recommended by the panel, proposes construction of a major national research instrument capable of observing discrete radio sources more than a hundred times fainter than presently possible. The system would use an array of 36 85-foot telescopes movable along railroad tracks and arranged along the arms of a "Y" shaped configuration, each arm of the telescope array being 13 miles long. The level of performance envisioned for such an instrument could yield data having an important bearing on the question of the origin of the universe.

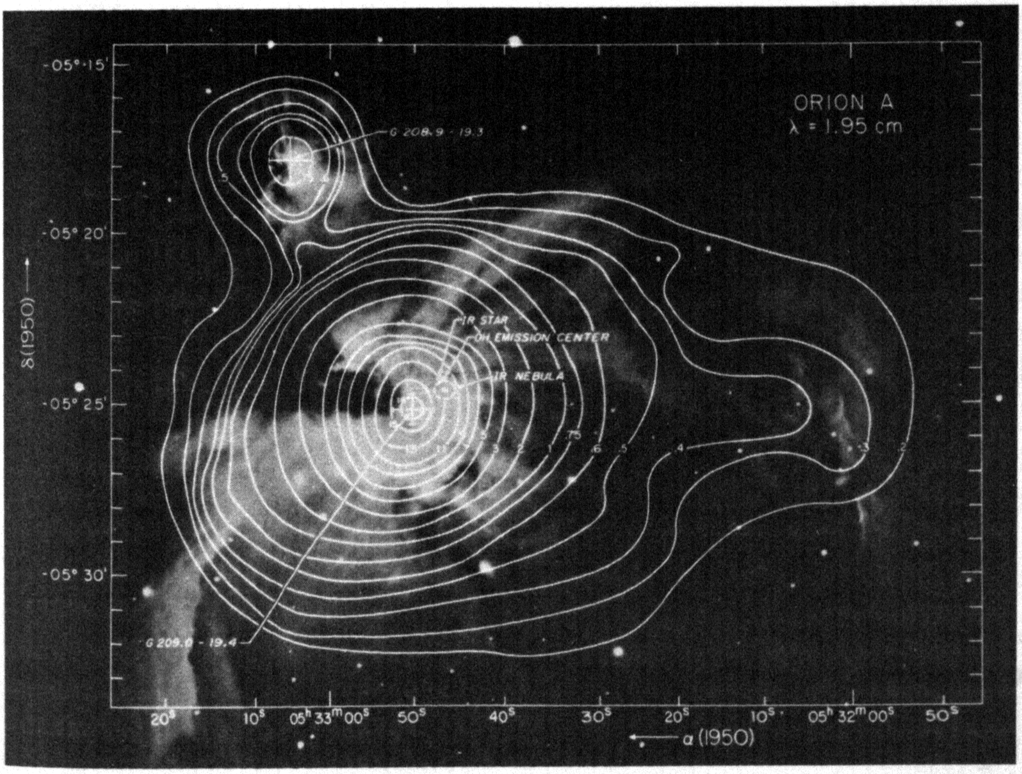
Efforts during fiscal year 1968 proved the feasibility of a synthetic beam (a beam formed by combining the readings of two or more telescopes) having one second of arc resolution and adequate phase stability. This was achieved by successful, regular operation of a 100,000 wavelength interferometer consisting of the 42-foot portable antenna located 10.4 km distant from a fixed 85-foot telescope (the distance between the two telescopes is precisely 100,000 times the length of the radio wave under study).

Computer simulated arrays have shown the minimum number of antennas needed to satisfy VLA requirements. Three possible sites are being evaluated and regular measurements of the atmospheric water vapor content, which is the main cause of phase fluctuations, are being made at each site. Further critical parts of the electronic equipment are being investigated and certain engineering prototypes have been built.

NRAO Research Projects

New Spectral Lines

Like his colleague in the area of optical astronomy, the radio astronomer finds fruitful fields for study in spectrum analysis as electromagnetic waves are broken down into component wavelengths. And the spectral



NRAO Photo

Contours of radio emission at a wavelength of 1.95 cm. taken with the 140-foot radio telescope and superimposed on an optical photograph of the Orion Nebula. A number of programs carried out with the 140-foot telescope in 1968 led to research findings of considerable significance.

lines by which the optical astronomer can identify the composition, temperature, pressure, radial motion and surrounding magnetic field of celestial bodies are also available to the radio astronomer in the longer invisible waves of the radio spectrum.

Research during the past year has produced a marked increase in the number of spectral lines available for study. A previously unobserved line of microwave radiation at 6.3 cm. wavelength was detected in the direction toward the gaseous nebula IC 1795 by a group of astronomers at Harvard University that included B. Zuckerman, P. Palmer, H. Penfield, and A. E. Lilley. This discovery, made on the NRAO 140-foot telescope, was aided by a precise laboratory measurement of the line frequency by H. E. Radford (National Bureau of Standards), and is attributed to a downward transition between energy levels in the excited state of the OH (hydroxyl) molecule. Since 1963, four radio lines from the OH molecule have been known to exist, but the intensities of these lines are seen to vary from source to source, and in some sources they often undergo time variations from one observation to the next. Moreover, the line intensities, together with the remarkably small diameters of the OH sources, indicate apparent temperatures that are so high that astronomers know that the mechanism that causes the radiation cannot possibly be thermal in origin.

One familiar example of a nonthermal emitter is the antenna of a radio broadcasting station that emits a large amount of energy in a narrow frequency range but emits only a small amount of normal, thermal emission elsewhere in the spectrum. Similarly, in nature, some type of special mechanism causes the OH molecule to radiate. Astronomers suspect these OH sources to be stars in very early stages of formation and that somewhere within the boundaries of the "protostar" a large stimulating mechanism is acting to excite the OH molecules into higher than normal energy states from which they discharge, thus giving rise to the radio lines received by the telescope. The discovery by the Harvard group is important because it gives additional insight into the modes of excitation of the OH molecule and may help to unravel the mystery of how such stimulation phenomena can occur in interstellar space.

Measurement of Magnetic Fields

Better knowledge of the vast magnetic fields in space is basic to a better understanding of the universe. A number of individual programs were carried out at the neutral hydrogen line frequency (21 cm.) on both the 140- and 300-foot telescopes leading to research findings of significance. Especially noteworthy was the discovery by G. L. Verschuur of Zeeman splitting of the hydrogen line. (Zeeman splitting is the energy change in an electron caused by the influence of the magnetic field in which the atom is placed.) Attempts to determine the magnetic field in the Milky Way system in this manner have often been made in recent years, but no positive, confirmed result had been achieved.

Verschuur's measurements show that fields of the order of 2×10^{-5} gauss exist in the Perseus spiral arm in the direction of Cassiopeia A and that a field of 3×10^{-6} gauss exists in the direction of Taurus A. Near the sun, the field strength is less tan 3×10^{-6} gauss. Since the presence of a significant magnetic field in the galaxy, as well as gravitational forces, may determine the motions of the gas in the Milky Way system, a direct determination of the field strength will show the extent to which the magnetic field influences these motions. Such studies are important to the understanding of galactic rotation and the formation of galactic spiral arms.

Very Long Baseline (VLB) Experiments

Advanced techniques in the use of multiple radio telescopes can produce a degree of resolution equivalent to the ability to measure the size of a postage stamp in Sweden, as seen from Green Bank, or to measure the size of an automobile on the moon. At the same time, they point the way toward the answers to questions of both theoretical and practical interest.

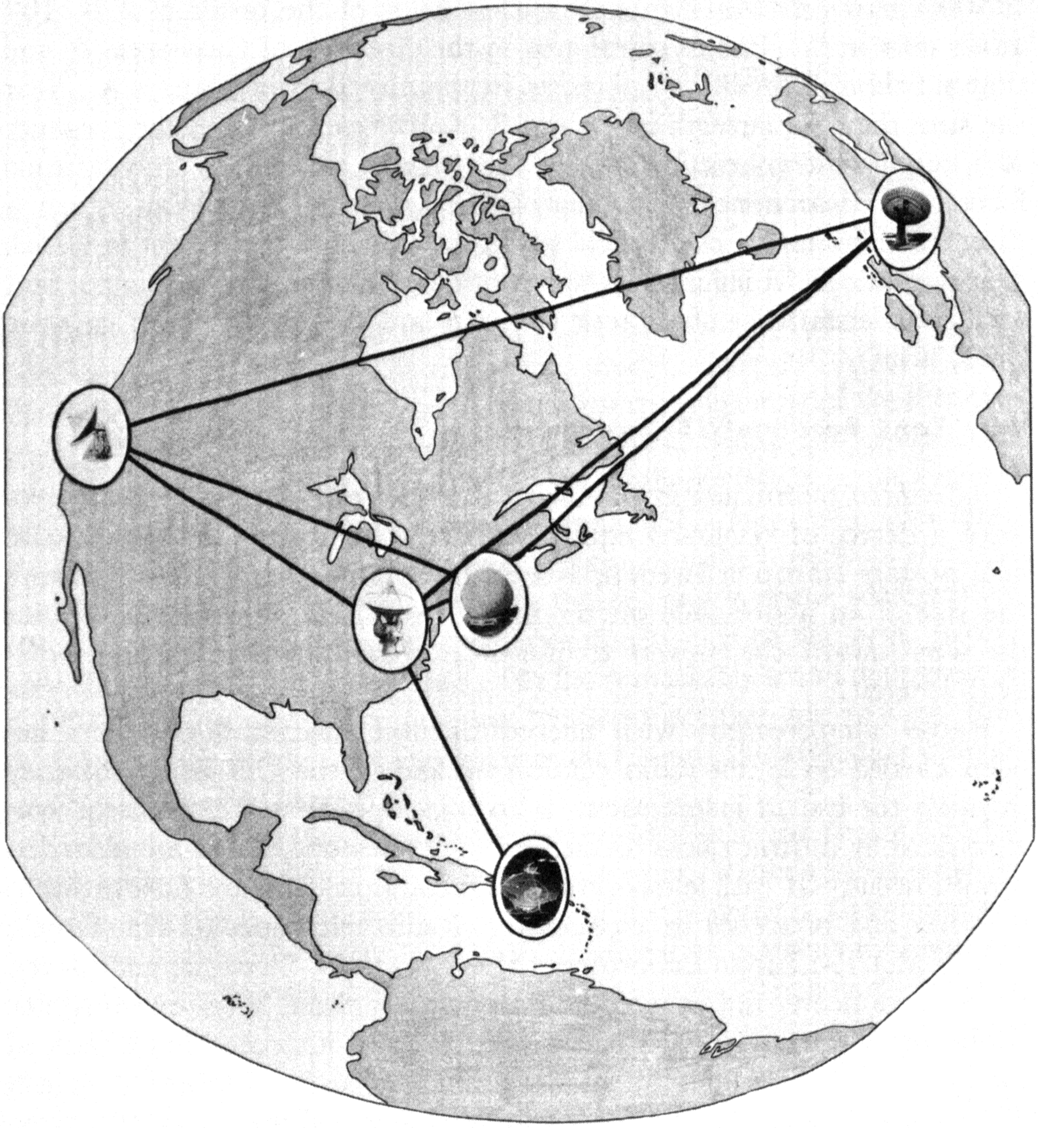
Radio interferometry with intercontinental antenna separations has been carried on in the radio continuum and at the OH line frequency through the use of independent radio telescopes that are precisely synchronized by atomic clocks located at each telescope. Data are recorded simultaneously at each telescope on magnetic tapes and are later brought together and processed in a computer. Radio telescopes at Hat Creek, Calif.; M.I.T.-Lincoln Laboratory, Mass.; Onsala, Sweden; and Green Bank have been used in a coordinated set of these VLB experiments. Preliminary results on the radio source 3C 273 indicate that a part of the radiation comes from the known position of a star-like optical object, the quasar. The quasar itself is a double object and measurements were made of its component parts.

This technique is potentially a powerful one for measuring the motions of radio sources in space, and for performing tests of general relativity, measuring accurate intercontinental distances and intercontinental drift, as well as earth tides and irregularities of the rotation period of the earth and changes in the earth's rotation axis.

University Astronomy Research Facilities and Equipment

Foundation support for university astronomy research facilities and equipment included three grants of particular interest in fiscal year 1968.

An award to the University of Virginia will provide partial support for construction of an optical telescope of 40-inch aperture especially designed for work in the field of astrometry, the determination of precise positions of stars. The research program for this telescope includes the



NRAO Photo

Schematic representation of the locations of radio telescopes that participated in Very Long Baseline experiments during fiscal year 1968. Telescopes are precisely synchronized by atomic clocks, and data recorded simultaneously are later assembled and processed by computer.

determination of the parallaxes (i.e., the distances) and the proper motions (i.e., motions across the sky) of selected stars. In each case observations of the stars chosen for the program must be repeated over a period of several years. The results are basic to the problem of setting up the distance scale in the observable universe.

The useful lifetime of an existing radio telescope will be extended appreciably as the result of a grant to the University of Colorado. This telescope has been in use for a number of years in research on the sun and planets, but has recently been encountering increasing manmade noise in its frequency range. To overcome this, it became necessary to relocate the telescope in a radio quiet area. The Foundation furnished partial support for the move and some improvements to the equipment used with the instrument.

The Foundation has also continued its support to the Massachusetts Institute of Technology in sponsoring a study of desirable design features for the next generation of large single-unit radio telescopes. The study is conducted by a group of scientists assembled from several institutions. Their work will emphasize design studies for a large steerable antenna for radio and radar astronomy.

Basic Research Projects

Star Clusters

A common characteristic of stars is that they often occur in clusters, with considerable variety as to the numbers of stars in each cluster and also as to the overall dimensions of these stellar groups. The cluster characteristic that allows us to think of a family relationship is the finding that all of the stars in such a group have apparently developed at about the same time by condensation from the same parent mass of dust and gas in interstellar space. As with human families, the number of offspring in new generation is quite variable, and indeed the offspring may consist of but a single star just as a human family may be limited to an "only" child.

The sun is such an only child, but only if one ignores the planets as appendages to the sun. Double and multiple stars frequently develop and there is no clear dividing line between the multiple star domain and the groups known as clusters of stars. Additional interest attaches to the clusters because with the greater variety in membership and the common and roughly simultaneous origin from parent gas and dust cloud, we can then trace the evolution of these stars over millions of years—a short time in astronomical time reckoning—secure in the knowledge that we are dealing with a family grouping, composed however of individuals.

Some clusters of stars reveal their extreme youth when they are found to contain large amounts of the gas and dust left over from the recent starmaking process. This dust and gas is revealed either because of its illumination by the new stars or because it partially obscures our view of the cluster. But often the youthful character of the cluster is best shown by the spendthrift nature of some of its members who start life with an aggressively energetic phase which by its very nature cannot last long—as stellar lives go. For example, in the Pleiades cluster seen in the fall and winter sky—often called the Seven Sisters—we find that there is a large range in the brightness and color of the stars, from those of easy naked eye brightness down to many which can be seen only with telescopic aid. This cluster contains about 120 stars and is situated about 450 light-years from the sun. The stars are spread over an apparent angular diameter of more than one degree as we see them in the sky so the true diameter of the group is roughly 13 light-years, plenty of room for 120 stars but a far closer packing of stars than is found outside such clusters. Much gas and dust are still present in the Pleiades cluster and the brightest stars are of the spendthrift type. At their present rate of emission of energy they will use up their intrinsic energy supply, furnished from the deep interior of such a star by nuclear fusion, in a few hundred thousand or at most a few million years, a very small part of the expected lifetime of billions of years for the same star following its spendthrift phase.

But during this bright but brief phase the star can be seen at great distances, as a blue giant or supergiant star, and attract attention to its family or cluster at a time when the cluster itself is very new. Later as the brighter stars of a cluster dim by this rapid spending of their energy the cluster becomes less conspicuous, and indeed, over a much longer period, tends to lose its close family characteristic through actual disruption of the cluster by dynamic forces within its galaxy. The cluster may eventually be spread out into the general field of stars.

Paul W. Hodge of the University of Washington, working with Frances W. Wright of the Smithsonian Astrophysical Observatory, Cambridge, Mass., has been assisted by the Foundation in a study of the star clusters which are members of the Large Magellanic Cloud, an irregular galaxy located near the south pole of the sky and hence available for study only with Southern Hemisphere telescopes. This galaxy and the associated Small Magellanic Cloud, a similar irregular galaxy, are the nearest objects of this kind to the much larger Milky Way galaxy in which our sun and planets are situated. The Clouds of Magellan are about 80,000 light-years from the sun, near enough to permit us to photograph individual bright stars with reasonable exposure times, using southern telescopes. Much of the photographic material for this study was obtained with the Baker Schmidt telescope, shared by the Armagh and Dunsink Observatories, in Northern Ireland and the Republic of Ireland, respectively, and the Harvard College Observatory in this country. The telescope shared by the three observatories is located near Bloemfontein in the Republic of South Africa.

Making use of the feature of cluster evolution described above, where the brilliant spendthrift stars in a cluster pick it out as a new cluster, and looking somewhat deeper into the cluster to detect the slower evolving fainter stars, Drs. Hodge and Wright have recently presented a detailed and dramatic picture of the evolution of the star clusters in the Large Cloud over its recent past history. They have established the distribution of clusters as a function of age for about 1,200 clusters over the entire face of the cloud. They are able to explore the spatial pattern of cluster formation at various times. Enough material was available so that it was possible to construct a picture of the clusters which were prominent at the several stages of the recent past. These stages were numerous enough so that it was possible to illustrate the cluster evolution by a greatly accelerated time-lapse movie in which it is clearly shown how clusters come into prominence shortly after formation from gas and dust because of the great immediate brilliance of the blue-giant spendthrift stars. Later these clusters dim in lustre, to be replaced by others evolving out of other gas and dust clouds at other points in that galaxy. In this movie, a vivid picture is presented of the recent past history of the Large Cloud but one cannot escape the impression that this is a continuing process, active also at the present time, and a process that will extend far into the future of this nearby galaxy. A similar picture of cluster evolution for our own Milky Way galaxy is essentially impossible to obtain because the dust and gas clouds in the solar neighborhood obscure many of the more distant regions from our view. The importance of this overall picture of cluster evolution for a nearby galaxy is thus enhanced.

New Pulsar Discovered

On June 15, 1968, two radio astronomers, G. R. Huguenin and J. H. Taylor, from Harvard College Observatory, working with the 300-foot transit telescope of the National Radio Astronomy Observatory (NRAO) at Green Bank, W. Va., with NSF support, detected a hitherto undetected pulsating radio source in space. These perplexing celestial sources of energy are called pulsars because of the rhythmic radio pulses emitted. The astronomers were using the telescope at a frequency near to 110 MHz when the pulses were recorded. The source is located in the general vicinity of the constellation of the Little Dipper.

This pulsar is the first to be found by American astronomers. Four pulsars were discovered in the preceding year by scientists at the Mullard Observatory of the University of Cambridge in England. The period of the pulsations have been measured to be 0.7397 seconds with a 20 millisecond pulse width. The newly discovered pulsar has a pulse period lying between those observed for the earlier four.

The physical nature of pulsars is still not understood. It has been proposed that they may be stars of the condensed form known as "white dwarfs" meaning stars which have burned up their nuclear fuel. These "cinders" of extreme density and small size might spin or throb at the observed pulse rate. Another theory suggests that they may be neutron stars resulting from the explosions of supernovae. The explanations have been varied but have in no case so far been sufficiently plausible to win general acceptance. Attempts have been made to associate the radio pulsars with visible celestial objects, but these have not been very successful either since the radio positions are not known precisely enough to pinpoint their location. Furthermore, all visual objects in these regions seem to be exceedingly faint. In any event, it is accepted that they are of natural origin although their physical processes require further explanations.

When the first pulsar was discovered by the Cambridge astronomers a year ago, they considered the possibility that these uniform pulsing signals might originate from some intelligent beings in other parts of the universe. This imaginative hypothesis was rejected as study of the objects continued. It was apparent that the energy of these sources exceeded by many times the total manmade power generating resources of the entire earth, and in addition the frequency radiated was in a very general broad spectrum which presumably would not be the case if the source was controlled by some alien intelligence who would tend to broadcast on a narrow frequency band for maximum coherence by a receiver.

It is possible to estimate their distances from earth by measuring the effects on the pulsar waves by electrons encountered along the signal path. The lower frequency portions of each pulse are delayed by the electrons and reach the receiver seconds later than the higher frequency portions. The extent of this delay is then used to measure how far the signal has traveled from its source. In this way it has been calculated that the nearest pulsar is 50 light-years away and the most distant perhaps 300 light-years. A preliminary estimate by Dr. Huguenin places the new pulsar in the same range of distance from the earth, or perhaps slightly more than the others. This would put all the known pulsars in the same part of the Milky Way Galaxy as the solar system.

Shortly after the discovery of the Harvard Pulsar at Green Bank in June, two additional sources of rhythmic phenomena were detected by the Cambridge group in England followed by the discovery of two more by Australian astronomers, bringing the total to nine. The two found by the Australians are the first to be discovered in the Southern Hemisphere.

The Australian discovery was made on the Mills Cross telescope, consisting of two mile-long antennas in the form of a cross. It is named for its designer B. Y. Mills of the University of Sydney which operates the telescope in a joint effort with Cornell University. The Foundation provided assistance for construction of the Mills Cross and continues to provide partial support for the operational cost of research.

Mathematics

Research in the mathematical sciences continues to flourish in the complementary areas which are jointly responsible for its continuing vitality: the study of mathematics for its own sake and the application of mathematical results to the understanding of natural phenomena. The former is usually called pure mathematics and the latter applied mathematics. This division, while convenient and even meaningful in many instances, is not easy to maintain, for the origin of many important mathematical concepts can be ultimately traced to attempts to understand the physical world, while mathematics which was created for its own sake frequently is found useful in understanding the phenomena of nature.

Topology is that branch of geometry which deals with properties of curves and surfaces and other geometric objects which are independent of all changes of size and shape which can be accomplished without cutting or tearing. For example, the most important properties of an electrical network are independent of the lengths and positions of the connecting wires aside from their terminal connections, and this fact is used to good advantage in drawing circuit diagrams with many straight parallel lines and right angles to display schematically the essential connections, rather than the jumble of actual paths into which wires may be packed to make a device compact.

By looking at geometry from their particular point of view, able topologists discover distinctly unobvious properties of geometric objects, and connections between these properties and other more obvious properties, which ultimately shed light on such classical subjects of scientific study as fluid flow, electromagnetic phenomena, and satellite orbits.

It is perhaps not so clearly inherent in the above remarks that the methods of attacking topological problems have called for new mathematical tools, but this is also true, and, in particular, the resulting additions have vastly enriched the field of algebra in the last two or three decades. The result is a whole array of new notions and new techniques, initially inspired by topology's problems, but since applied to a far greater range of mathematical problems, some new and some old. In opening up new fields and developing new methods, mathematicians must have specific problems against which to try their powers. One such problem is known as the "four-color problem."

In coloring a geographical map it is customary to give different colors to any two countries that have a portion of their boundary in common. It has been found empirically that any map, no matter how many countries it contains nor how they are situated, can be so colored by using no more than four different colors. It is easy to see that no smaller number of colors will suffice for all cases.

The fact that no map has yet been found whose coloring requires more than four colors suggests the following mathematical theorem: for any subdivision of a sphere into nonoverlapping regions, it is always possible to mark the regions with one of the numbers 1, 2, 3, 4 in such a way that no two adjacent regions receive the same number.

Many famous mathematicians have tried without success to prove this theorem, although many techniques which have subsequently found application elsewhere have been invented in an attempt to solve it. It has been proven that five colors suffice for all maps, and also that four suffice for all maps containing less than 38 regions. In view of this, it appears that even if the general theorem is false, it cannot be disproved by any very simple example.

A remarkable fact connected with the four-color problem is that for some surfaces more complicated than the sphere, the corresponding theorems have actually been proven, so that, paradoxically enough, the analysis of more complicated geometrical surfaces appears in this respect to be easier than that of the simplest cases. For example, on the surface of a torus, whose shape is that of a doughnut or an inflated inner tube, it has been shown that any map may be colored by using seven colors, while maps may be constructed containing seven regions, each of which touches the other six.

Although we cannot report any success on the four-color problem itself, one NSF grantee, J. W. T. Youngs of the University of California at Santa Cruz, in collaboration with a German mathematician, Gerhard Ringel, of the Free University of Berlin, and with William Gustin of the University of Indiana, has succeeded during the past year in establishing the corresponding theorems for more complicated surfaces. A long-standing conjecture of the mathematician Heawood gave an explicit and rather simple algebraic formula for determining the minimum number of colors necessary for properly coloring any map on a surface more complicated than a sphere. This formula depends upon the number, h, of "handles" that must be attached to a sphere to produce a surface which may be stretched and shrunk without cutting or tearing until it has the shape of the given surface. For example, a sphere with one handle ($h=1$) attached may be deformed in this way into a torus, and the formula does indeed give the correct number seven for this case. In general, the number of colors, c, is the largest whole number less than or equal to

$$\frac{7+\sqrt{1+48h}}{2}.$$

An ingenious attack upon the problem transformed it into a related problem whose solution would yield at once the desired solution. This related problem in turn was divided into 12 cases, and Drs. Youngs, Ringel, and Gustin have developed a theory which has enabled them to pass beyond the previously known cases to dispose of all possible uses. The transformed conjecture asserts that a certain number of handles h is the smallest whole number greater than or equal to

$$\frac{(c-3)(c-4)}{12}.$$

Thus it is now known that this formula is correct, and the earlier one is also, provided c is at least 5, i.e., for all surfaces *except* the sphere.

Optimal Utilization of Airport Facilities

Congestion on airport runways and in the airspace around major terminals has become a serious problem and there is considerable evidence that it will become worse, unless better utilization can be made of airport facilities. Construction of new airports does not necessarily reduce the popularity of existing transfer terminals, and the enlargement of present airports creates new problems of increased travel time spent on the ground.

A study directed by Gordon F. Newell, research mathematician at the University of California, Berkeley, seeks to determine, by the use of mathematical techniques, "optimal strategies" for air traffic control under various conditions.

The capacity of a runway or system of runways (maximum number of takeoffs and landings per unit of time) depends upon the strategy for sequencing takeoffs and landings, also on sequencing of different type of aircraft. There are three basic plans used for sequencing landings and takeoffs on the same runway:

1. Landings have priority over takeoffs, i.e., landings are served without regard to the takeoff requests, takeoffs are released whenever a large enough gap occurs between landings;
2. Same as 1 except that the landings are occasionally interrupted to serve a group of takeoffs, whenever a sufficiently large queue of takeoffs has formed;
3. Whenever an aircraft is waiting to take off, the time interval between landings is increased somewhat (thereby retarding the landings) so that a single takeoff can be intersperced between two landings.

The first plan is used at most uncongested airports but leads to very large takeoff queues at busy airports. Of the two plans to eliminate this problem, strategy 3 gives higher capacity than 2. To alternate takeoffs and landings requires less total time than to serve the same number of operations in groups of takeoffs and of landings. The third plan is actually being used at most major airports where landings and takeoffs can use the same runway. If an airport can use two runways simultaneously, the capacity is larger if both runways are used for mixed operation than if one is used for landings and the other for takeoffs.

In the present study, it is assumed that there is a certain implied cost associated with delay, the cost of delay in the air being larger than on the ground (typical costs might be about $10 per minute for an aircraft in the air, $5 per minute on the ground). The objective is to determine a strategy for sequencing operations so as to minimize the total cost, for any given sequence of times at which aircraft request clearance to take off or land, given minimum times between various pairs of operations. If costs in the air are sufficiently large compared with those on the ground, the minimum cost strategy is plan 1. For realistic cost estimates (cost in the air less than about four times that on the ground), however, the minimum cost strategy is very similar to plan 3.

Although this study deals, to a large extent, with mathematical techniques for determining "optimal strategies," it also furnishes a firm basis for the comparison of various strategies for air traffic control. It also shows how delays depend upon the rate at which requests are made for takeoffs and landings, which in turn depends upon flight schedules. In particular it shows how delays would be reduced if the schedules were arranged so as to give a fairly even distribution of both takeoffs and of landings over time (i.e., if the airlines would abandon the policy of departures on the hour or half-hour, arrivals off the hour).

BIOLOGICAL AND MEDICAL SCIENCES

Biology, like other sciences, exhibits shifts in emphasis which often seem cyclic. Rather than progressing steadily in one direction, interests which have become unfashionable will at some later time recapture the attention and enthusiasm of a large part of the scientific community. These fashions are not, of course, capricious, but are a reflection of the fact that answers to some questions permit new questions about old problems to be framed in such a way that significant advances in understanding can be anticipated. In a sense, biology has come full circle with respect to the interest in systematics and environmental biology. Early biology was largely concerned with the description and classification of plants and animals, and with observations of the kind that may be spoken of as the concern of the naturalist. Once the framework of such cataloging and description had been substantially completed, the major thrust of biology shifted to an investigation of function and mechanism, and eventually to attempts to understand biological processes at a molecular level.

The progress which has been achieved in molecular biology during the past decade has been documented repeatedly in these annual reports. Using the tools and insights generated by basic research activities in mathematics, physics, and chemistry, it has been possible to establish the broad outlines of chemical reactions which yield the energy and the chemical structures required by living organisms. As was noted in the report for last year, attention can now be directed to the regulatory processes which confer upon biological systems their unique characteristics of organization, replication, and self-correction. Much has yet to be learned about the organization of biological systems at the molecular, subcellular, and cellular level; but at the same time attention can now be directed in a new way at systems of cells to form organs, systems of organs to form an organism, and systems of organisms to form an ecosystem.

Thus a cycle has been completed with this renewed interest in taxonomic relations and in the interactions between organisms in a community and between these organisms and their environment. Over the past several years the approaches of molecular biology have been applied increasingly to the classification of organisms and to questions of evolutionary relations between organisms. Systems of organisms can now be studied within the framework of a basic knowledge of nutritional requirements for individual species, factors governing the energy yield from photosynthesis, and chemical factors which may participate in regulatory processes within or between organisms. Behavioral studies have provided some indication of the kinds of questions which should be asked about social interactions. Moreover, advances in computer sciences have now made it feasible to manage the mass of data which must be dealt with in the analysis of something as complex as an ecosystem. Advances in mathematical modeling, together with computer capabilities have also made it possible to initiate the development of models of biological systems at various levels, and to test theories resulting from the study of regulation in biological systems.

Our position of relative strength is a consequence of the generous support which has been given in the past to "little science." The support of "big science," and that more specifically directed toward practical solutions to national problems must be managed in such a way that the support of basic research is strengthened and not eroded. "Little science," directed only toward asking the questions about nature which each individual scientist views as important, is not really amenable to cost-utility analysis except in retrospect, and each bit of such research can be made to look trivial and frivolous against the backdrop of the problems which face any society. However, as recognized by the creation of the National Science Foundation, this is the source of the knowledge and manpower from which will come the ability to deal with the future problems which can at best be perceived only dimly at the present.

Scientists have frequently concerned themselves as individuals with problems of conservation, and many biologists have been actively involved in areas which relate to their professional interests. Until recently, however, this has been a very piecemeal effort, as has been true of conservation efforts generally. Human societies, including our own, have continued to be dominated by the psychology of our hunting ancestors. If there is something in our environment which we need or want, it is regarded as having been put there to serve man.

Only now, after our technological capacity for consumption has reached proportions which are clearly inconsistent with this primitive psychology, has general and acute concern been expressed. Much of the damage to our environment could have been avoided if the advice of biologists had been heeded, but individual problems have often seemed somewhat inconsequential. Thousands of species have been eliminated by evolutionary processes and in the past it was not regarded as important if a few more were eliminated in the course of achieving a great economic benefit for human society. However, at this point we can see that the problem has quite different proportions. In the future we must be able to make a reasonable evaluation of alternatives, with some ability

322-215 O—68——7

to weigh the immediate economic gains against the long term economic and social losses associated with these alternatives.

The currently renewed interest in environmental biology is not only an indication of a social concern on the part of biologists, it is also a reflection of the fact that support of basic biological research in past years has given biology a new platform for further advances in the study of environmental problems. We do not know enough about the behavior of large biomes (ecological units comprising many kinds of plants and animals) to make the kinds of predictive judgments which will have to be made in the future, but we do know better how to frame the required questions and we do have or can develop the instrumental methods necessary to make a major advance in this area of biology. This is the general problem to which the International Biological Program is directed, as indicated below.

The International Biological Program

The concept and general plan of the International Biological Program (IBP) was approved in 1963 by the Executive Committee of the International Union of Biological Sciences and the General Assembly of the International Council of Scientific Unions. Biologists in the United States have participated from the early planning stages, and a U.S. National Committee for the International Biological Program has been acting for the National Research Council since 1965. In that year, Federal interest in the International Biological Program was formally expressed in a letter from Dr. Donald Hornig, Director of the Office of Science and Technology, to Dr. Leland Haworth, Director of the National Science Foundation. The Foundation was designated as the lead agency for the program. Coordination of the activities was undertaken by the formation of an Interagency Coordinating Committee and by assigning staff responsibility for program development and evaluation within the Division of Biological and Medical Sciences.

Financial support for the U.S. National Committee and its planning activities has been provided by the National Science Foundation and other agencies, and during the current year an operational phase has been initiated. In line with the general title of the IBP, "The Biological Basis of Productivity and Human Welfare," planning has been directed toward studies of: (1) organic production of the land, in fresh water, and in the seas, so that adequate estimate may be made of the potential yield of new as well as existing natural resources, and (2) human adaptability to changing conditions. For these purposes 17 major research programs have now been planned. Ten of these have had at least minor financial support during Fiscal Year 1968, and a total of almost $2,500,000 of research obligations can be identified as supporting these or projects related to IBP objectives. One component of the major program, "Analysis of Ecosystems," has been initiated with funds of $450,000 for the "Study of the Grasslands Biome."

George Van Dyne, College of Forestry and Natural Resources, Colorado State University, serves as director of this study, which is being conducted in Colorado within the Central Plains Experimental Range of the Agricultural Research Service and the Pawnee National Grassland of the Forest Service. First phase operational funding from the National Science Foundation and Atomic Energy Commission is being devoted to site development, construction and equipment; to an information synthesis program which will bring together presently available information on grasslands; and to the initiation of some research programs. Approximately 50 scientists from 19 institutions and from four Federal agency groups have a major involvement in this work, which will be concerned with climatology, hydrology, meteorology, photosynthesis, herbage dynamics, large consumers, consumer diets and small animals, grassland birds, insects, decomposers, and soils and the nitrogen cycle.

While major studies such as those initiated under IBP and certain oceanographic programs are being directed toward some of the problems which man is creating as he modifies his environment, development of an understanding of the molecular basis of biology has continued. Some examples follow.

Basic Research Projects

Proteins and Color Vision

Recognition was given, in late 1967, to a series of distinguished contributions to our understanding of the way in which light is converted to a nerve impulse in the retinal rods and cones of the eye. George Wald of Harvard University was a joint recipient of the Nobel Prize in Medicine or Physiology, with Halden Keffer Hartline of the Rockefeller University and Ragnar Garnit of Sweden for their work in this area over a number of years.

Dr. Wald's studies of the chemistry of visual pigments and the molecular changes associated with the absorption of light by these pigments have been supported by the National Science Foundation over a period of several years. Dr. Wald has also served the Foundation as a member of the Advisory Committee for the Division of Biological and Medical Sciences.

Dr. Wald's early studies of rhodopsin, the light-absorbing pigment in the retinal rods, defined the role of vitamin A as the precursor of this pigment. Subsequently, he has extended these studies to the red-green sensitive pigments involved in color vision. The demonstration that these pigments contain the same small light-absorbing molecule but in combination with a different protein shows that the presence or absence of certain proteins determines the sensitivity of the eye to different colors. Dr. Wald's studies indicate that color blindness results from a failure to form the proper protein rather than from a defect in vitamin A utilization or metabolism.

Since Dr. Wald's work has been dependent upon the extraction of the visual pigments from functioning retinas, it has depended upon the use of animal material and to a large extent upon the choice of animals with particular visual capabilities. This has led to studies of a number of crabs and crayfish which have eyes with unusual properties. One of these, the horseshoe crab, has been found to have a photoreceptor for ultraviolet light rather than the wavelengths of light which we ordinarily think of as visible. These studies covering a wide range of kinds of eyes have not only extended our understanding of the way in which animals may respond to light, but have permitted the development of nondestructive methods of examining visual pigments in the living animal, and the testing of the theories relating pigments to vision in man.

Among the problems to which Dr. Wald has recently directed his attention is the mechanism of amplification in the eye. A single photon, with a very small amount of energy, appears to be able to initiate a nerve impulse with substantially greater energy from one rod in the retina. This is not a unique biological phenomenon, since we are all familiar with the fact that a nerve impulse may initiate the contraction of a muscle with the release of much more energy than that of the nerve impulse. It represents, rather, another example of the regulatory mechanisms basic to all biological phenomena which it may now be possible to understand on the detailed molecular basis necessary to fully understand the effects of disease and to adequately correct them.

Replication in Biology

A major achievement of the past few years has been the identification of deoxyribonucleic (DNA) as the material of the gene, the establishment of the molecular mechanism by which it copies itself and thus provides for the transmission of inherited information from generation to generation. The recovery of this information by the cell has also been shown to operate through a mechanism for forming specific ribonucleic acids (RNA) from the pattern of DNA and using the RNA, in turn, as a kind of template for the assembly of amino acids into the specific proteins which are required by a given cell.

During the past year, a viral DNA molecule with biological activity has been successfully replicated outside of the living cell. The achievement was announced by Arthur Kornberg, a Nobel laureate at Stanford University, in collaboration with Mehran Goulian and with Robert Sinsheimer at the California Institute of Technology. DNA usually exists in living organisms as a pair of nucleic acid chains. Dr. Kornberg and his collaborators chose to work, however, with the DNA of the bacterial virus $\phi X174$ which is present in the virus as a circular, single-stranded structure. Upon entry into a cell, this DNA forms a circular double-stranded replicative form consisting of the viral DNA (+strand), and its complementary form (−strand). The −strand is used as a template for synthesis of additional +strands which are subsequently covered with viral protein to form the complete $\phi \times$ virus. Dr. Kornberg and his associates started with viral DNA (+strand) and by the addition of two enzymes, DNA polymerase and ligase were able to observe formation of the replicative form. Separation of the —strand from the synthetically made replicative form revealed that true and complete copying of the viral strand had been accomplished. The —strand was infectious and could be used as a template for the in vitro synthesis of additional replicative form from which infectious +strands could be separated. Although DNA had previously been synthesized in the test tube, this is the first time that such DNA has had the full biological activity of a natural DNA. The techniques used by Dr. Kornberg and his associates now permit a more detailed study of the mechanism of DNA synthesis and its control and the modification of the processes involved for the benefit of mankind.

Only 2 years ago, Sol Spiegelman at the University of Illinois announced the complete extracellular synthesis of the single-stranded RNA contained in the QB-virus which attacks bacteria. Within the short period since that announcement, substantial progress has been made toward understanding the mechanism by which this occurs. As in the case of DNA, a double-stranded intermediate stage in the synthesis of RNA has been demonstrated by Dr. Spiegelman's group and others. Even more exciting is the finding that something which mimics the postulated natural selection of the evolutionary process can be obtained with this RNA molecule in vitro, i.e., in the test tube. Dr. Spiegelman has observed that by selecting the most rapidly replicating molecules, the nature of the RNA which is being synthesized can be altered. Starting with the viral RNA which has several functions, a much smaller piece is evolved which retains only that information which is absolutely necessary for rapid replication in vitro.

This accomplishment has broad significance in several directions. For instance, by starting with the RNA of a harmful virus and applying appropriate selective procedures, it may be possible to produce a shortened piece of RNA which is not infective, but which can act as a blocking agent for the RNA-synthesizing enzyme and hence for virus growth in a cell. In another direction, the production of RNA which retains only enough information for its own replication will provide material which can be used to determine the mechanism for the recognition of RNA by its specific replicating enzyme.

Levels of Biological Organization

Only quite recently have techniques been sufficiently developed to study the manner in which macromolecules are assembled to form complex biological structures. This type of investigation has been proceeding simultaneously at several different levels of biological organization by a number of NSF grantees. One such group working with Howard Schachman at the University of California, Berkeley, has been studying an enzyme, asparate transcarbamylase, which catalyzes the initial step in a series of synthetic reactions leading to the formation of pyrimidines, essential components of nucleic acids. Gerhart and Schachman demonstrated several years ago that the catalytic and regulatory sites were situated on different subunits of the enzyme. Within the past year the number of each kind of subunit has been established. Klaus Weber, working in the biological laboratories at Harvard, and Don C. Wiley and William N. Lipscomb, working in the chemistry laboratory at the same institution, have reported essentially simultaneously that the enzyme contains six regulatory and six catalytic species. Dr. Weber concludes that the molecular weight of the polypeptide chain containing the catalytic site is 33,000, whereas molecular weight of the chain containing the regulatory site is 17,000. Using X-ray crystallographic procedures Wiley and Lipscomb independently concluded from symmetry considerations that the enzyme must consist of six regulatory and catalytic pairs of subunits.

A still more complex level of biological organization under study is the ribosome, a cell structure on which proteins are synthesized. In bacteria the ribosome is composed of two components, designated 50S and 30S. Both of these components are composed of at least a dozen different kinds of proteins. Little is known about the way in which the ribosome carries out its catalytic function, and the large number of protein components has made the task of delineating the structure of ribosomes discouragingly complex. Attempts at partial disruption of the structure and reassembly have met with some success and it has been possible to relate certain of the ribosome proteins with particular aspects of activity.

The reconstitution of functional ribosomes by mixing separated RNA and proteins has recently been achieved in the laboratory of Masayasu Nomura at the University of Wisconsin. Working with the 30S subunit from the bacterium *E. coli,* Dr. Nomura and Peter Traub were able to reconstitute a 30S unit with biological activity. The recombination of nucleic acid and proteins into an active 30S particle involves a high degree of specificity. The proteins from 50S subunits were unable to replace their counterparts from the 30S unit. The spontaneous reassembly of such a complex structure is an unprecedented event which not only staggers the imagination, but offers new possibilities for studying both the structure and function of this important cellular constituent.

Biochemical Studies of Ecosystems

Investigations of butterflies may seem unimportant and of relatively limited value to mankind, but an ingenious biochemical study of the Monarch butterfly is providing a crucial insight into the complex links and interactions of ecosystems. Lincoln Pierson Brower and his associates at Amherst College have been investigating "secondary plant products" as they relate to the problem of mimicry using a new field of research, ecological chemistry, which opens important new vistas into animal behavior, physiology, community ecology, pharmacology, and evolution.

"Secondary plant products" serve no obvious primary function in the growth and reproduction of plants, but have attracted man's attention since prehistoric times as medicines and poisons. They include cyanogenic glucosides which hydrolyze top roduce cyanic acid; cardiac glycosides which, like digitalis, effect heart muscle; saponins which are hemorrhagic in their action on the gut; and alkaloids, a heterogeneous group of compounds generally potent in their effects on the nervous system. They probably serve a protective function for the plants, but also have been shown to play a protective role for insects which feed on plants. Dr. Brower has shown that the palatability of the Monarch butterfly to predators is determined by the milkweed food plants that the butterfly fed upon as larvae, thus involving a complex interaction of three levels in the food chain. Those larvae feeding on milkweeds which contain cardiac glycosides, and the pupae and adults derived from them, cause extreme vomiting when eaten by birds; milkweeds lacking these digitalis-like poisons produce Monarchs which are completely palatable to avian predators. Dr. Brower postulates that a spectrum of palatability exists within a single species, with highly palatable and unpalatable butterflies flying together in the same habitats, and the palatable individuals deriving a mimitic advantage from the unpalatable ones.

In looking back over the endless controveries that have existed on the subject of mimicry, it is evident that much of the debate has hinged on the assumption that all individuals of a species are either palatable or unpalatable. Even though the present studies are limited to a single insect species, the results contribute substantially to a broader and more fundamental comprehension of animal behavior and physiology. Chemical defense in anthropods is widespread and there is a tremendous array of substances which are noxious to predators. Likewise, many of the secondary substances in plants are repellant or poisonous to herbivores. Thus the subject of mimicry, as approached through ecological chemistry, provides a new understanding of the basis for a selection process which operates through the interactions of animals and plants in their natural environment.

ENVIRONMENTAL SCIENCES

Foundation programs in the environmental sciences include the atmospheric, earth, and oceanographic sciences; a number of national programs concerned with the environmental sciences (e.g., the U.S. Antarctic Research Program, the Ocean Sediment Coring Program, Weather Modification and the Global Atmospheric Research Program) and the research activities of the National Center for Atmospheric Research.

One national program, the International Years of the Quiet Sun (IQSY) has been concluded with the final analyses of data completed and reported.

Because of the importance of the environment to the advancement of civilization, these programs are dedicated to the study of the surroundings of man, from the high atmosphere above the earth that receives constant bombardment of ionized particles from the sun, manifested in such phenomena as the aurora, to the mantle of the earth which involves man in the great forces of earthquakes and volcanoes.

Study of environmental phenomena often involve complicated, interdisciplinary efforts both in the field and in the laboratory. Some of these efforts take the form of large-scale field operations including scientists from many nations and requiring the use of ships, aircraft, satellites, rockets and other facilities. A few of these programs and activities are described in the discussion which follows.

The U.S. Antarctic Research Program

In fiscal year 1968, the U.S. Antarctic Research Program (USARP) completed a decade of active research with gratifying success. Technological advances figured to considerable degree in this progress, making available to scientists new tools which alleviate dependence upon tedious exertions and expenditure of time to accomplish research objectives.

An example of the utilization of new technical equipment in research is found in an airborne project aimed at the detection and measurement of infrared radiation for the first time in Antarctica. The Willow Run Laboratories of the University of Michigan in performing these measurements were primarily concerned with determining the research capability of airborne infrared devices and testing available equipment under field conditions. The investigators secured data near a volcano identified as active only 2 years ago, as well as on other thermal and coastal areas. The photographic image of an incandescent lava pool in the interior crator of Mount Erebus on Ross Island, taken through steam clouds so dense as to obscure the crater from vision, was the first direct evidence of the current presence of liquid lava on the Antarctic continent.

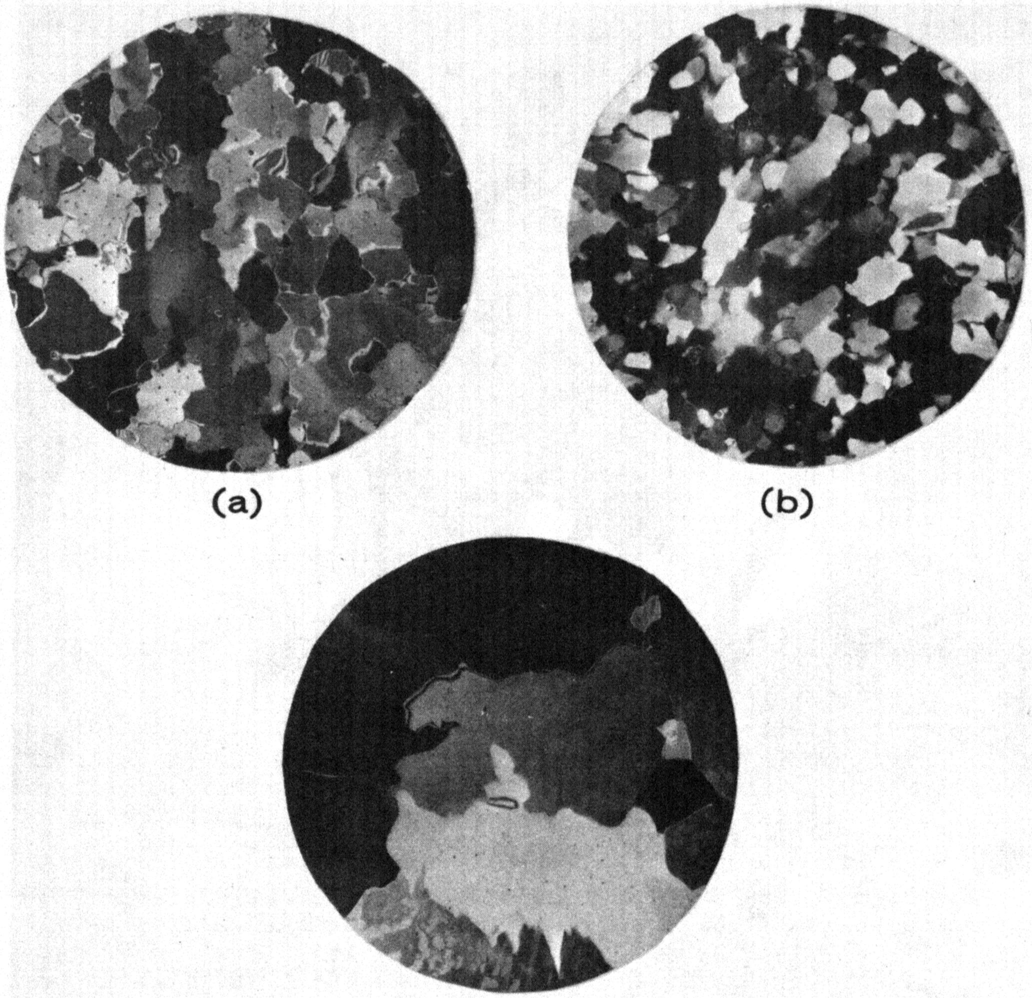
Ten years ago, in the period of the International Geophysical Year, glaciologists cored a hole at Byrd Station, using a standard oil well rig modified to drill in ice. At slightly over 1,000 feet the limit of the apparatus had been reached and the investigators reluctantly concluded operations. In the 1967–68 Antarctic summer the deep drilling conducted at Byrd Station by the U.S. Army Terrestrial Science Center (formerly Cold Regions Research and Engineering Laboratory) penetrated 7,100 feet through the ice cap to the basement rock. The coring device consisted of an electrically driven mechanical drill mounted at the end of the drill string—the result of years of development and testing in Greenland.

U.S. Navy Photo

Technician examines a section of ice-core immediately after its removal from the drill hole at Byrd Station. The ice-core drilling program was successfully completed when the bit reached the bottom of the ice cap at 2,164 meters (7,100 feet) in January 1968.

Ice core for over 99 percent of the depth was recovered, and a small portion has been returned to the United States for analyses.

On March 28, 1968, the 125-foot trawler *Hero* was launched at South Bristol, Maine. This uniquely equipped research vessel, the product of several years of ship design and construction, will be operated under contract for the National Science Foundation. At the end of the year, *Hero* will proceed to the Antarctic Peninsula to support programs of research in the marine sciences. The vessel is designed for trawling, bioacoustic investigations, and other work, principally in marine biology. She will have the capability of transporting small parties of about 10 scientists among the fjords and offshore islands of the Peninsula area in the Antarctic summer. In winter *Hero* will be based in South American ports for the support of marine work in cooperation with Argentina and



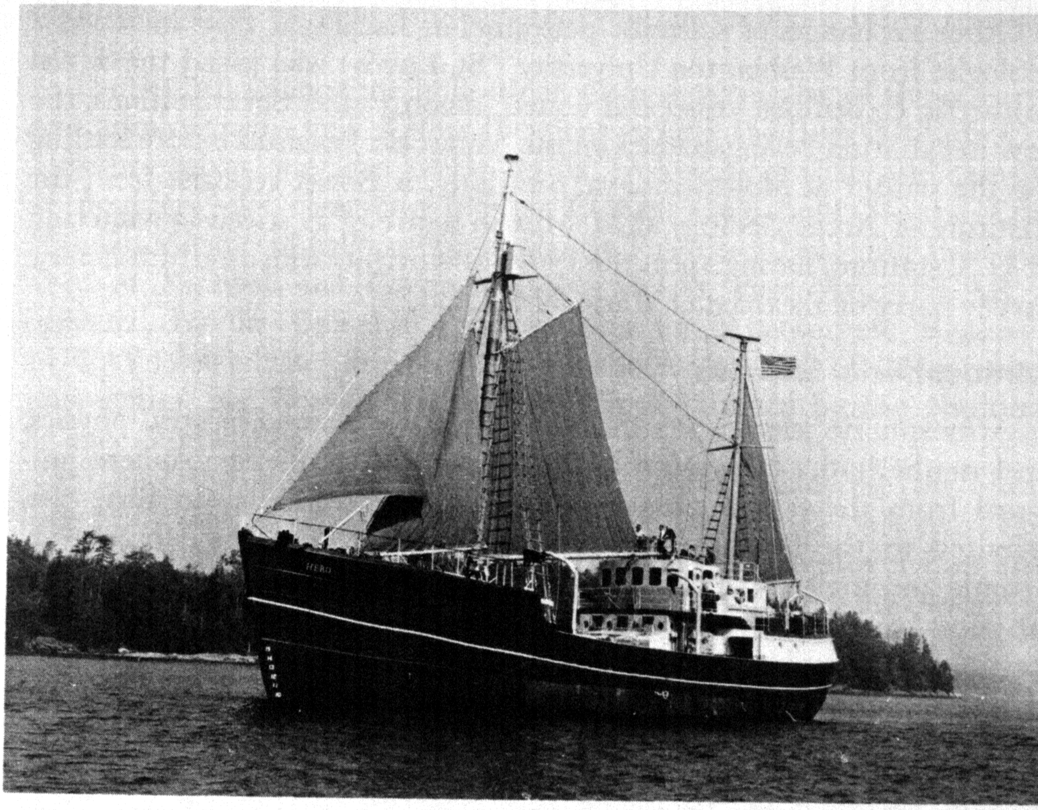
(a) (b) (c)

Photo by U.S. Army Cold Regions Research and Engineering Laboratory

Distinct differences in crystal structure can be seen in these thin sections of ice cores recovered from depths of (a) 340 meters, (b) 1,576 meters, and (c) 2,138 meters. Upon completion of the drilling project, 59 tubes of 1.5-meter cores were shipped to laboratories in the United States for detailed study.

Chile at the tip of South America. Wooden construction, including tropical greenheart sheathing on keel and sides, is intended to give her greater security against ice pressure and abrasion from floating ice. The 1,700 square feet of sail will serve to steady *Hero* at sea and permit silent ship operations. Sophisticated electronic equipment aboard will provide for navigation by satellite.

A venture into the dense and enduring ice pack of the Weddell Sea by icebreakers of Argentina and the United States illustrated the value of the international cooperation fostered by the Antarctic Treaty. The U.S.C.G.C. *Glacier,* with two oceanographers from the University of Bergen and a dozen U.S. marine scientists aboard, succeeded in emplacing four strings of Norwegian-developed current meters on the bottom of the Weddell Sea, the first and major stage in an effort to determine the



NSF Photo

The unique research vessel *Hero*, launched in March 1968, will be operated under contract for the National Science Foundation. Her wooden hull and auxiliary sails are among the special features of this floating laboratory designed for scientific research in the Antarctic. *Hero* is the namesake of an American sloop commanded by Nathaniel B. Palmer in 1820, and who is believed to be the first person to view the Antarctic continent.

dynamics and morphology of the Antarctic Bottom Water which is believed to have its genesis in the cold, saline deep waters of the Weddell Sea. Working together, the A.R.A. *San Martin* and *Glacier* completed 70 oceanographic stations, most of them in areas never before penetrated by ship. In the next summer, a follow-on expedition will attempt to recover the current meters with their year-long accumulation of data.

The USARP research ship *Eltanin* of the Military Sea Transportation Service returned to the United States in September 1967 for the first time since 1962 for a shipyard overhaul at San Francisco. Despite this interruption in her normal series of scientific cruises in the Southern Hemisphere waters, the ship logged 37,177 miles in support of ocean research under USARP during the year covered by this report. One of her six cruises took her into McMurdo Sound at the height of the Antarctic summer for the second successive year. In the course of the year, *Eltanin* provided billets and laboratory space aboard for Australian and French scientists, who were part of the scientific complement which averaged 28 persons per cruise.

Other exchanges of scientific personnel in fiscal year 1968 included a geologist from Washington University (St. Louis) who joined the Soviet Antarctic Expedition vessel and visited, among other Soviet stations, the new installation Bellingshausen on the Antarctic Peninsula before settling for the winter at Molodezhnaya. Similarly, a Soviet geologist from the Institute of Arctic Geology at McMurdo is one of 29 scientists wintering at U.S. stations, having spent the 1967–68 summer with a multidiscipline survey party on the coast of Marie Byrd Land.

Atmospheric Sciences

Atmospheric science uses the tools available from chemistry, physics, and mathematics to provide an understanding of the atmosphere outward from the earth's surface. This area of research has in turn contributed to the fundamental understanding of fluid flow, low-energy atomic and molecular collision processes, plasma physics, and cosmic ray physics. In addition to the importance of this research for weather forecasting and possible control, intercontinental radio communication, air pollution, and space flight safety, Foundation-supported research has provided for the development of scientific manpower in these areas.

Included in Foundation support for the atmospheric sciences is research on phenomena in the lower atmosphere (meteorology) where surface interactions and internal processes of the neutral gas produce weather and climate changes; the middle atmosphere (aeronomy) where atomic and molecular processes involving solar radiation occur that permit high-frequency long distance radio communication; and the high atmosphere (solar-terrestrial programs) merging with the interplanetary medium and energized by the incoming solar wind or particle flux.

Of particular interest in the atmospheric sciences is the establishment of the Inter Union Commission for Solar-Terrestrial Physics and the start of cooperative study in this area including the 1968–70 period, termed the International Years of the Active Sun. This effort recognizes that the terrestrial response to solar activity is global and must continue to be studied cooperatively by many nations. A series of experiments is planned to study earth magnetic effects, and the effects and characteristics of solar proton flare and other events. The description and theory of the formation of solar flares has been the subject of several international conferences this year.

National Center for Atmospheric Research

The National Center for Atmospheric Research (NCAR) was founded in 1960 to help accelerate the advancement of basic knowledge in the atmospheric sciences, to develop facilities for atmospheric research for the joint use of the university scientific community, and to serve as a planning center for joint projects involving university or other research groups.

The NCAR Laboratory in Boulder, Colo., houses most of the research and administrative staff. Other locations include the High Altitude Observatory laboratories and offices on the University of Colorado campus at Boulder, solar observing sites at Climax, Colo., and Mauna Loa, Hawaii, a national ballooning station at Palestine, Tex., and field stations at Marshall and Raymer, Colo., and at Page, Ariz. NCAR is operated by the University Corporation for Atmospheric Research (UCAR), a private, nonprofit corporation composed of 24 member universities, and is sponsored and principally funded by the National Science Foundation.

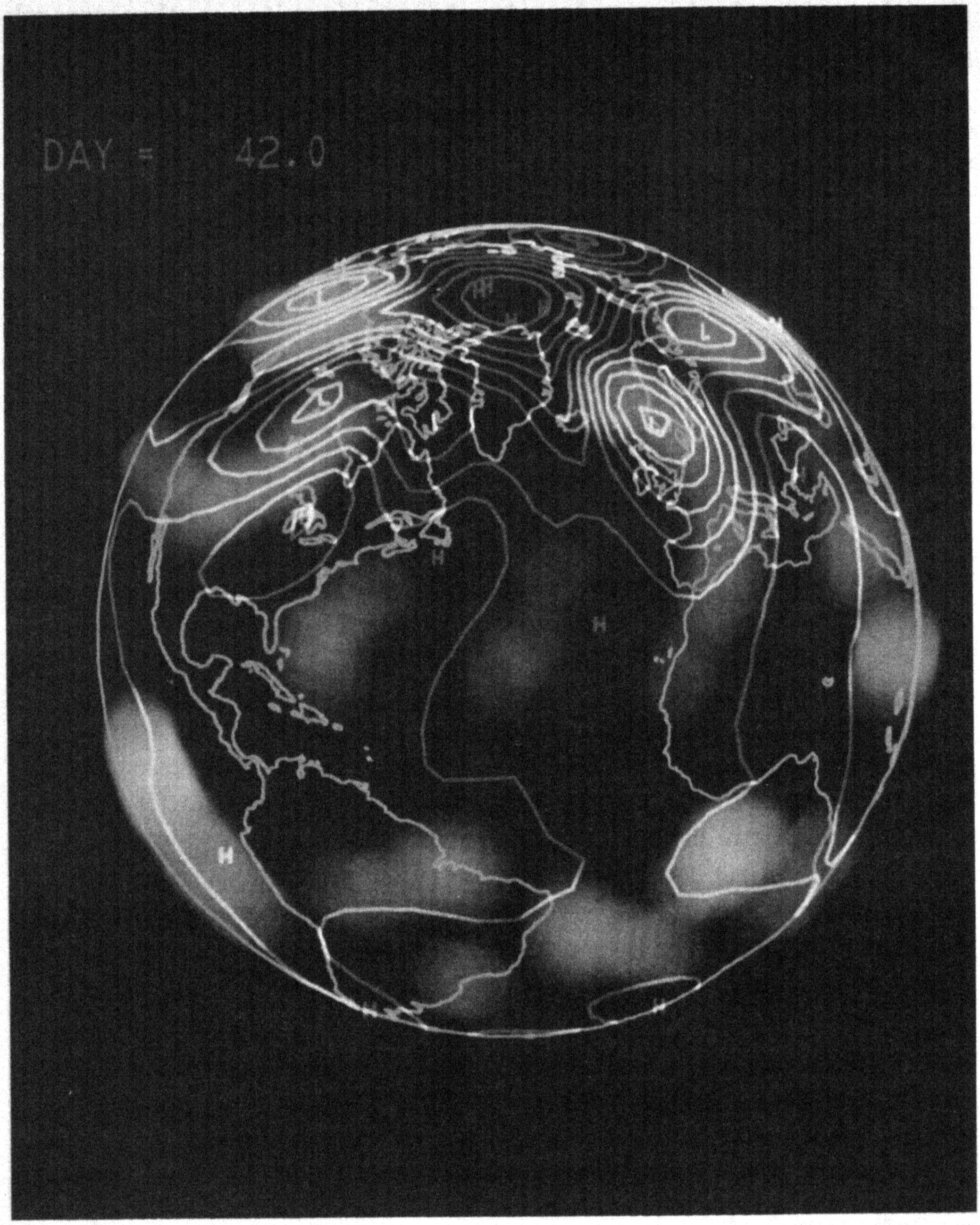
NCAR now has approximately 500 full-time employees (including long-term visitors), 95 of them at the Ph. D. level. In the past year, 165 short- and long-term scientific visitors, representing 70 universities and 30 private or government laboratories in the United States and 14 foreign countries, worked at or visited NCAR.

Research on the Earth's Atmosphere

Atmospheric Dynamics.—Recognition that motions of the atmosphere are governed by physical laws which can be expressed mathematically has led to an attack on problems of general circulation that was unthinkable before the era of high-speed, large-capacity computers. At NCAR, continuing development of dynamic models of the general circulation has resulted in a six-layer numerical model treating motions and physical processes in the upper troposphere and lower stratosphere, and a two-layer model including thermal and orographic effects of continental areas. To check the forecasting ability of these general circulation models, a program is now under way to use real data as initial conditions for the models, and to allow the computer to run through many successive days for comparison with actual weather developments.

A climatological atlas of atmospheric circulation in the Southern Hemisphere will provide a data source for an area of the world relatively unknown meteorologically. In cooperation with the University of Hawaii, a catalog has been prepared of data obtained during the Line Islands Experiment conducted and coordinated by NCAR in February–April 1967. (See NSF 17th Annual Report, p. 81.) This catalog provides the scientific community with ready access to the first comprehensive sample of meteorologic data from the oceanic Equatorial Trough Zone, and will therefore add immensely to availability of information for another data-poor area.

Global Atmospheric Research Program (GARP).—During the past 2 years, international planning efforts have been under way, with U.S. participation through membership in the World Meteorological Organization and international scientific groups, to organize a global atmos-



NCAR Photo

This computer-drawn map of sea-level pressures and areas of cloudiness shows results produced at NCAR with a six-layer model of circulation of the global atmosphere. The computer begins with the atmosphere at rest, and incorporates numerical equations of rotation, solar heating, long wave cooling, small-scale turbulence, and exchange processes. High and low pressure fields which resemble those occurring in the real atmosphere develop after about two weeks of simulated time.

pheric research experiment in the mid-1970's (see Introduction and Summary, page 14 and GARP discussion, page 105).

The following NCAR efforts were related to GARP and its precursors:

- Refinement of the previously mentioned NCAR six-layer mathematical model of the general circulation of the global atmosphere, which is a critical ingredient of the overall GARP effort.
- Development of the GHOST (Global Horizontal Sounding Technique) Balloon System, through continuing flights of constant-level balloons, launched from New Zealand in a cooperative program with the Environmental Science Services Administration (ESSA) of the Department of Commerce and the New Zealand Government. Ultimately, such balloons, linked to communications satellites, will provide global weather data at important levels of the atmosphere in order to provide an adequate three-dimensional analysis of the world's weather.
- Activities in the Barbados Oceanographic and Meteorological Expedition (BOMEX), which is being managed by ESSA on behalf of participating government agencies and university research groups. NCAR is providing systems engineering assistance and will participate in the scientific program. The aim of BOMEX is to increase our grasp of the interaction of oceanic and atmospheric processes, which are in turn linked to the general circulation.
- Participation in the planning for TROMEX (Tropical Meteorological Experiment), which will be conducted under international auspices in a large area of the western Pacific in the 1972–73 period, in order to extend the findings of BOMEX and its predecessor experiments. TROMEX, in addition to providing new data on tropical processes, will help to determine the kind of observational network required for the Global Atmospheric Research Program.
- Continued analytical studies of tropical and Southern Hemispheric circulations.

Weather Modification and Cloud Physics.—Since publication of reports on prospects for weather modification by the National Academy of Sciences and by the NSF Commission on Weather Modification in 1966, there has been a growing national interest in research on various types of weather modification—precipitation enhancement, hail suppression, lightning suppression, fog dispersal, etc.

The following NCAR efforts were related to weather modification and cloud physics:

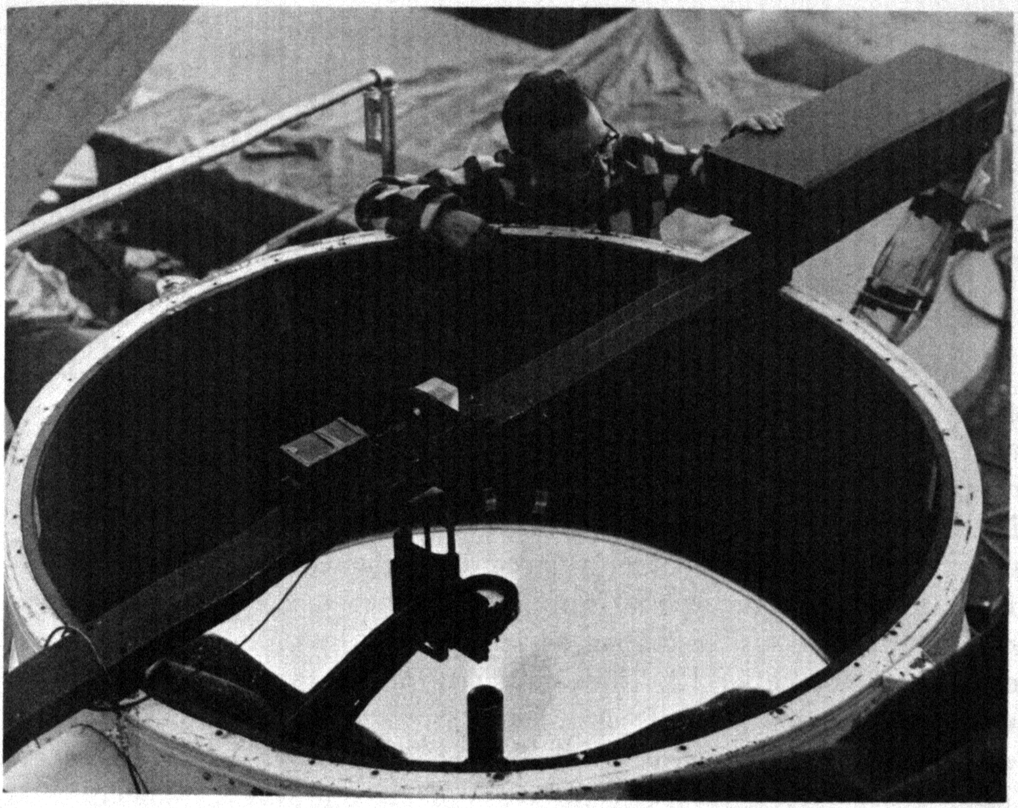
- Participation in a preliminary field study of hail-producing storms and in planning a follow-on experiment in northeastern Colorado to test the feasibility of suppressing hail by placing explosives impregnated with silver iodide in hail-producing clouds (see pages 100 to 105, Weather Modification). In addition to the actual seeding operation which will be carried out in cooperation with Colorado State University, ESSA, and other groups, NCAR plans to probe the structure of the storms with advanced radars, with instruments dropped through the storms from the NCAR jet aircraft, and with radiometric techniques to make airborne measurements of the intensity and extent of hailfall on the ground.

- Airborne and laboratory research into the relationship between electrical forces and the efficiency with which raindrops form through coalescence and accretion.
- Laboratory and mathematical modelling work on the nature of convective clouds and their interaction with the surrounding environment.
- Laboratory studies of cloud nucleation and ice crystal formation.
- Studies of worldwide distribution of freezing nuclei.

Precipitation Processes.—As part of the major effort being directed toward fuller understanding of precipitation processes, an Air Force–NCAR cooperative program is now engaged in sampling ozone, water vapor, freezing nuclei, and aerosols in tropospheric and stratospheric air near the jet stream. Results from these tests may reveal whether injection of air from the stratosphere into the troposphere associated with well-defined frontal systems is accompanied by flow of air from the troposphere into the stratosphere on the other side of the jet stream, and whether there is a correlative high concentration of freezing nuclei in the vicinity of jet streams during cyclonic disturbances.

Another effort to explain the conditions controlling the development of rain continues to explore the conditions under which atmospheric water droplets coalesce. The processes observed in the laboratory, coupled with theoretical studies of collision efficiencies of small drops, indicate that electric fields are enhanced in clouds by large drops passing close to small ones or colliding with them and bouncing apart. Computations of the electric field which would be produced in a cloud in this way are in accord with many observations of thunderstorm electrification. Once an enhanced field is formed in clouds, and correspondingly high charges exist on the particles, the growth rate for cloud drops is greatly increased. Calculations of growth rates are now being extended to studies of larger drops, including raindrops and hail.

There are still many unanswered questions concerning the mechanisms by which natural hailstones are formed. To gain a better understanding of one of the aspects of this process, calorimetric measurements of the rate of freezing of artificial spongy hailstones were made in the laboratory. The results were used in a computer program to determine how much water could freeze during the trajectory of a hailstone as represented in various hailstorm models. The computations indicate, in most cases, the presence at the ground of moderate to large quantities of liquid water. These results are incompatible with field measurements carried out during the past three summers, which revealed less than 4 percent



NCAR Photo

This laser device is used by the National Center for Atmospheric Research in the study of atmospheric aerosols. The laser head (source of light) and a prism rest on a bar over a large searchlight mirror. Laser impulses, directed skyward by the prism, are reflected by layers of atmospheric aerosols, and returning impulses are collected by the mirror and measured electronically. Time in transit indicates the height of the aerosol layers.

liquid water in 90 percent of the hailstones examined, and suggest that a satisfactory hailstorm model has not yet been devised.

Atmospheric Pollution and Transport.—A number of programs at NCAR are devoted to problems of atmospheric pollution. Photochemical smog, particularly the roles played by nitrogen dioxide, sulfur dioxide, trace organics, nuclei, and water vapor, are being studied under laboratory, conditions and in the field. New and improved sampling techniques, including sampling equipment for aircraft and balloons, have been developed for these programs. A rocket sampler developed for measurements above 40 km, the practical ceiling for balloon systems, was tested in May 1968 at White Sands Missile Range in New Mexico.

The chain of events leading to rapid local accumulation of urban smog is being studied by analysis of atmospheric constituents during smog development, and by laboratory studies which break down the complex patterns of smog accumulation into simple individual processes. The reactions of several free radicals with oxides of nitrogen have been studied to determine their relative importance in a photochemical smog environment.

322-215 O—68——8

A field study of trace chemicals of the tropical atmosphere, to determine the sources and concentrations of airborne materials in the tropics, is now near completion. NCAR scientists cooperated with the U.S. Army Tropic Test Center, the Smithsonian Institution, and the U.S. Army Chemical Corps in this program. A three-dimensional picture was obtained of diurnal and seasonal variations in sulfur dioxide, ammonia, nitrogen oxides, and some of the lighter organics.

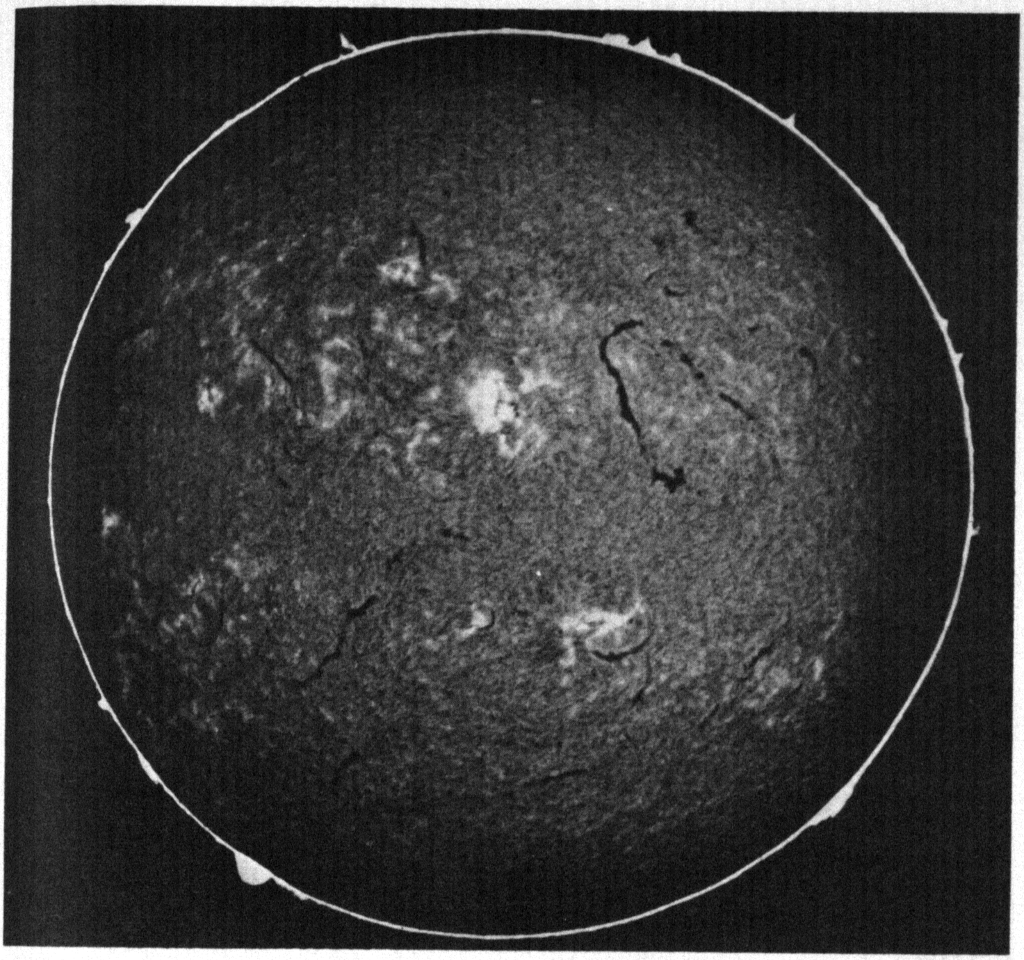
Research on the Sun and Sun-Earth Interactions

The Corona.—It has become increasingly evident that the primary agent which molds the corona is the solar magnetic field, and attempts are being made to determine whether a correlation exists between coronal magnetic fields and visible structures. Applying computer methods to Mount Wilson Observatory measurements of magnetic fields of the solar surface for November 1966, a three-dimensional map of the magnetic fields in the corona at that time was prepared. Comparison with the structure of the visible corona as represented by photographs from the eclipse of November 12, 1966, and synoptic koronameter observations revealed that the bases of coronal streamers form in arcades of loops of magnetic field lines, while "open" field lines channel coronal material into gently curved rays. Several years of Mount Wilson magnetic data are now being depicted in such three-dimensional magnetic maps, in order to study the time changes of the magnetic field above active solar regions. Additional data on changes in the corona were derived from observations made almost daily during the year at the Mauna Loa field station in Hawaii.

Solar Magnetic Fields.—Working largely with the magnetograph at Climax, Colo., NCAR scientists have continued to study electric currents and magnetic fields of active regions of the sun, as revealed by their effects on hydrogen and helium lines in the solar spectrum. Magnetic fields of a large number of active prominences, including loops and surges, were measured. The location and development of several major flares were studied relative to the configuration of the magnetic fields of the active regions involved; flare outlines often closely follow the contours of the longitudinal magnetic field. Modifications in the magnetic structure of the active regions follow some flares.

Postdoctoral Studies

The NCAR Advanced Study Program (ASP) draws to NCAR a small group of scientists working in the atmospheric sciences and in physics, chemistry, and mathematics, and provides them with opportunities to pursue problems in atmospheric research. This year, the ASP sponsored 14 postdoctoral fellows and a number of senior scientists. These visitors conducted research of their own or worked with members of the NCAR permanent staff on such varied problems as the hydromagnetics of the earth's interior, the dynamics of ocean currents and lake circulation,



NCAR Photo

Terrestrial response to solar activity is global, and is therefore of interest to scientists of many nations. The High Altitude Observatory of the National Center for Atmospheric Research photographs the sun every 10 seconds (weather permitting) as part of flare patrol activities initiated a decade ago. Flare photographs serve in studies relating solar activities to radiation in space and to disturbances in the earth's upper atmosphere.

atmospheric turbulence, mountain waves, atmospheric ozone, tidal variations of meteorological and geomagnetic parameters, ionospheric regions, and solar physics.

The ASP also sponsored summer colloquia on the physics of the solar corona, presented jointly with the Department of Astro-Geophysics of the University of Colorado in the summer of 1967, and on internal gravity and acoustic waves in the atmosphere in 1968.

Facilities for NCAR and the Universities

The NCAR Facilities Laboratory operates four joint-use facilities, the Scientific Balloon Facility, the Computing Facility, the Research Aviation Facility, and the Field Observing Facility.

In fiscal year 1968 the Scientific Balloon Facility launched about 100 balloon flights from field stations in Palestine, Tex., and Page, Ariz.

Most of these flights carried instrumentation for experiments in polarimetry, photography, solar radiation, stellar and solar astronomy, cosmic rays, atmospheric composition, temperature-humidity distribution, and earth albedo. Some flights were research and development flights to identify causes of balloon failure or to test improvements in launch techniques. During the past few years, the development program has made possible a marked increased in performance and reliability, and has enabled the facility to launch increasingly large balloons in response to requests for large payload capability and higher float altitudes.

The NCAR Computing Facility supplies computer services and systems, and problem programming for the research needs of the atmospheric sciences. The facility also trains scientists and scientific aides in the use of the computer. In fiscal year 1968, about half the computer time was used for numerical weather simulation experiments. Time was also allotted for studies of the climatology of the Southern Hemisphere, analysis of data from the 1967 Line Islands Experiment, and other NCAR and non-NCAR programs.

The Research Aviation Facility provided almost 2,000 hours of airborne research time to NCAR and other research groups. Aircraft instrumentation was modified for studies of atmospheric composition, atmospheric electricity, thunderstorm structure, cloud physics, mountain lee waves, and atmospheric refractivity.

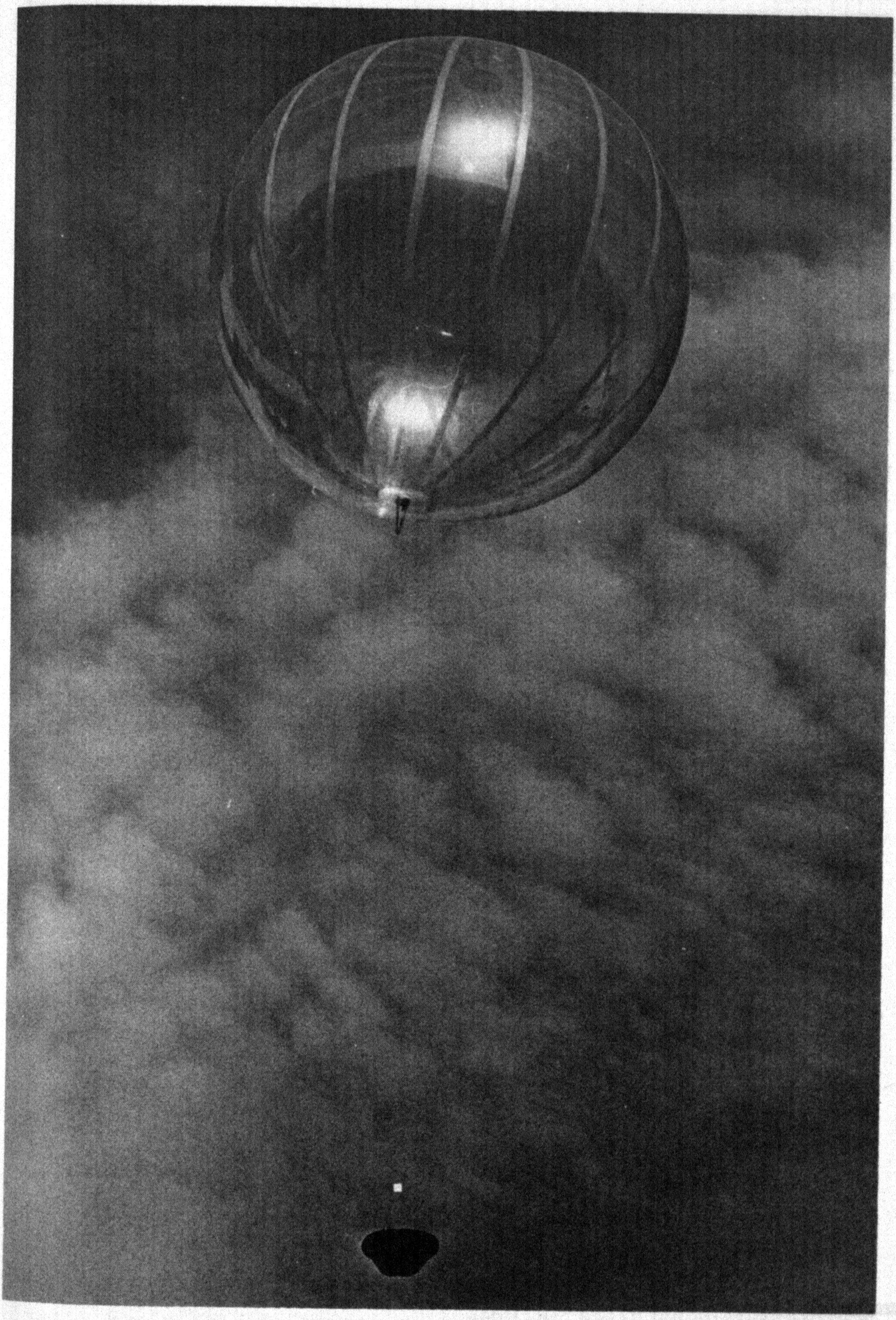
In April 1968 the Research Aviation Facility acquired a de Havilland DHC–5 Buffalo. An inertial platform and other instruments are being installed so that mesoscale vertical motions can be measured.

The Field Observing Facility supplies staff assistance, technical advice, and field equipment to a growing number of NCAR and non-NCAR research projects. The facility supported field programs investigating mountain waves, atmospheric chemistry, thunderstorm activity, exchange of air parcels between stratosphere and troposphere, sea breezes, and hailstorms.

The Global Atmospheric Measurements Program (GAMP) was formed in 1966 as part of the Facilities Laboratory devoted to developing new techniques and instruments for obtaining atmospheric measurements. During 1968, GAMP concentrated on further tests of the Global Horizontal Sounding Technique (GHOST). Small superpressure balloons carrying lightweight electronics packages were released in the Southern Hemisphere to drift with the wind at altitudes of 10,000 to 75,000 feet. New balloon shapes were designed in efforts to provide minimum response to vertical air currents and to overcome icing problems. Location systems are being studied which will permit real-time analysis of balloon trajectories.

Weather Modification

The Foundation program in weather modification continues to provide support on a broad front for research activities at universities and



NCAR Photo

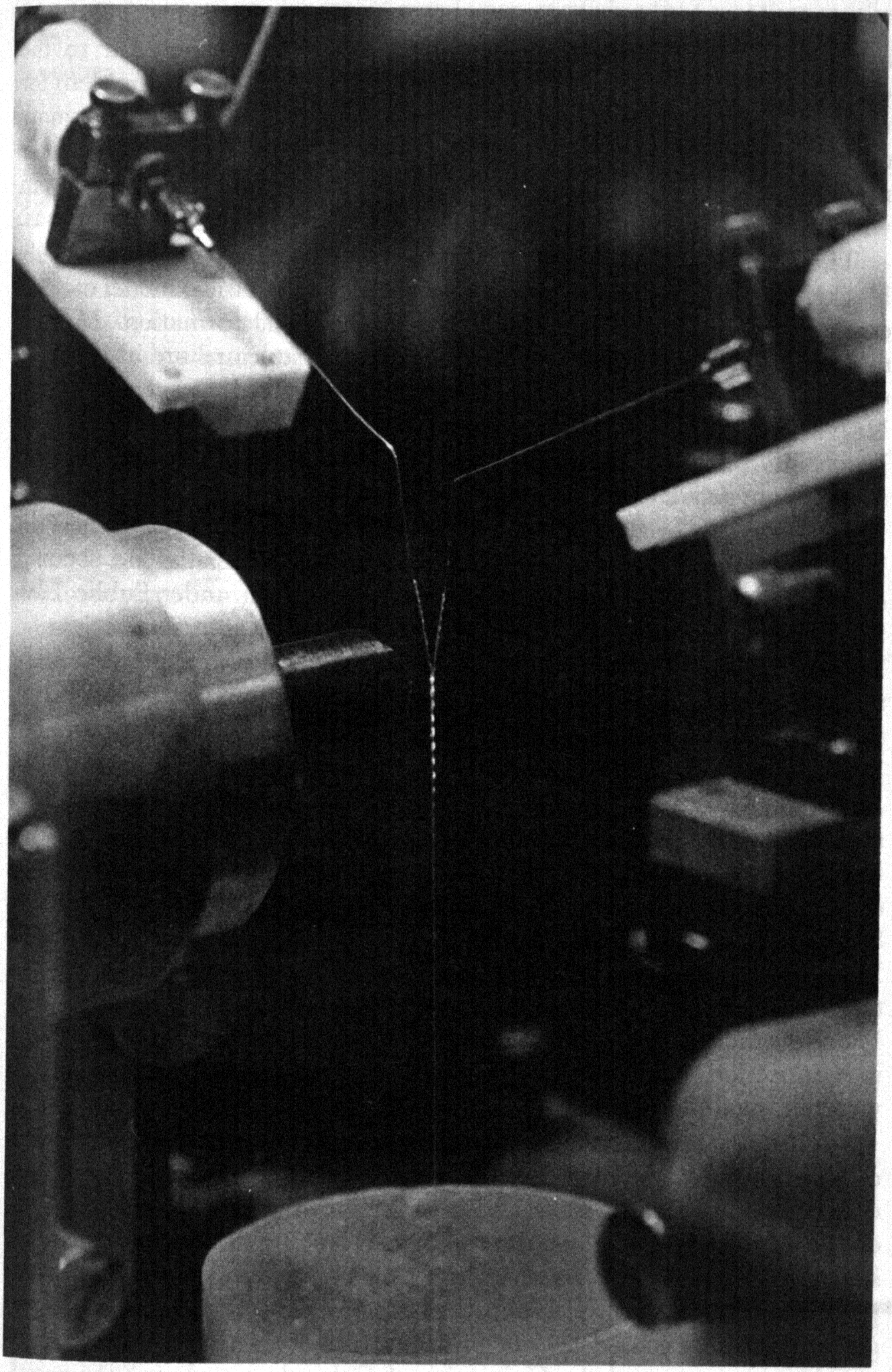
This GHOST balloon (Global Horizontal Sounding Technique) carries a lightweight solar-powered instrument package. During daylight hours the instruments transmit data to ground receiving stations up to 5,000 miles distant. Flight tests show that, above 30,000 feet, GHOST balloons can be kept aloft for several months, providing economical airborne meteorological observations. Ultimately, such balloons will be linked to orbiting satellites as part of a system to provide three-dimensional analysis of the world's weather.

other institutions in the mechanisms of precipitation enhancement, warm fog dissipation, hail suppression, and severe storm modification. In addition, projects have been initiated to explore the social, economic, legal and ecological impact of weather modification on modern society structure and institutions.

Theoretical studies and laboratory research indicate that the prospect is encouraging of inducing rainfall from clouds through the use of nuclei that absorb water droplets. Field experiments to test the use of common table salt which has been finely ground into size range of 10 to 20 microns in diameter for increasing precipitation from warm clouds are being conducted over the island of St. Croix in the Virgin Islands by Wallace E. Howell Associates. This work is being evaluated jointly by both commercial and university personnel under Foundation sponsorship. The possibility of dissipating warm fog by use of finely ground salt or urea is also being explored, and appears to show promising results in laboratory simulation chambers. Field tests are also under way at the present time to test the technique under full-scale atmospheric conditions.

During this year, increasing attention is being placed on the study of intense convective storms in the field, with particular emphasis on those which produce damaging hail. Large-scale programs to study the dynamics of storm growth and the mechanism for the formation of hail are under way at Rapid City, S. Dak.; Alliance, Nebr.; and the Pawnee National Grasslands in northeastern Colorado. These studies are being carried on jointly with the Department of Commerce and the Department of Agriculture, with the technical and scientific manpower recruited from government laboratories, universities and commercial operators. The National Center for Atmospheric Research is playing a leading role in furnishing field radars, aircraft, and facilities to the university and government staff, and is also participating in the scientific observations and evaluation. The Pawnee Grasslands field program will include a test of the hail suppression technique of U.S.S.R. scientists, by using small rockets launched into the liquid accumulation zone of the storm from aircraft to convert the hail-forming supercooled water droplets into snowflakes, resulting in increased rainfall on the ground instead of large hailstones. In the Rapid City project, a specially modified military type of aircraft will penetrate into the heart of the storm to obtain samples of ice and other meteorological information. This aircraft will be specially reinforced with armored wing and tail leading edges to withstand damage from the hail.

Experience in cloud seeding has indicated that it is often difficult to predict where precipitation will fall as the result of silver iodide released from a ground generator. Under Foundation sponsorship, Joseph Warburton of the University of Nevada has developed a technique for the determination of minute quantities of silver which are present in rain, snow, or hail falling to the ground as a result of silver iodide seeding.



NCAR Photo

Knowledge of the processes of droplet collision and coalescence is vital to studies of precipitation under various cloud conditions. In a laboratory study at NCAR, tiny water drops formed with hypodermic needles are made to collide in front of the camera lens, providing a visual record to support data from many other sources.

This technique has revealed several instances where the silver iodide released from the ground has failed to reach the target area due to the complex wind structure aloft. A reassessment of the targeting problem for the release of seeding materials from the ground or from the air is now under way; it involves the basic understanding of the motion of air masses under conditions of lifting over mountain peaks and the ways in which air is drawn into the base of growing convective cumulus clouds.

The University of Miami is studying the lifting of air above artificially blackened surfaces on the ground to derive a mathematical model of such convective motions—which lead to cumulus cloud formation. Mathematical models of cloud growth and internal structure are also under development with Foundation support at the Rand Corporation, the University of Nevada, Pennsylvania State University, and at New York University for the purpose of evaluating and predicting the best way to modify convective cloud systems.

A study has been initiated with the Travelers Research Center in Hartford, Conn., to examine the records of commercial cloud seeding operations which are maintained by the Foundation under Public Law 85–510 and to determine whether these records can contribute scientific knowledge on the effective use of cloud seeding for precipitation augmentation and hail suppression as practiced by present commercial operators.

The First National Conference on Weather Modification was held at Albany, N.Y., in April of 1968 to discuss the latest techniques and results of cloud seeding experiments. The conference was organized by the American Meteorological Society under Foundation sponsorship. A conference on the legal aspects of weather modification was also held by Southern Methodist University in Dallas, Tex., in December 1967 under Foundation sponsorship. This conference brought together the legal talents of university professors, practicing lawyers, State legislators, and Federal officials to discuss the problems which arise in the field of law in connection with the experimental and operational application of weather modification.

Montana State University has been granted Foundation support to establish a field study on the effects of artificially induced increases or decreases in rainfall or snowfall upon the growth of vegetation, the incidence of fungus and plant disease, the reproduction and habits of destructive insects such as grasshoppers, and the effects on the small animal population such as the jackrabbit. The University of Missouri is investigating the economic impact of weather modification on a typical community economy, and the University of Colorado is exploring the social aspects of weather modification and the nature of the interaction between man and the atmosphere.

On the whole, the Foundation has fostered basic and applied research over a broad area of the physical and social sciences in the area of weather modification. Under its regulation requiring that weather modifiers notify the Foundation 30 days in advance of conducting weather modification activities in the atmosphere, 45 new projects were registered in fiscal year 1968, and 35 projects initiated in earlier years were continued into 1968.

Global Atmospheric Research Program

The United States has committed itself to support of the Global Atmospheric Research Program (GARP), a long range program that will involve the countries of the world for many years. The National Science Foundation's role in the commitment is to stimulate and intensify general circulation research designed to achieve a capability in long-range weather prediction, to explore the feasibility of large scale weather and climate modification, and to promote the education and training of atmospheric scientists. All of NSF's support will go to non-Government agencies.

Numerical simulation of the general circulation is of extreme importance to GARP. If the general circulation of the atmosphere can be reproduced accurately on a computer, it will be possible to determine (1) the amount of input data necessary to obtain a specified accuracy in the output or forecast of the weather; (2) the accuracy of the input data itself; and (3) the kinds of input data needed. Also, it will be feasible to make changes in the computer program that simulate significant modifications in the atmosphere such as the thawing of the arctic seas or the warming of the earth's surface by a degree or so. The results of such experiments can be monitored without ever having to produce the experiment in nature. Information gained from such simulation studies is invaluable and can be achieved for a small fraction of the cost of large field experiments.

During fiscal year 1968 GARP funds were used to support the numerical simulation studies being carried out at UCLA under the direction of Yale Mintz and Akio Arakawa. A numerical model of the atmospheric general circulation has been developed that will be run to simulate an entire year. The model will include higher vertical resolution to allow realistic modeling of the atmospheric boundary layer and interactions of the troposphere with the stratosphere; the effect of cumulus convection in the model to simulate the life cycles of cumulus clouds that transport heat and momentum especially in the tropical regions; and the inclusion of sea-surface temperatures as a time-dependent variable to allow an exchange of heat and momentum between the deep oceans and the atmosphere.

Besides the work at UCLA, several grants were made to support the Barbadoes Oceanographic and Meteorological Experiment (BOMEX) which is a GARP sub-program or GARP Project. The field phase of BOMEX is scheduled to take place during May–July 1969 in the area around the Island of Barbadoes. It is designed as a sub-tropical and tropical air-sea interaction experiment and is a necessity before any large scale experiment such as GARP is contemplated. The goals of BOMEX are to study (1) the vertical flux of momentum, heat and other properties at the interface of the sea and the atmosphere, (2) the horizontal transport of these properties through lateral boundaries, and (3) the vertical and horizontal divergence of the fluxes.

International Years of the Quiet Sun

The activity of the sun varies from year to year, even from month to month, taking on the average 11 years to complete a cycle. In the period from January 1964 to December 1965, the sun was in a stage of minimum activity, and this period was designated the International Years of the Quiet Sun (IQSY). During IQSY an intensified, broad, international program was conducted to attain a better knowledge of the solar-terrestrial relationship. Although no new funds were added to the program this year, the past investment by the Foundation continues to produce additional results.

Information developed on a broad front in atmospheric sciences during the IQSY is in the process of being published in a comprehensive form through a seven volume series entitled "Annals of the IQSY." The first volume entitled "Geophysical Measurement: Techniques, Observational Schedules and Treatment of Data" has been issued by the Massachusetts Institute of Technology Press this year.

Solar radiation absorbed in the lower D-region, approximately 70 to 90 km. above the earth, produces an ozone layer that helps to shield plant and animal life from the strong ultraviolet and X-ray radiation. The ozone circulates with the atmosphere and is an effective tracer to the movements of large air masses. A global ozone distribution study was made as a part of the IQSY. The Foundation supported this global distribution program by support to various universities to launch balloons locally. Foundation support to the Environmental Science Services Administration was provided for systematic launches at more distant locations. One standard instrument, developed by V. Regener at the University of New Mexico, was flown by several groups, including Regener's group at Albuquerque. At Florida State University, R. Craig has obtained analytical results from these hundreds of observations to indicate on a global scale that the atmosphere is well mixed and turbulent up to altitudes near 12 km. This result is of interest both in dynamic meterology studies and in discussing the life cycle of atmospheric pollutants. Richard Reed at the University of Washington developed these data into a description of the movement of continental size air masses, independently confirmed their trajectories and investigated tropospheric-stratospheric exchange processes.

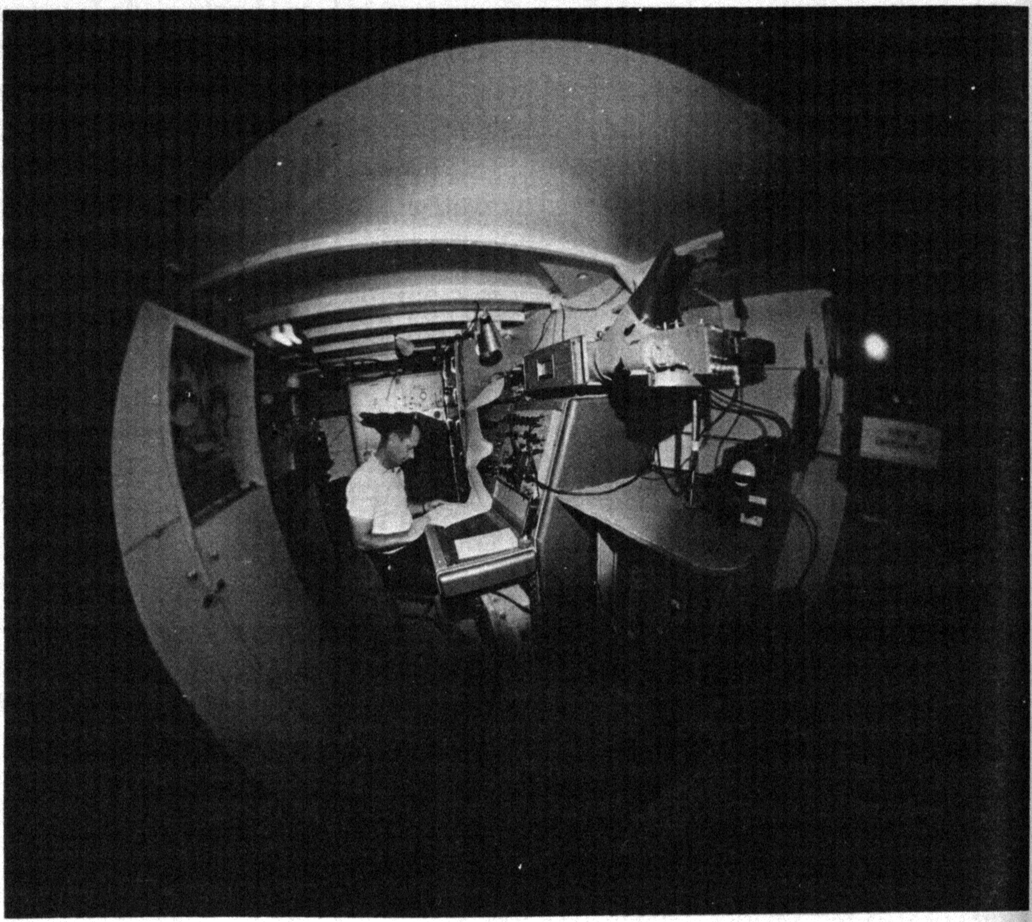
The atmosphere is a very difficult environment in which to make measurements, yet measurements and observations are vital for an accurate description and eventual understanding, prediction and even modification of atmospheric phenomena. Often it is impossible to make measurements at the exact location where such measurements are desired. The use of indirect probes is one way to circumvent the problem. Many indirect probing studies use ground based equipment to observe changes in atmospheric variables because the equipment is easily accessible and observations can be made routinely, night or day, as well as during periods of geophysical significance.

Radar is one kind of indirect probe. Radio frequency energy is emitted by a transmitter, focused by an antenna and then propagated outward usually in a narrow beam. Objects lying in the beam path either absorb, scatter or reflect the energy. Only a small part of the scattered and reflected energy is returned to the receiving antenna. The returning energy is called the target signal. Hydrometeors such as rain, snow and hail scatter radio energy. Thus radars are useful tools for observing and detecting the presence of hydrometeors at distances up to several hundred miles from the transmitting site.

The following paragraphs highlight a few radar studies that are supported by the National Science Foundation although research using other kinds of indirect probes is sponsored, too.

Radar is used in meteorology to obtain observations that lead to a better understanding of atmospheric structure, whether it be thunderclouds, precipitating stratiform clouds or the layering of the atmosphere during clear skies. The primary information gained from radar is the location of a target or echo in space, the change of that target's location in time and the intensity with which the signal is reflected or returned from the target. Interpretation of signal returns has lead to understanding of the structure of clouds and the kinds of precipitation associated with various cloud forms. Some problems remaining are what is the motion field within clouds, what is the size distribution of rain droplets and hailstones, how fast do these hydrometeors fall, and what is the detailed structure of the clouds and atmosphere when observed by radar? Research on aspects of these problems is being conducted at the Universities of Arizona, Chicago, and Texas.

Atmospheric physicists at the University of Arizona under the direction of Louis Battan are using a 3 cm. pulsed doppler radar with a vertically pointing antenna to make their observations. The University of Chicago group under David Atlas is just beginning to assemble a doppler radar facility. Data processing equipment is a part of both facilities because the amount of information received from a single doppler radar is enormous.



University of Arizona Photo

Data recording equipment used in cloud physics studies at the University of Arizona is housed in a trailer on top of Mount Lemmon. During summer months, rain-producing storm activity is almost a daily occurrence at the research site. Accummulated data are sent to the main campus for analysis.

Doppler radars offer the advantage of being able to ascertain the instantaneous motion or the radial velocity of targets as well as their location in space and time. This is accomplished by electronically detecting and interpreting the doppler shift or change in frequency caused by a moving target. In the case of the vertically pointing system at Arizona it is possible to determine the vertical velocity of reflecting particles. The Chicago system will use two separate doppler systems to observe a single phenomenon such as a thunderstorm. Such a configuration offers a better definition of the flow field than a single doppler system.

The doppler systems are designed and used so that at each observing altitude, usually at intervals of 500 feet, a doppler spectrum is measured that is representative of the reflected radar power in terms of the speed at which the reflecting particles approach or recede from the radar set. Having knowledge of doppler spectra as a function of altitude and time, it is possible to map vertical motion fields in cloud systems. Until the advent of pulsed doppler radar, there was no other practical

NCAR Photo

Technician adjusts recording equipment for a wind sensor used in meteorological studies at the University of Texas.

scheme for measuring updrafts and downdrafts except by means of aircraft. Measurements of updrafts in violent thunderstorms should assist in an explanation of hail and tornado formation.

Raindrop and hail size can be calculated from doppler radar data. Such studies will make it possible to explain changes in raindrop size in terms of mechanisms such as condensation, evaporation, coalescence and droplet breakup. Improved knowledge of processes governing the evolution of raindrop size will aid in research for means of modifying rainfall. Although estimates of hail size are subject to more uncertainties than are rainfall size, the great importance of being able to estimate the presence and size of hail aloft is recognized.

Pulsed doppler radar is also useful in measuring wind velocity, divergence within a column of air, and wind shear aloft. These research areas are being pursued at both the Universities of Arizona and Chicago.

Although doppler radars can give much useful information, there are other radar systems that are equally useful in observing the atmosphere. A group of electrical engineers at the University of Texas at Austin under the direction of Alfred LaGrone uses two wavelengths, 3 and 10 cm., and a bistatic radar system to observe the atmosphere. The bistatic configuration means that the transmitter and receiver are separated allowing more flexibility and meaningful observations. The two wavelengths allow discrimination between different kinds of targets since the target signal is dependent on the wavelength of the transmitted signal and the size of the scattering particles.

The Texas group is concentrating on observations of "angel" echoes or return from targets not observable with the naked eye. Many of these radar returns come from insects while others come from high concentration of particulates that concentrate in certain areas in response to atmospheric motions. Changes in the refractive index (a measure of the amount that the radar signal is bent) in the atmosphere is a major factor in the production of clear air echoes.

Regions of disturbed index of refraction occur in layers and volume forms called blobs. They may occur at any time and at any level in the atmosphere. Particulate matter and insects concentrate in area where the index of refraction is most disturbed thus complicating observations. Results from tracking such echoes can be applied to directing aircraft around turbulent areas and in a better understanding of vertical air currents, thermals, and pollution concentrations in the atmosphere.

Aeronomy

Indirect Probing of the Mesophere

Progress towards understanding of the upper atmosphere has been rapid during the space age, particularly because of the use of rockets and satellites for *in situ* measurements. Ground-based indirect probing of the upper atmosphere, on the other hand, is also providing aeronomers with basic data on the important physical parameters that are needed for the interpretation of the physical processes that take place under conditions of solar and cosmic radiation and particle bombardment. Indirect probing, as in the case of meteorology, also affords scientists the opportunity and capability of making measurements on a routine basis and during times of geophysical significance such as during periods of solar flares and geomagnetic activity, and at sunset and sunrise.

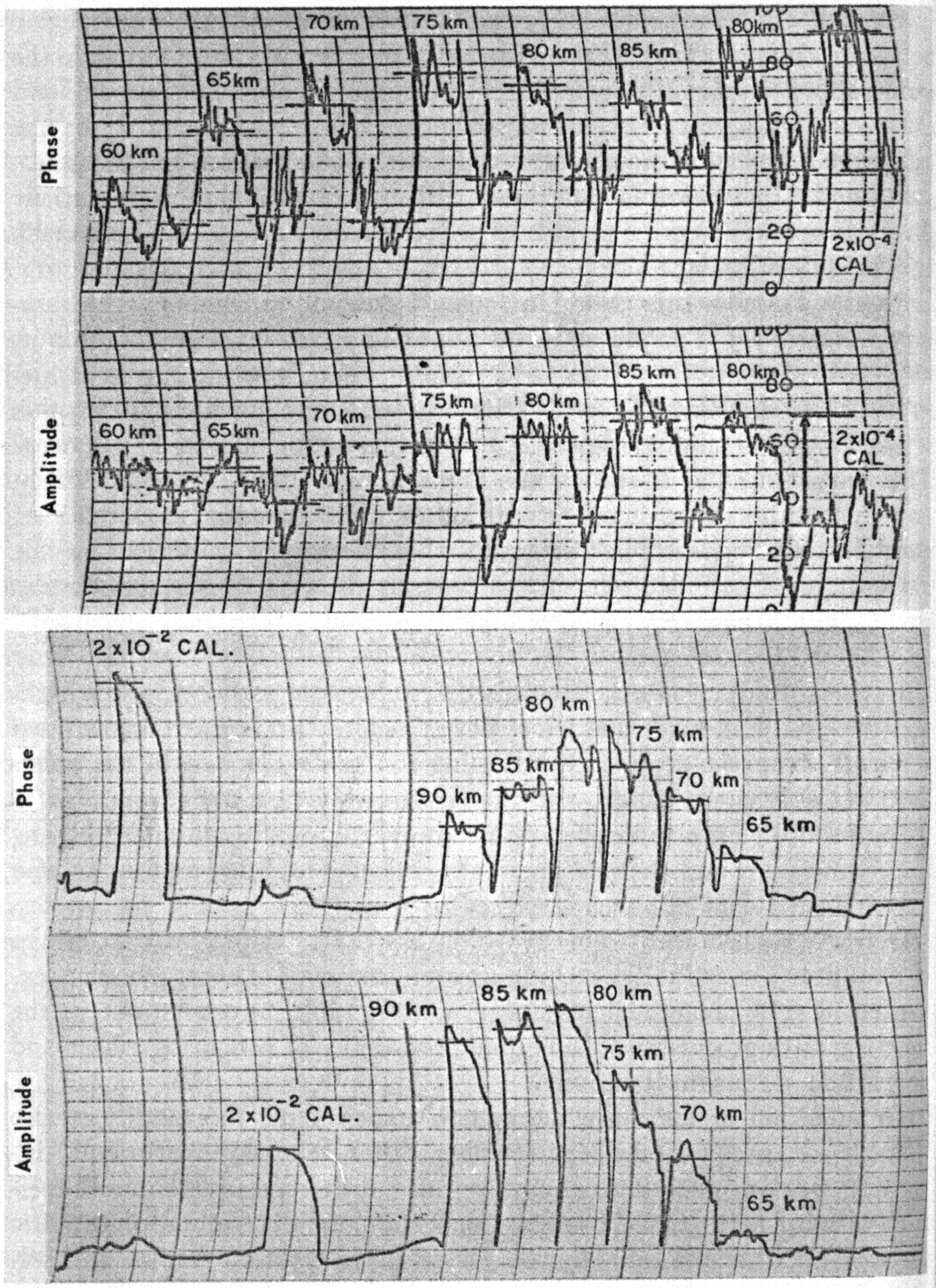
One of the least understood regions of the atmosphere is the region between about 50 and 90 km. (mesosphere). In this altitude range the atmosphere is partially ionized and undergoes complex physical and chemical transformations that are oftentimes governed primarily by the existence of minor atmospheric constituents. Contributions to the understanding of phenomena associated with this region are being made through ground-based experiments at the Pennsylvania State University and Brigham Young University.

At the Pennsylvania State University's Ionosphere Research Laboratory, Anthony J. Ferraro and Hai Sup Lee have developed a unique, high-power, wave interaction experiment that is being used to systematically measure D–region (the region where primary absorption of radio waves takes place) electron density and collision frequencies. The experiment is based on the Luxembourg effect in which high-powered radio waves interfere with other radio waves at different frequencies by imparting a fraction of their energy to electrons in the ionosphere. These electrons in turn govern the characteristics of radio waves which pass through the ionosphere and which may eventually be reflected back to earth.

In the actual experiment two pulsed, synchronous radio waves (a high-power *disturbing* wave and a low-power *wanted* wave) are transmitted vertically from the ground. By adjusting the relative timing of the pulses and by alternately turning off the disturbing wave they are able to measure both amplitude and phase interaction between the upgoing disturbing wave and the ionospherically reflected and downgoing wanted wave. These data are then analyzed to give the D–region parameters (electron and collision frequency) of interest. The improved capabilities of the high-power facility include greater accuracy of measurement, extended height range and resolution, considerable improvement in the time for data procurement and equal probability of procuring phase and amplitude data simultaneously.

In addition to the wave interaction experiment, the facility is also capable of simultaneously performing other related experiments, including partial reflections, absorption and drift measurements. The effects of solar flares on the D–region ionization, the determination of nitric oxide concentrations from diurnal variations in electron density and collision frequency, and the study of meteorological influences on D–region ionization are problems which are being actively pursued. The research is also contributing to our understanding of the many problems that beset radio communications systems that either use the ionosphere's reflecting properties for their operation or that must contend with the ionosphere's presence. The latter category includes earth-satellite and earth-space communications systems.

Another new tool for studying the upper atmosphere at stratospheric and mesospheric heights is being developed at Brigham Young University



Pennsylvania State University Photo

Top: Interaction measurements with the low power feasibility experiment. Bottom: Interaction measurements with the final high power facility.

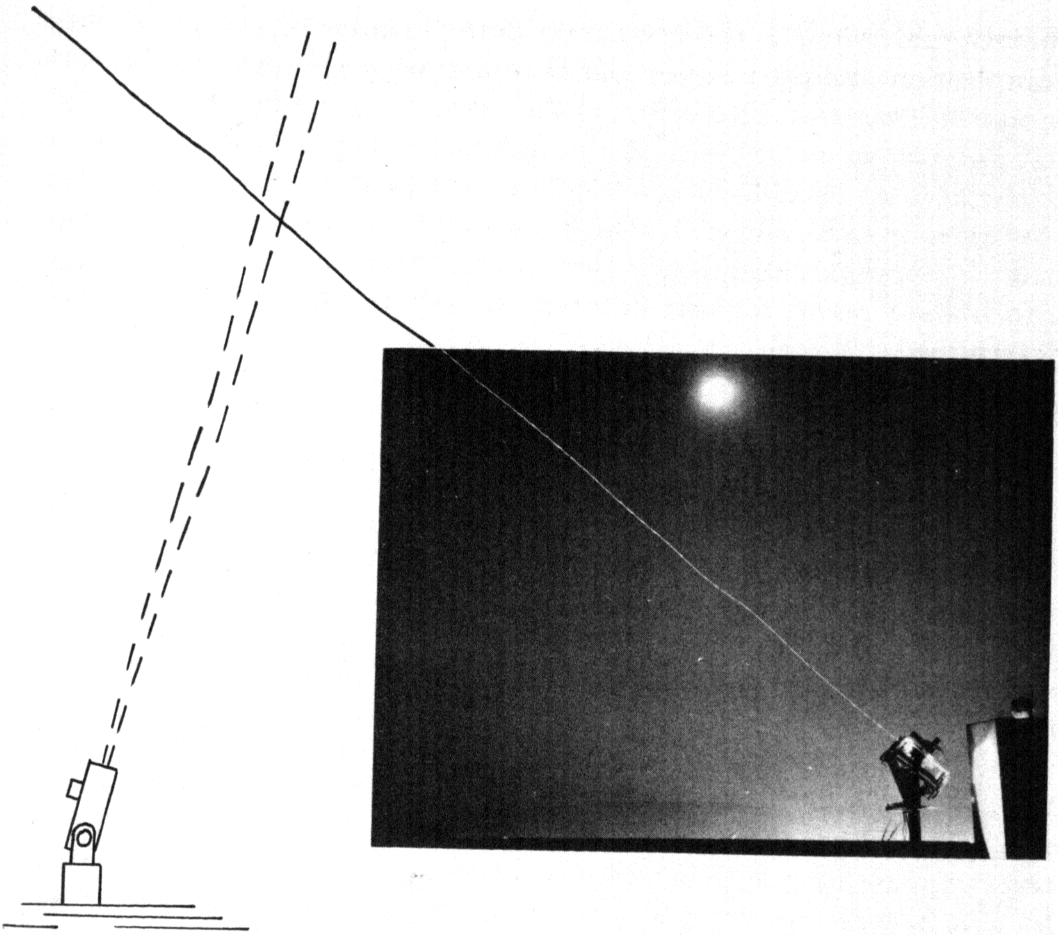


Photo Brigham Young University

Photograph of laser with schematic drawing of telescope viewing the light scattered from the laser beam by high-altitude aerosol. Telescope and laser are about 12 miles apart for stratospheric measurements.

by E. Paul Palmer. Dr. Palmer is using a bistatic laser probe (i.e., the laser is separated from the detector) to obtain data on aerosol content and particle distribution size in the atmosphere. It is suspected that many terrestrial and extraterrestrial sources of aerosol, such as volcanoes, jet aircraft exhaust, nuclear weapons and interplanetary dust, can affect the physical processes occurring in air masses. The technique may have important applications to the air pollution problem, since changes in the aerosol content and its structure at high altitudes are oftentimes sensitive to low altitude atmospheric composition and thus to manmade pollutants.

The experimental procedure is to send a laser beam to high altitude and study the light scattered by molecules and particles in the path of the beam. The scattered light is measured using a ground-based telescope, situated at various distances from the laser, depending on the altitude range that is being investigated. The significant advantage of this new system is that it provides data at more than one scattering angle,

322-215 O—68——9

thereby permitting a more accurate determination of particle density, composition and particle size distribution than is presently possible with monostatic systems. The nature of the aerosol present in a region is determined from an analysis of the light-scattering data. Each type of particle such as ice, ammonium sulfate, or silicate gives a characteristic scattering pattern. Differences between scattering from ice and from silicate, for example, have been observed and these along with the angular information permit the size distribution and densities of particles to be determined.

Solar-Terrestrial Research

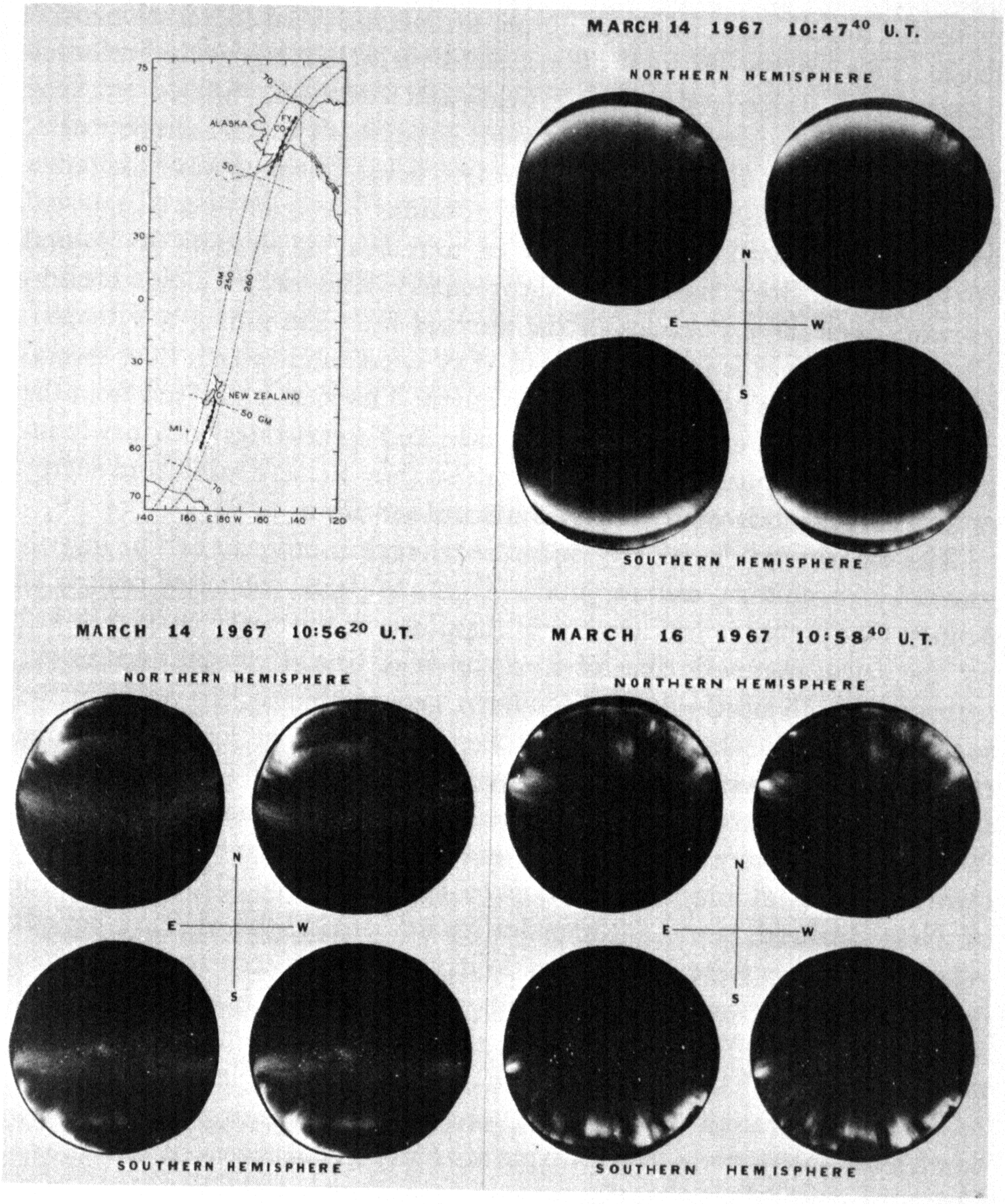
Auroras and the Van Allen Radiation Belts

The solar-terrestrial processes have their origin in the atmosphere of the sun and the solar wind of radiation that streams outward from the sun. While the earth's atmosphere shields us from the X-ray and ultraviolet radiation, the magnetic field of the earth is a barrier to the arriving solar wind. The outward edge of the barrier is the limit of the terrestrial magnetosphere.

Within the magnetosphere, a wide variety of interactions takes place with the magnetic field dragging the trapped radiation and other charged particles with it as the field rotates with the earth each day. Particles in the magnetosphere are controlled by the magnetic field lines rather than by gravitational forces or the gas pressure laws that are the dominating forces in the lower atmosphere. These magnetic particles are charged (ionized) and form a state of matter termed the plasma. The density of this plasma cannot be reproduced in the laboratory; indeed the magnetosphere is the only true plasma laboratory.

One interesting phenomenon that is now becoming better understood by the new solar wind concept is that of the auroras. These were for a long time considered to be the result of direct impact of particles from the sun, but during the International Geophysical Year it was found that an aurora is produced by electrons of higher energies than are present in the solar wind. To obtain these high energies, a natural particle accelerator must operate in the magnetosphere.

During this past year, balloon operations from Fairbanks, Alaska, made by a University of Minnesota group led by George Parks observed a discharge of high energy electrons to cause the aurora. At the same time some of the electrons were trapped by the magnetic field of the earth in regions known as the Van Allen radiation belts. It is now believed that the midnight aurora is caused by an original discharge of accelerated electrons that also fill the Van Allen belts, while the midmorning aurora represented accelerated electrons which had been retained in the Van Allen belts until that portion moved into the sunlight. These results agreed with the theoretical picture developed by Neil Brice of Cornell University.



This record of a 1967 operation shows flight plans (upper left) of the two aircraft flying simultaneously along courses at magnetic conjugate locations over Alaska and south of New Zealand, some 6,000 miles apart. Although very quiet auroral conditions prevailed during this flight, similar aurora fluctuations can be observed in the two series of photographs.

A direct investigation of the causes of the acceleration process depends on a measurement of electric fields. Electric field measurements have been historically difficult to make in the atmosphere since the motion of a radiant cloud of ions can be related to the average electric field only if certain simplifying assumptions are used. Forrest Mozer, at the Space Sciences Laboratory of the University of California, Berkeley, has been successful in measuring local electric fields by observing the developed potential across capacitor gaps during an international cooperative rocket flight. This analysis of local electric field variations has yielded information on both stable or d.c. electric fields and alternating fields.

By using data from two independent capacitor gaps on a single rocket, Dr. Mozer has found alternating electric fields having a wave character similar to an acoustic wave. Such ion acoustic waves have been suggested by theoretical work to be capable of accelerating electrons to auroral energies. Dr. Brice has shown theoretically that electric fields are important over large portions of the auroral latitudes during a substorm. This electric field is large scale, but very weak and extends over several tens of thousands of miles above the earth. The field is directed from the dawn side of the earth to the dusk side and accelerates both newly injected and previously trapped electrons so they achieve maximum energy which corresponds with observed auroral maxima.

The location of the source for the acceleration processes can be investigated by comparing aurora produced at magnetic conjugate regions or points. Conjugate points are a pair of points on the earth's surface linked by the same magnetic line of force or field line. If fluctuations in the aurora at both northern and southern geographic regions occur at the same time, then the source must be equidistant or located near the equator. Neil Davis of the University of Alaska placed auroral television systems aboard two aircraft operated for the AEC laboratories at Los Alamos and Albuquerque. These were flown simultaneously along accurate courses at magnetic conjugate locations over Alaska and south of New Zealand, some 6,000 miles apart, during the equinox periods when both areas were in darkness. Within a timing accuracy of less than a second, similar aurora fluctuations were observed from both aircraft at the same time. With this method, the acceleration process were shown to take place near the equator, some 10,000 miles out in space.

The identification of a plasma acceleration process at work in the earth's magnetosphere is important also in the discussions of cosmology. Once the auroral acceleration process is understood, this knowledge may be applied to other plasma-field systems such as the radiation belts of Jupiter, the Crab Nebula, radio galaxies, and perhaps even quasars.

Oceanography

Oceanography brings the techniques of the more classical scientific disciplines to bear upon the unique problems of the marine environment and its biota. Studies are typically interdisciplinary, and the National Science Foundation supports research studies in oceanography through the Division of Environmental Sciences' Oceanography Program, Antarctic Program, and the National Ocean Sediment Coring Program; as well as through the Division of Biological and Medical Sciences' Biological Oceanography Program. Although there are notable exceptions, productivity of marine scientists tends to be maximum when they work in close contact with a diverse group polarized around a common interest in the sea and sharing access to ships and other specialized tools that make the ocean accessible to observations.

Recent expansion of the science base has stimulated an intense national interest in the exploitation of marine resources and technology. In support of this interest, the Foundation has established the National Sea Grant Program (see pages 197 to 202 for details). Research undertaken in the Sea Grant Program is especially directed at practices, techniques, and design of equipment applicable to the development of marine resources. This at once gives more impetus to the science and increases the need for expanding our knowledge of the environment.

National Ocean Sediment Coring Program

The National Ocean Sediment Coring Program was established by the Foundation to acquire long core samples of the unconsolidated sedimentary layers in the deep oceans. The program should advance fundamental knowledge of the history and structure of the deep ocean basins and help to exploit the natural resources of the sea beds.

Phase I of the Mohole Project demonstrated the feasibility of obtaining continuous core samples of deep ocean sediments. In that effort, conventional floating oil well drilling equipment was successfully modified for use in deep water. In 1963 *Submarex* and in 1965 the R/V *Caldrill,* conducted test projects off Jamaica and Florida, respectively. The R/V *Caldrill* was successful in obtaining sediment samples 1,000 feet long.

The present Ocean Sediment Coring Program activities, focused on the deep oceans, are being managed by the Scripps Institution of Oceanography of the University of California under a prime contract with the Foundation. The university has made a subcontract with Global Marine, Inc., of Los Angeles, to provide and operate a drilling vessel to obtain the cores. The university, with the help of scientists drawn from its own staff and from many institutions and organizations throughout the country, will prepare preliminary descriptions of the core material, which then will be made available to qualified scientists for specialized studies.

Global Marine's new drilling vessel *Glomar Challenger,* at the close of fiscal year 1968, was undergoing trial operations in the Gulf of Mexico to check out the drilling and positioning equipment. Some of the positioning equipment was transferred to this project from the Mohole Project. The ship will be able to collect samples in depths of water up to 20,000 feet and with total core lengths up to 2,500 feet, depending upon conditions. In the Mohole Project it was planned to penetrate the subsedimentary crystalline basement rocks and drill to the earth's mantle. It was, therefore, necessary to be able to withdraw and replace a worn drill bit and reenter the hole. In contrast the present program will be concentrated on the sediments and hole reentry is not planned. Drilling and coring will continue to 2,500 feet or until the drill bit is worn out,

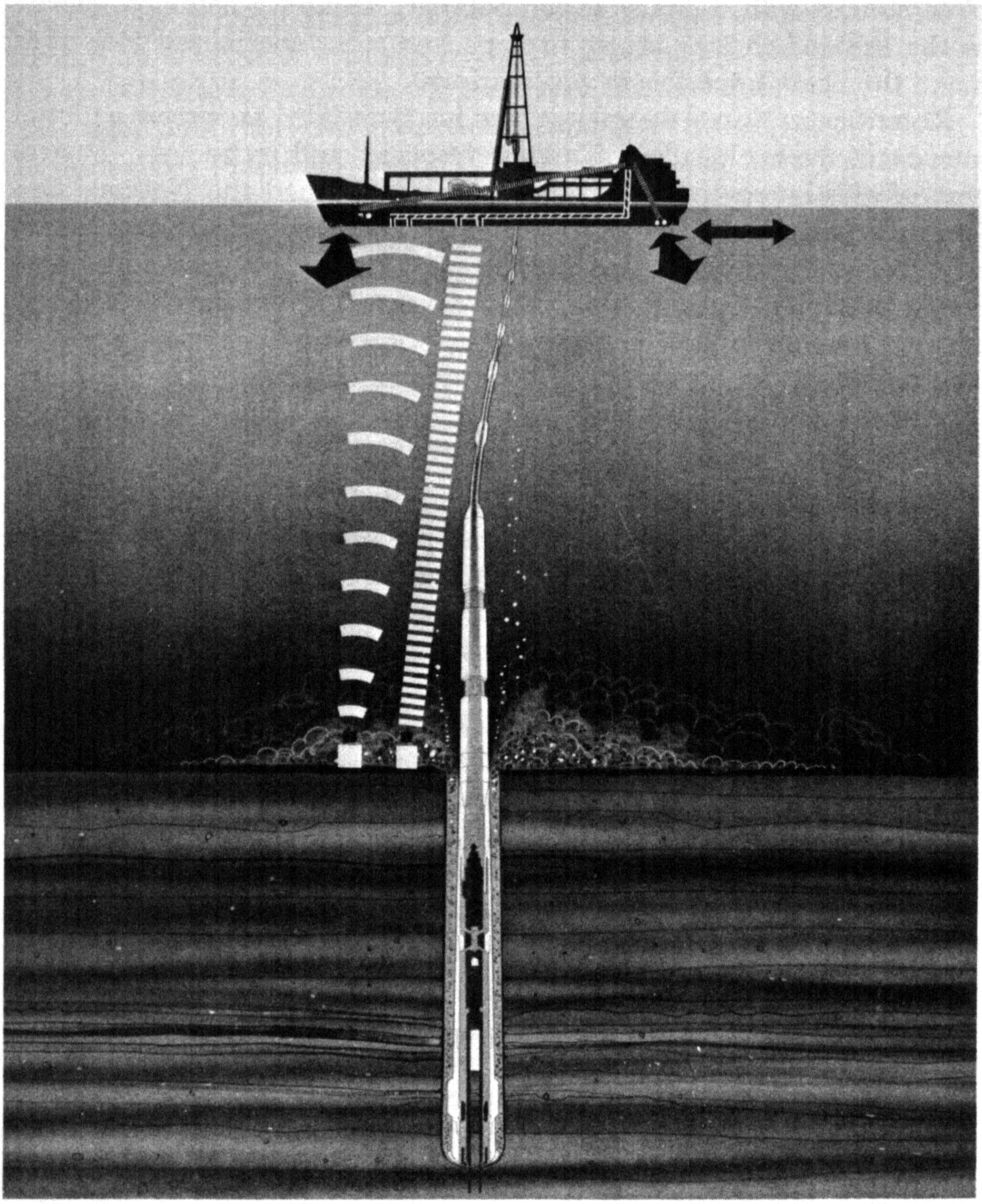


Photo Scripps Institution of Oceanography

This drawing illustrates "dynamic positioning" concept which will enable the *Glomar Challenger* to remain precisely on station while drilling in water depths up to 20,000 feet. Dynamic positioning uses a computerized system of pulses from acoustic beacons on the ocean floor which are picked up by a ship-mounted hydrophone array, fed into a computer, and translated into corrective action by propulsion units which automatically keep the ship on station. Drawing also shows the flexibility of the drill string which weighs 400,000 pounds at a depth of 20,000 feet.

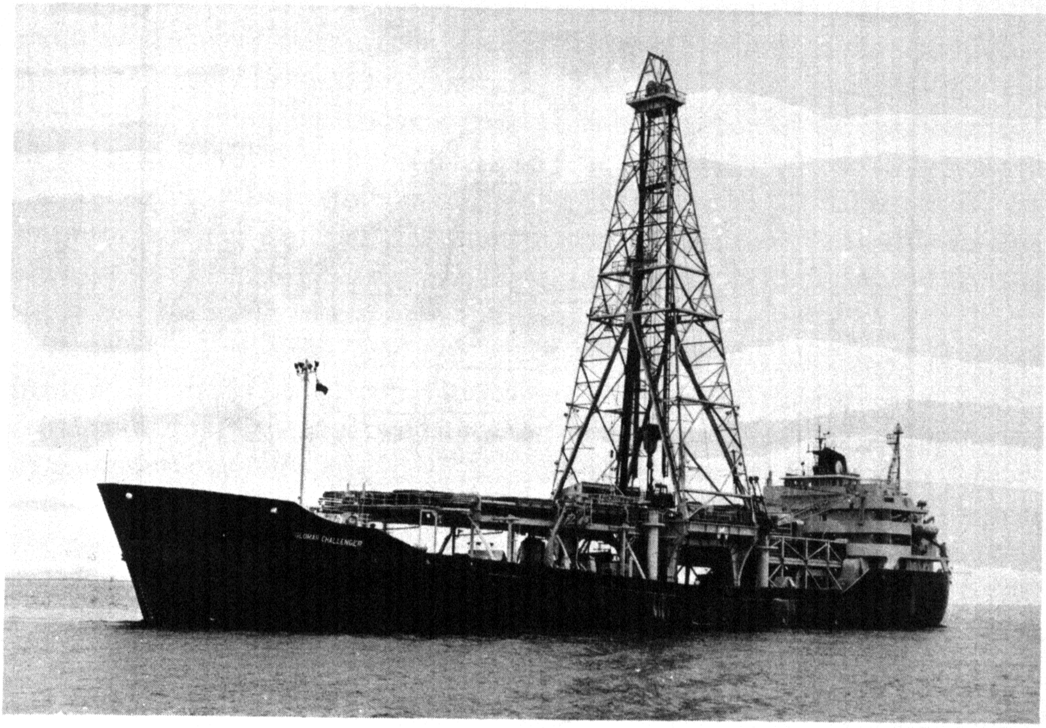


Photo Scripps Institution of Oceanography

New drilling vessel *Glomar Challenger* underwent trial operations in the Gulf of Mexico during the summer of 1968. The ship will be equipped to collect samples in depths of water up to 20,000 feet, and with total core lengths up to 2,500 feet, depending upon conditions.

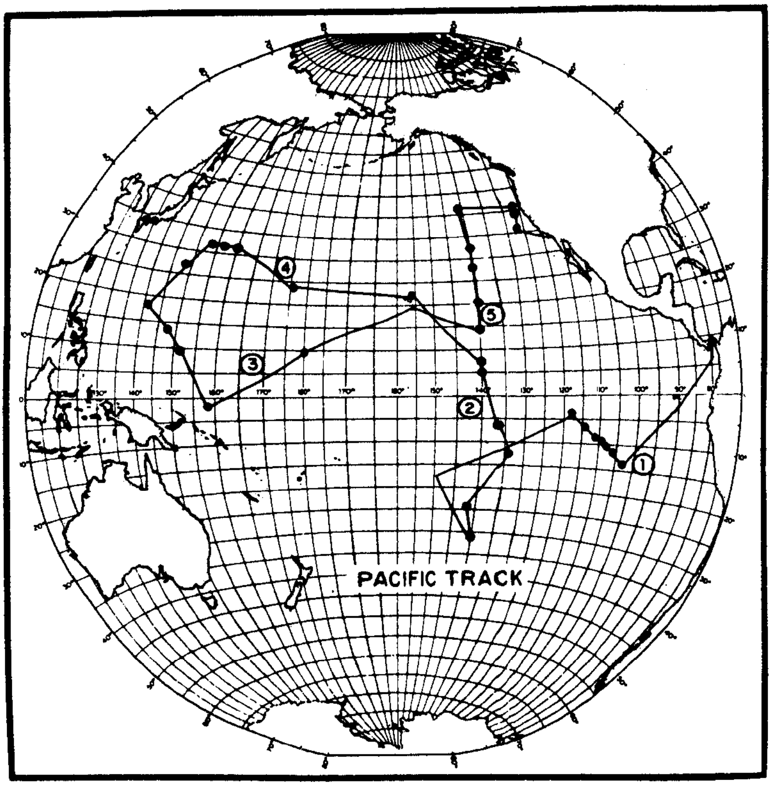
at which time the ship will move to a new location and work will begin on a new hole.

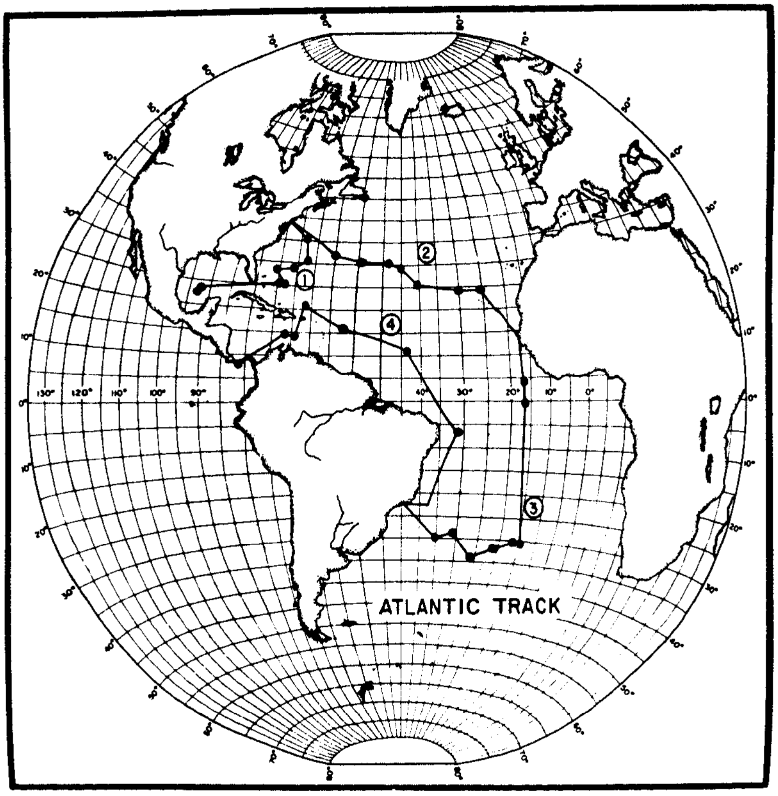
Planning for the program has been carried out with the aid of panels of scientists drawn from both academic and commercial organizations. These panels, which are advising the University of California, have been convened under the auspices of the JOIDES organization (Joint Oceanographic Institutions for Deep Earth Sampling), and have formulated many of the plans. Two panels were convened to suggest the tracks and sites for drilling in the Atlantic Ocean and the Pacific Ocean. In addition, special panels were formed to advise on special preliminary studies and descriptions of the recovered core samples, including Panels on Sedimentary Petrography and Chemistry, Paleontology and Biostratigraphy, Igneous and Metamorphic Petrography, Paleomagnetism and Geochronology, Geothermal Gradient, and Geophysical Logging. The planned location of the selected tracks for drilling in the Atlantic and Pacific Oceans are shown on the maps on page 120.

Basic Research Projects

Chemical Interaction Between Marine Organisms

Chemical oceanography has been slow to develop because of the difficulty in measuring concentrates of chemical compounds and treat-





Photos Scripps Institution of Oceanography

Proposed tracks and sites for drilling operations to be conducted by the *Glomar Challenger* under contract with the National Science Foundation. During the planned 18-month sea-going phase of the project, *Challenger* will travel approximately 40,000 miles to drill holes in the ocean floor at water depths up to 20,000 feet.

ment of chemical reactions in such a complex medium as the sea. Also, many different chemical reactions are constantly taking place within the same water volume and there is frequently interaction by the involvement of living organisms in chemical processes, by important exchanges with the atmosphere and with the sediments of the ocean floor. However, an impressive array of the sophisticated tools has become available to the chemist in the last decade, and these are rapidly being adapted to the study of chemical processes in the ocean.

Illustrative examples are the programs under the direction of Max Blumer of the Woods Hole Oceanographic Institution aimed at better understanding of the organic chemistry of the ocean. Organic compounds in seawater owe their origin almost entirely to the activities of living organisms. The fate and quantity of the organic material depends upon the production and consumption by the organisms. It is now known that the standard nutrients such as phosphates, nitrates, and silicates are not enough for marine life and that vitamins, particularly vitamin B–12, and other compounds in minute quantities may also be required. Many organisms produce nutrients needed by others and remove or add inhibitory substances as well. Several organisms are also known to produce antibiotics.

The Woods Hole chemists have shown that pristane, one of the most ubiquitous hydrocarbons in the marine environment, is formed by copepods (minute crustaceans) from phytol in their food. This was learned by radioactive tagging of the diet (predominantly zooplankton, i.e., floating or weakly swimming organisms) of laboratory-raised Calanid copepods. The precursor to pristane is shown to be a plant acid which, as well as pristanic acid, has been isolated in recent marine sediments.

The Woods Hole chemists also obtained the structure of three olefinic hydrocarbons from the Calanid copepod providing a tool for the further study of the dynamics of the marine food chain. It was found that the hydrocarbons of the zooplankton pass unaltered through the digestive tract of the basking shark and are deposited in the liver. Analysis of the composition is indicative of the food source and feeding grounds of the shark.

Regional variations in the hydrocarbon assemblages of mixed phytoplankton (floating plant life) have been demonstrated, and the Woods Hole scientists have begun to collaborate with the Bureau of Commercial Fisheries scientists to see if the reflection of this in hydrocarbons of fish can separate the three distinct populations of herring believed to inhabit the Gulf of Maine.

Dr. Blumer's program has also discovered that a marine invertebrate is attracted to chemicals, when present in extremely low concentration, which are emitted by an organism on which the invertebrate preys. The structure of the stimulants is being studied and the investigation is being extended to other organisms. The extension of this study holds possibilities for attraction or repulsion of beneficial or noxious species of marine life, for bioassay at great dilution, and for understanding the modes of communication and interaction between marine organisms.

Dating of Sediment Cores and Seismic Reflection Horizons in the Ocean Floor

Major advances continue to be made on studies of the ocean seabed underlying 70 percent of the globe and obviously holding great future economic potential. Two of the most promising recent developments in the exploration of the seabed are the dating of sediment cores from the ocean floor by paleomagnetic stratigraphy, and the identification of seismic reflection horizons by obtaining cores from the ocean floor.

It has now been well established by studies of remanent magnetism on lava sequences, dated by the potassium-argon methods, that the earth's magnetic field has reversed itself several times in the past few million years. The date of the last reversal of the earth's field is now established at 700,000 years. Since rate of sedimentation in the major ocean basins is in the order of 1 cm. per 1,000 years, this reversal is applicable to dating cores which can be taken with the standard piston coring equipment on research vessels, These piston cores average about 10 meters in length, reaching a maximum of 25 meters in some of the softer sediments. Studies of the rates of sedimentation for all oceans using these magnetic reversals are now underway. A reversal of the magnetic field to the normal (present-day) direction took place about 3.5 million years ago, and about 2.5 million years ago magnetic direction again turned to a reversed field, followed by the last reversal to normal about 700,000 years ago.

In areas where sediment accumulation is very small and these earlier reversals are reached in the cores, any changes in sedimentation rates can also be determined. This method has been applied successfully to establish the age of the first evidence of glacial detritus and of carbonate fluctuations which are related to water temperature, and thus determine when Antarctica was first glaciated. These studies in Antarctic waters by Norman Watkins at Florida State University and Neil Opdyke of Columbia University have shown that Antarctica became ice covered at least three million years ago.

Seismic reflection profiling from surface research vessels has now covered sufficient ocean areas so that many reflection horizons can be correlated over large distances. In the northwestern Atlantic Ocean, John Ewing and others of the Lamont Geological Observatory of Columbia University have identified major subbottom reflecting horizons. Two are designated the A and B horizons, in order of increasing depths beneath the ocean floor. These reflection horizons are normally far too deep for piston cores to reach, being generally between 500 and 4,000 meters below the ocean floor. It has been possible, however, to sample them directly in out-crop areas, one of these being located northeast of the island of San Salvador. Horizon A represents an abyssal plain probably deposited at the end of the Mesozoic era, which began 225 million years ago and ended 70 million years ago. Cores from horizon B contained lower Cretaceous, which began 135 million years ago and ended 70 million years ago, sediments over a sandstone of unknown age. If these cores are representative of the regional depositional environments of their respective horizon, an area of sea floor at least 600 miles east of the present continental shelf margin was once a shallow sea on a continental platform that subsided about 5,000 meters during the Cretaceous period.

Two horizons quite similar to A and B are also found in extensive areas of the Atlantic, Pacific, and Caribbean. If these are related to the horizons A and B found in the northwest Atlantic, horizon A must represent an ocean-wide change in sediment deposition at the end of the Mesozoic era, and horizon B could represent broad areas of sunken continental margins once covered by shallow seas.

Deep Boundary Currents in the Western South Pacific

Oceanographers have long known that the deep water in the North and South Pacific must come from the Atlantic, entering the Pacific from the south. The worldwide distribution of temperature and salinity of ocean water admits of no other interpretation, and points to the North Atlantic and the Weddell Sea off Antarctica as the areas where deep and bottom waters originate, that is , acquire their characteristics. The prevalent concept has been of broad sluggish flow in the deep waters replacing water that diffuses upward into the surface water layer. Direct measurements have been unavailable and theories of the dynamics uncertain.

Henry Stommel and Arnold Arons, in papers published in 1958 and 1960, presented a simple linear theory of the deep water circulation which required that the inflow to the Pacific basin be confined to a narrow western boundary current along the Tonga-Kermadec Ridge north of New Zealand. It also required that there be broad slow southward flow over most of the basin, thus increasing the required strength of the boundary current. This picture of source water moving in a narrow current when it has the full width of the South Pacific within which it might flow seemed remarkable in the light of previous ideas, and in the absence of collaborating evidence, there was understandable skepticism as to the validity of the simple theory.

Four scientists from four institutions, using the research ship of the Antarctic Research Program, USNS *Eltanin,* undertook to collect the necessary evidence to check the theory. They were J. L. Reid, Scripps Institution of Oceanography; H. M. Stommel, Massachusetts Institute of Technology; E. D. Stroup, University of Hawaii; and B. A. Warren, Woods Hole Oceanographic Institution. Lines of oceanographic stations were occupied in two trans-Pacific crossings along the latitude lines of 43° 15′S and 28° 15′S. Precise measurements of temperature, salinity and dissolved oxygen content were made in vertical series at each station and the stations were spaced more closely together in the western part of the crossings.

Flow patterns can be deduced from the patterns of distribution of the physical variables and the mass (density) field can be computed from the temperature, salinity, and pressure (depth). From the density distribution and position on the rotating earth, computations can be made of current velocity and transport.

Clear evidence was found of northward flow in both crossings. East of New Zealand the current was some 500 kilometers in width and, close against the Tonga-Kermadec Ridge, it was confined to a narrow band about 70 kilometers wide, in good agreement with the simple theory being checked. The computations of flow always have an element of uncertainty because a reference depth must be picked at which the current is assumed to be zero. Flow relative to that depth is what is actually computed. In the northern section, the computed flow to the north between depths of 2,500 meters and 4,500 meters amounted to from 8 to 12 million cubic meters per second. This compares to a value of 12–15 million cubic meters per second, which B. Bolin and Stommel estimated in 1961 on the basis of a steady state budget of heat, mass, salt, and radiocarbon.

Dissolved Organic Matter

Apart from local concentrations, such as in fishing grounds and plankton blooms, most organic matter in the sea is in dissolved form. In inland waters the proportion of dissolved to particulate organic matter is even higher than in the ocean. Being colorless, odorless, and tasteless to man, at least in the normal state of high dilution, this huge reservoir of edible carbon did not attract much attention until methods for its analysis became available. The chemical nature of the material is now being studied by chromatography, while its movements into and out of organisms are followed by means of radioactive and stable-isotope tracers. Obviously such material can nourish bacteria and algae; the idea that it can nourish animals is receiving intensive study after a half-century of denial and doubt.

Dissolved organic matter is an extremely active reservoir. Many animals draw on it directly, by absorption, thereby obtaining certain compounds that were previously thought to come entirely from particulate food. Release of such compounds occurs, eventually, when an animal or its predator dies and a carcass is broken down by bacterial attack. Ordinarily, a faster route is release from food that is eaten but unassimilated and captured food that is rejected uneaten. Many animals, especially molluscs and the smaller zooplankton, "waste" (and solubilize) much organic matter in this way. A previously undetected route, by which dissolved compounds are also added to the reservoir, is exudation, or leakage from the living body.

Robert Johannes of the University of Georgia and his collaborators have now shown that the leakage of dissolved compounds by animals usually exceeds the absorption. It follows that the flux of organic matter into and out of the reservoir is faster than was assumed, even though the net gain to an animal may be zero or negative. Some animal populations studied by Johannes could theoretically replace the entire reservoir of free amino-acid nitrogen in their water column at a rate of once per month; the flux of carbon appears to be appreciably faster than that of nitrogen. The carbon exuded in soluble organic form is a large fraction of that respired, and released in inorganic form as carbon dioxide. More surprisingly, the carbon so leaked by animals is a substantial fraction of the carbon fixed during photosynthesis by plants in the same environments. John Sieburth of the University of Rhode Island has been studying seaweeds in the same way, and finds that some of them exude almost as much organic carbon as they fix.

In Johannes' experiments, the smallest animals leaked more dissolved organic matter than large ones, and marine animals were leakier than true freshwater animals of the same size. Marine animals in fresh water (like Sieburth's marine seaweeds in rainwater) are notably leaky. Estuarine animals, however, tend to conserve their organic matter (as they do their salts) as the medium is diluted.

As one result of these investigations, a new world of waterborne odors is opening. Aromatic compounds, such as the polyphenols exuded by brown seaweeds, presumably attract some species of animals and repel others. The homing salmon, responding to specific substances exuded by pondweeds, is a famous example of the use of odor cues at sea. At least one predator, a freshwater flatworm, is now known to detect specific amino acids exuded by its prey.

Though less abundant than the salts, the organic compounds in seawater are no less important to oceanography. Few salts leave the ocean after delivery; organic compounds, being actively metabolized, take part in a two-way exchange of carbon, hydrogen, oxygen, and nitrogen between the ocean and the atmosphere. Without organic compounds, the "foaming brine" would not foam so readily; without spindrift, the air-sea interface would not yield aerosols, which are now believed to carry chloride (but not sulfate) to the interiors of all continents. The same aerosols may trap gases, such as hydrogen sulfide, and transport them from sea to air to land. Because of its yellow color, dissolved organic matter is the main cause of the opacity of coastal waters, and of lakes, as compared with the wide blue sea.

Specialized Oceanographic Research Facilities

For the past 9 years the support of oceanographic facilities has constituted a vital part of the Foundation's total effort with respect to the field of oceanography. During these 9 years, support totaling approximately $35 million has been provided to 20 U.S. institutions actively engaged in oceanographic research. (Figures do not reflect costs associated with R/V *Hero,* see page 89.) These institutions are presently operating 21 major ships (100 to 213 feet in length) and 14 smaller vessels (50 to 100 feet). Exclusive of support for operating costs, more than $15 million has been granted for the construction, conversion, or improvement of half the fleet of 35 ships and smaller vessels. Nearly $15 million has been provided for construction or improvement of shore laboratory facilities and the remaining $5 million for piers and related buildings.

Although funds were not available in fiscal year 1968 to initiate a ship replacement construction program, a first step was taken in that direction with support for the final design phase of a prototype ship of intermediate size (about 170 feet). The design is based on the general lines of an open-deck supply boat, which lends itself to the use of removable modular laboratory units and interchangeable equipment arrays. In addition to the characteristic of increased flexibility of use, the design is expected to be less costly to construct and to operate than a comparable sized ship of conventional configuration.

Support was also provided for the acquisition of a 54-foot vessel to be used by oceanographers at Nova University for research in the Gulf Stream. Funds were also provided for modification of two existing vessels R/V *Vema,* operated by Lamont Geological Observatory, and R/V *Acona,* operated by University of Alaska.

Funding for these four ship-related support actions totaled $730,000. Other support for oceanographic facilities in fiscal year 1968 included funding ($960,800) of the final construction phase of the new pier for the Woods Hole Oceanographic Institution, partial support ($452,700) for a new Marine Science Center at the University of Miami Institute of Marine Sciences, and partial support for a new radiocarbon and tritium laboratory at Scripps Institution of Oceanography.

Earth Sciences

Foundation support for research in the earth sciences includes geological investigations and physical and chemical studies of the earth and the materials of which it is composed. The history of the earth has been marked by extensive and profound processes of change, and the nature of these changes, their causes and consequences, are of interest to scientists of many disciplines. Even in the span of a single lifetime, significant changes are observable, and a better knowledge of these processes can lead to increased understanding of their relevance to human society.

When we look at the diversity of the earth's features—earthquakes, island arcs, volcanoes, deep ocean trenches, and mountain ranges—it seems hard to believe that any simple theory can be found to help us understand our complex earth. However, in recent years the acquisition of vastly improved seismograph data has made possible the formulation of a unifying theory for many of the large-scale movements and processes within the earth. This theory, called the "new global tectonics" has been proposed by Jack Oliver, Bryan Isacks, and Lynn R. Sykes of the Lamont Geological Observatory of Columbia University and relates the concepts of continental drift, sea-floor spreading, midoceanic ridges and transverse faults. It is only in the last decade or so that the midocean ridge system and the great transverse faults of the ocean basins have been recognized and mapped, and the remarkable system of linear magnetic anomalies, symmetrical to the ocean ridges, has been delineated. These magnetic anomalies in the oceans, correlated with the dated sequence of reversals of the earth's magnetic field obtained on the continents, can be matched on either side of the ocean ridges to measure the actual rate of sea-floor spreading.

According to the new global tectonics, a mobile near-surface layer about 100 km. thick, the lithosphere, plays a key role in seismic events. This lithosphere, which generally includes the crust and uppermost mantle of the earth, has significant strength. Underlying the lithosphere is the asthenosphere, a layer of low strength which extends from the base of the lithosphere to a depth of several hundred kilometers. The new global tectonics theorizes that the lithosphere of the earth consists of about half a dozen large mobile plates which are bounded by ocean ridges, transverse faults, island arcs and arc-like structures. These plates are being spread apart at the worldwide system of ocean ridges where new surface materials ascend. The plates slide horizontally past one another along the transverse faults, and then converge at the island arcs and arc-like structures, where they plunge deep into the earth. Thus the crust of the ocean floors is continually being created in some areas and absorbed in others.

Oliver, Isacks, and Sykes by their studies of the worldwide distribution of earthquakes; the direction of movement along faults during earthquakes; and investigations of the earthquakes in the Tonga-Kermadek arc in the South Pacific north of New Zealand provide a strong basis for the theory they propound.

Data collected in recent years show that the ocean floor is not a flat, even surface with layer on layer of sediment eroded from the continents and deposited evenly. Instead, there are ridges, more or less linked together, extending throughout the oceans of the world.

These midocean ridges have certain features which suggest that they are the site for emplacement of new, hot material generated at greater depths. The ridges have a higher heat flow than other portions of the ocean floor. Also, earthquake swarms, i.e., frequent small shocks over a specific area, are found most frequently in ridge areas, and indicate eruptive activity.

Since it appears that new hot material is coming up along the ridge lines, where does it go? Two converging lines of evidence, radioactive dating and the magnetism of sea floor rocks, suggest that material rising along the midocean ridges is spreading outward from the ridges and toward the continents.

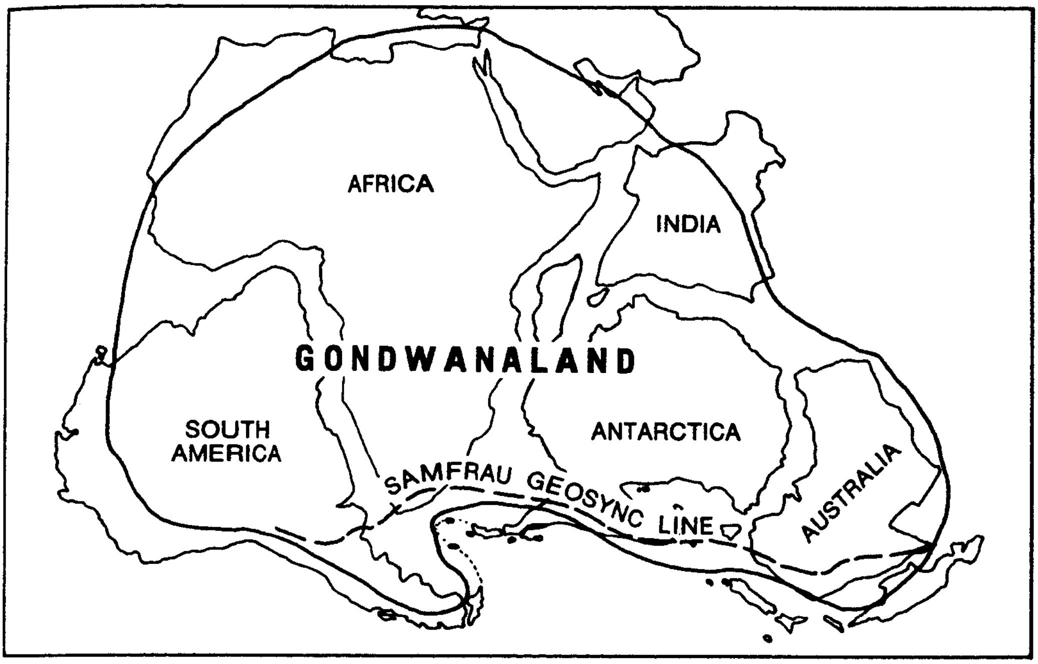
In contrast to the linear patterns of topography and magnetism in regions of rising ocean floors, arc-like patterns are frequently found in regions of sinking ocean floors. Associated with island arcs or similar arc-like features are the major ocean deeps of the world; nearly all the world's deep (more than 300 km.) and intermediate depth earthquakes as well as most of the shallow earthquakes; volcanoes and other movements of the earth's crust; seismic sea waves (tsunamis); and unusually low earth gravity readings.

In addition to these features, a zone has been discovered beneath island arcs north of New Zealand in which earthquake waves travel at greater speed and are stronger than other locations of comparable depths. This anomaly is explained, tentatively by the Lamont Observatory scientists, as the result of the descent beneath the island arc of a mobile strong, near-surface layer or slab about 100 kilometers thick (the lithosphere) into a layer of effectively no strength (the asthenosphere).

This new concept of global tectonics as outlined briefly above should be far-reaching in its effect on future investigations by providing a basis for understanding deep earthquakes in different arc areas; by linking seismic activities in widely separated regions; by correlating seismology and other geophysical fields relating to the interior of the earth; and by improving the designs for model experiments for predicting earthquake activities. It is expected that information developed in connection with the National Ocean Sediment Coring Program (see page 117) will be extremely valuable in assessing this theory.

Gondwanaland

In the early part of the 20th century, Alfred Wegener of Germany and A. L. DuToit of South Africa conceived of and speculated about continental drift. They postulated an ancient, large southern land area, Gondwanaland which was made up of what is now India, Australia, Antarctica, and parts of southern Africa and South America. This continent is supposed to have fragmented and drifted apart since the Cretaceous Period about 150 million years ago.



Early attempts to correlate geologic strata between continents were successful. However, this age correlation was not conclusive in regard to continental drift as each of the similar fossil animals or plants found in various fragments of Gondwanaland could conceivably have been carried across oceans as spores or have migrated through the oceans in larvae or adult form. Firm evidence for the breakup and drift of Gondwanaland has been meager until the last decade, and, as a result, interest in continental drift remained dormant in the United States until recently.

A major effort has been made by earth scientists working in and around Antarctica to find evidence of the relationship of Antarctica to the rest of Gondwanaland and regarding the theory of continental drift. Field investigations of the geological structure of Antarctica, particularly in the area of the Marie Byrd Land Coast, now show that tectonic trends are of the same age and would line up with trends in South America and southern Africa, if the continents were brought together.

It is known from several studies that continental glaciation took place throughout Gondwanaland during the same time interval, previous to the Cretaceous Period. Research carried out by John Crowell and Lawrence Frakes of the University of California, Santa Barbara and Los Angeles campuses, found that the pattern of ice movement, location of centers of accumulation, and the relationship between the glacier termini and the sea give the consistently logical pattern that the tectonic trends required.

The determination of paleomagnetic directions in oriented samples of rocks of various ages from different parts of Antarctica also reveals the location of Antarctica in relation to the South Pole at different times in

322-215 O—68——10

geologic history. Sufficient paleomagnetic data are now available to show that the continent has moved in relation to the South Pole in approximately the pattern that is indicated by the other evidence, pointing to the breakup and drift of Gondwanaland.

During the Antarctic summer of 1967–68, a piece of fossilized jawbone from a type of large fresh-water amphibian of the sub-class Labyrinthodontia was found in the Transantarctic Mountains by geologists carrying out research on the stratigraphy and petrology of the area under Peter Barrett of Ohio State University. Fossil Labyrinthodonts have been found in other parts of Gondwanaland, in rocks of the same age. However, this was the first time that fossil remains had been found of an animal that could not have reached what is now Antarctica across salt water.

It is now evident that Antarctica was joined to the rest of Gondwanaland at the time the Labyrinthodonts were evolving. Because of this, E. H. Colbert of the American Museum of Natural History, who is studying the Antarctic Labyrinthodont bone, has described its discovery as one of the most important fossils to be found in the 20th century.

ENGINEERING

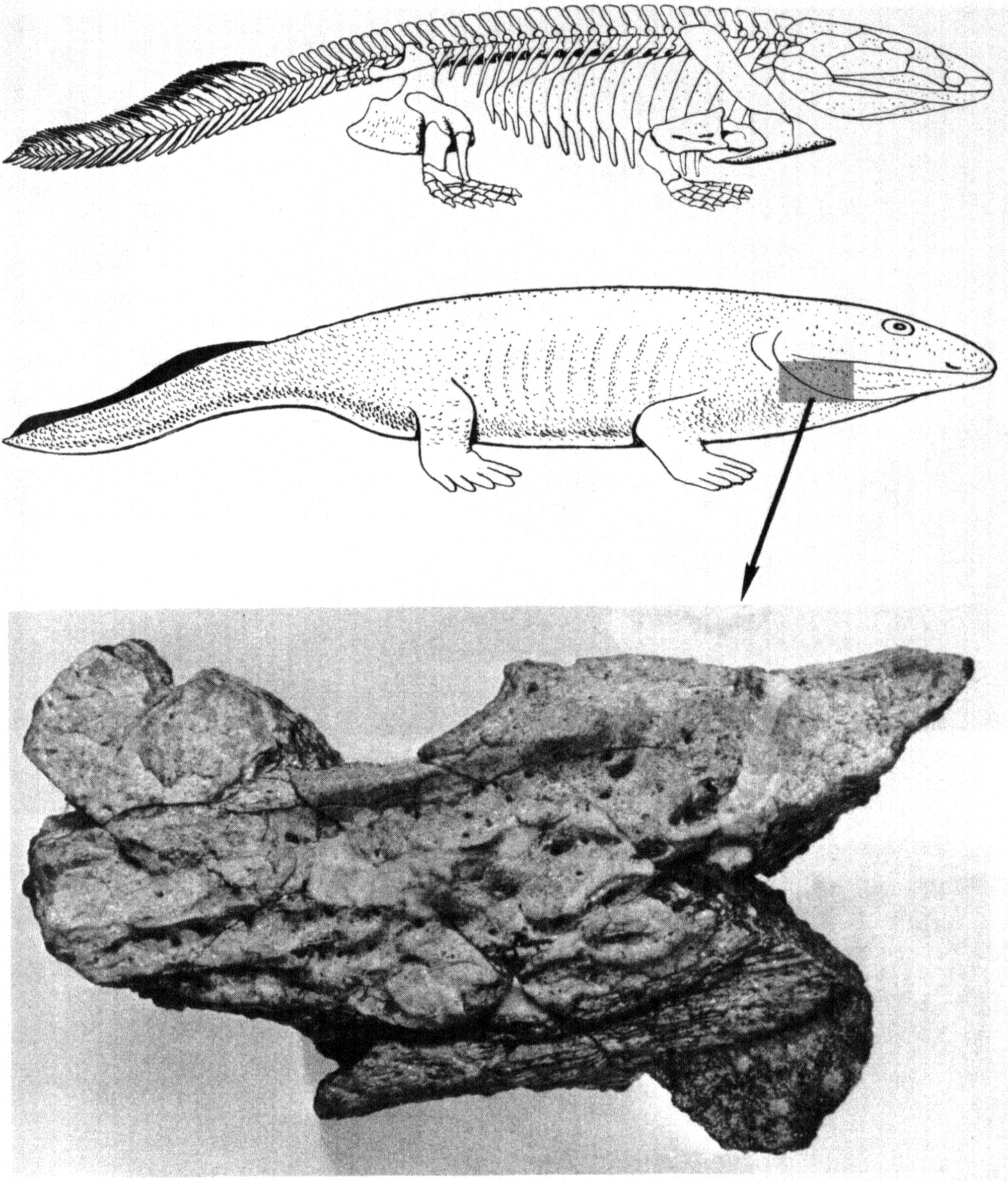
Engineering research during fiscal year 1968 produced major advances across a broad front, with a number of significant developments bearing on critical problems faced by society. There has been an increased trend toward applying engineering methods and knowledge to interdisciplinary areas, and to incorporate into engineering analyses the social-political-economic aspects of many problems, as in the case of systems analyses of urban problems.

Members of engineering faculties are no longer primarily practitioners of the art of engineering, as they were less than 20 years ago. Within the last decade they have become primarily productive research scholars and experimenters. Engineers are now prime contributors to the more classical fields of the physical sciences, as well as to the applications of science to technological development. The output of Ph. D. engineers has increased from about 600 11 years ago to a rate of 2,900 per year at present. The number is expected to reach 6,000 per year by 1974.

Engineering programs in the Foundation are extensive, and it is impossible to describe the variety of research projects under way in the space available. A few projects which are concerned with current problems of society mainly in the area of building construction and testing are described below.

Buckle-Shell Buildings

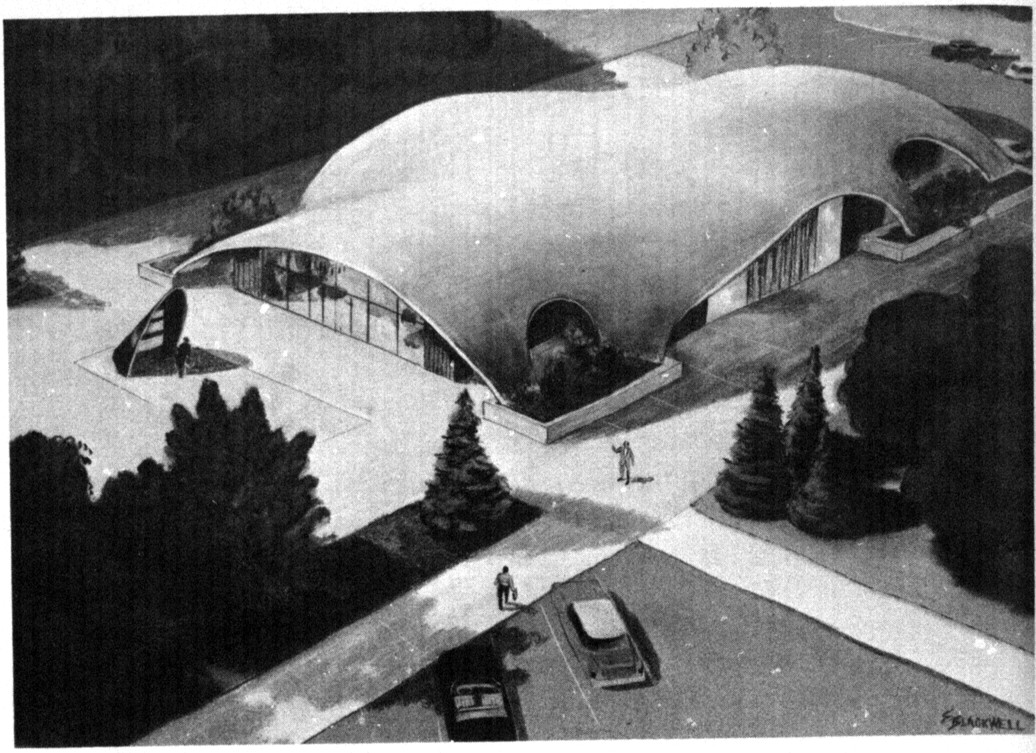
Laboratory experiments with a new construction process have demonstrated the feasibility of erecting a building rapidly and economically by buckling or bending a thin, flat, lightweight, plastic plate into a desired roof shape.

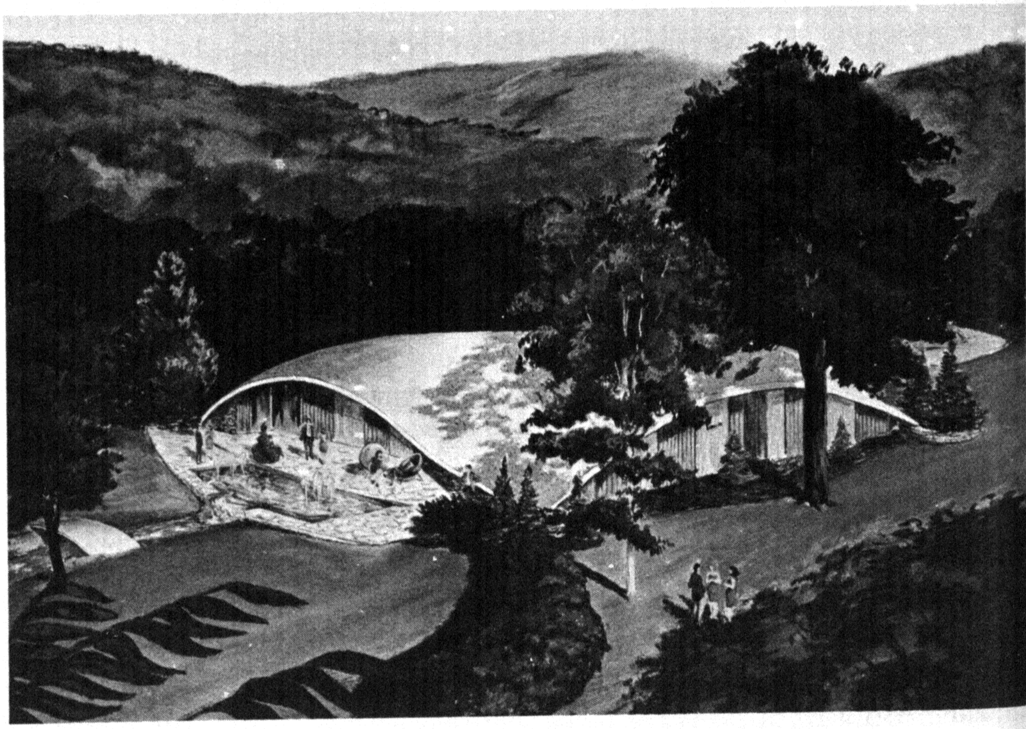


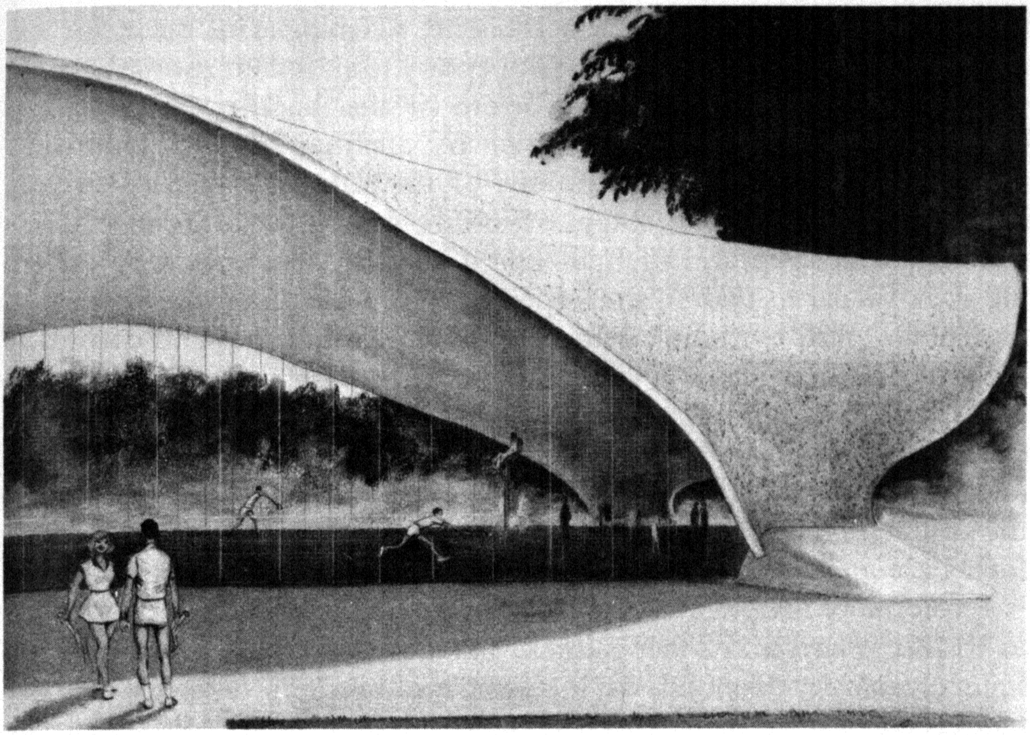
The artist's representation of a related type of Labyrinthodont from the Arctic shows the approximate location of the fossilized jawbone found in Antarctica.

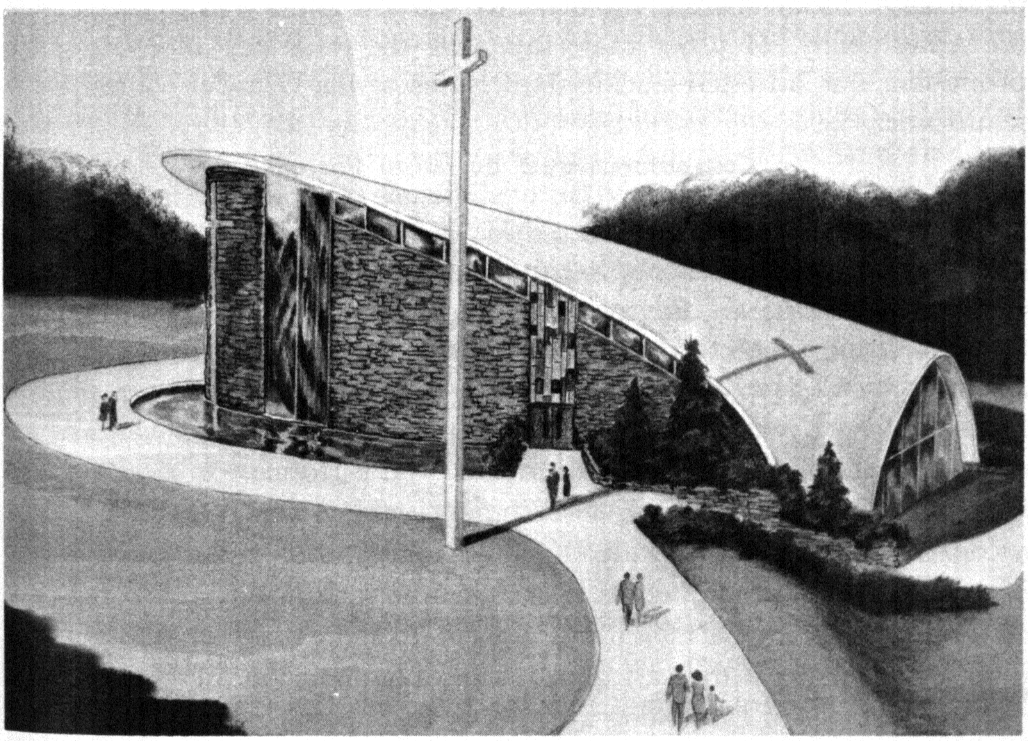
At Purdue University, Joseph Waling conceived the idea and V. J. Meyers has been directing a theoretical analysis and further development of the process, first with the assistance of the Dow Chemical Company and later under a grant from the National Science Foundation. Results of research to date indicate that the process has great potential for producing buildings as large as sports arenas or airplane hangars. It also shows promise as a means for building low-cost housing, as well as intermediate-size structures such as school buildings, office buildings, or covers for recreational areas such as picnic shelters and swimming pools.

As a first step in developing a "buckle-shell," a flat plate consisting of a relatively soft plastic material, such as foamed polystyrene or ure-


BLACKWELL







Photos Purdue University

These artist's conceptions illustrate some of the many potential applications for the buckle-shell process, including a church, an office building and recreational facilities.

thane, is assembled. A thin, less resilient, stiffening skin, made for example of fiberglass impregnated with epoxy resin, is then sprayed on the upper surface of the plate either before or after buckling. The plate is buckled upward from its flat position by applying force inwardly at a number of positions on the perimeter of the plate. The buckled surface is sufficiently distorted to obtain adequate double curvature to provide the shell with structural strength and a pleasing appearance. A stiffening skin, similar to that on the upper surface, is placed on the under surface of the shell to complete the buckle-shell sandwich. This extremely light and rigid structure is, with the proper choice of materials, weatherproof, and possesses innate insulating qualities. With the roof and bearing supports in place, the installation of curtain walls containing doors and windows is a fairly simple task. By varying the shape of the flat plate, the orientation of the forces applied, or the number of points at which forces are applied, different forms of buckle-shells may be produced.

Exploratory investigations have been completed with models as large as 18 feet square, and 2 inches thick. Various-shaped plates were tested—square, triangle, diamond, circle, cross, and free-form. Tests proved the models could be developed to withstand a load of 80 pounds per square foot, which is about double the requirement of most building codes.

Present plans call for increased emphasis on the construction and testing of large buckle-shells in the field. Research is under way to investigate the adaptability of other materials and the feasibility of using such promising but untested buckle-shell types as the cylinder, dome, and semidome.

Computer-Aided Building Design

A critical problem facing the nation is the tremendous need for construction of housing, schools, hospitals, and other public and private facilities. Because of the fragmented nature of the building industry, the analytical and theoretical advances that occur are likely to result from attempts to solve particular design and construction problems in isolation from an overall view. The design of buildings is becoming increasingly more complicated as code requirements and performance specifications become more stringent and, unfortunately, often contradictory. Technological advances complicate the situation by introducing new choices of structural systems, materials, methods, and environmental controls. All of these trends place a mounting burden upon the designer who is often unable to cope with the vast quantity of information available.

New methods of evaluating a multiplicity of possibilities have emerged from systems analysis research. These new methods coupled with advances in computer technology, e.g., computer-graphics and man-machine interaction, permit a designer to concentrate on major design goals by using the computer as an information base, for simulation of potential designs, for calculation, and for education purposes.

With Foundation support, research is underway on the development of computer systems for building design. At the Massachusetts Institute of Technology, A. G. H. Dietz and Alan M. Hershdorfer are formulating a special language called "Build" which a designer can use to communicate with a computer-based information system.

Although the program is still in the research stage, it presently has the capability to work with four building systems (activities, spaces, surfaces, and structure). The user can define relations among these systems and perform calculations of areas, volumes, weights, and costs. A simple building structure, including the framework that supports it, can be generated from the major geometry of the building spaces. This will enable the designer to take advantage of existing structural design capabilities and other programs for mechanical equipment, and other elements of the building. Work has also gone forward on computer graphics which will permit a designer to call up or modify information which is displayed on a cathode tube scope and which can be altered with a special light pen. Also, a significant refinement in computer graphics has been achieved through the development of 3-dimensional display and perspective. It has also been necessary to examine the design process itself with the aim of supplementing it with the computer as a design tool. It is not enough to simply translate drawingboard design procedures to drawing on a cathode ray tube. What is sought is augmentation of the design process through innovation in design theory and techniques. One objective is to bring the use of the computer closer to the conceptual design of the building; particularly in developing relationships among the activities in the building, communications among them, and the best arrangement of spaces to house these activities. Another objective is to make it possible for a practicing architect who has minimal knowledge of computer technology to use the computer in his design.

At the Pennsylvania State University, Lawrence Degelman is developing a problem-oriented computer language, which will form another component of the Integrated Civil Engineering Systems Program which was begun at MIT, to routinely apply computers in environmental design for buildings.

The program makes it possible for a designer to communicate with the computer in ordinary language or through graphical display devices. Input information is digitized for calculations taking into account different types of wall and roof systems and areas. Information which can be considered in the input are thermal properties of materials, orientation of the building, reflectance of surfaces, maintenance factors, weights, costs, shading factors, and weather data.

The computer automatically simulates the heat and moisture flow into or out of the building hour by hour for an entire year. Maximum heating and cooling loads can be obtained along with relative rates of change.

Although there are environmental analyses programs in use by a few firms, this work at Pennsylvania State will enable practicing designers who have limited knowledge in computer technology to improve their environmental designs with the aid of the computer.

As a result of these and other studies in progress, it is expected that substantial advances will be made in building design both from the standpoint of economy and more satisfactory buildings.

Full-Scale Testing of New York World's Fair Buildings

Historically, building engineering has been hampered by the dearth of information on the performance of full-scale structures. For the obvious reason of cost, total building structures traditionally have not been erected for the sole purpose of testing to or near to destruction—yet, doing so is an obvious necessity if one is to be able to truly validate design criteria. Present-day design criteria and building code requirements for building structures have primarily evolved from theoretical analysis backed by laboratory investigations of individual structural components, scale models, or relatively simple assemblages of components. The relationship between predicted and actual performance of full-scale, as-built structures has remained largely undetermined.

The complex of structures built for the 1964–65 New York World's Fair presented an opportunity almost without precedent for conducting such full-scale structural testing. Most of the structures already were scheduled for demolition, and, though this obviously imposed a time limitation on the testing program, their availability precluded the large financial commitment which would otherwise have been required to build the structures solely for testing. Also, although relatively new, the structures had been subjected to occupancy conditions. Thus, the complex of structures constituted a unique resource.

Many of the structures constructed for the fair represented innovations in design, but most were representative of contemporary, conventional construction. It was decided to select a representative sample of the latter for testing in the belief that resulting information would be of greater universal value since such structures would most likely reflect current design criteria and construction practices.

The concept of full-scale testing of selected structures of the 1964–65 New York World's Fair originated with the American Society of Civil Engineers (ASCE) in the latter part of 1965. To administer the actual program, a Special Advisory Committee was appointed by the Building Research Advisory Board of the National Academy of Sciences. Financial support was provided by NSF and a number of other organizations.

After examining the structural drawings for 15 different buildings at the World's Fair site, three were selected for testing: (a) the Bourbon Street, (b) The Rathskeller, and (c) The Chimes Tower. Several ingenious loading methods, including use of atmospheric pressure, and jacking from a building's own foundation, were used to deform two of the structures until failure took place. A conventional approach for loading would have been to use dead loads in the form of weights such as iron or brick, or to use water loading. In the tests using atmospheric pressure, the building was made airtight with plastic sheet material, and air was then sucked out of the building using a large blower. Atmospheric pressure naturally loaded the structure with increasing force as more air was evacuated. Eventually a point was reached where the loading was sufficient to cause structural failure. Some of the failures involved unanticipated types of behavior. As designed, ultimate structural failures should have been in flexure, i.e., bending, but in most tests, these failures actually were in shear. The results of the tests have been summarized and made available in three volumes, *Full-Scale Testing of New York World's Fair Structures*—each describing one of the structures tested. These volumes are available from the Building Research Advisory Board, National Research Council, National Academy of Sciences—National Academy of Engineering.

The World's Fair testing program demonstrated the complete feasibility of carrying out testing of full-scale structures in the field with a degree of precision approximating that attainable in the laboratory. The tests performed revealed unsuspected strengths and weaknesses; however, neither design practices nor building codes could reasonably be revised or modified solely on the basis of these few full-scale tests. Results of the tests do highlight specific areas in which further research and laboratory investigation could probably lead to considerable improvement in existing design criteria. At this stage of development, full-scale testing of structures must be viewed principally as a means for developing questions rather than answers; consequently, followup investigations involving both laboratory testing and theoretical analyses—with the aim of obtaining answers to the questions raised—must be pursued if the potential benefit of a full-scale testing program is to be realized.

Fire Research

The problem of unwanted fires has been with man from prehistoric times. Cost and severity have grown, however, until such fires now claim approximately 12,000 lives per year in the United States and destroy nearly $2 billion worth of property. The total cost including fire protection approximates $5 billion annually.

The National Science Foundation has for some time supported the work of the Fire Research Committee of the National Academy of Sciences, a group set up by the Academy to examine the fire problem, and especially the mass fire problem associated with national defense. During the 1966–67 academic year the chairman of the Committee, Howard Emmons of Harvard University, devoted a major part of the year to visiting with NSF sponsorship fire research laboratories, fire departments, and other related organizations throughout the world in order to obtain a more comprehensive picture of the overall fire problem and to identify the areas which need greater effort. In his writing and lecturing since the trip he has made it clear that firefighting has not benefited as have other elements of society by inputs from science and technology, and that major gaps exist in the knowledge needed to do an adequate job of cutting losses from unwanted fires. As examples of these gaps, Dr. Emmons points out that our knowledge of flammability is inadequate to devise tests which will properly rate materials on a scale of relative hazard, and that in fact standard tests in use in various parts of the world yield results which are in substantial disagreement. Furthermore even if adequate tests for flammability and fire resistance of materials were available, the knowledge of how to predict the fire resistance of a complete structure assembled from such materials is lacking.

Thus although a great deal of effort has been devoted to applied research concerned with the prevention or quenching of unwanted fires, there is as yet no real quantitative understanding of the exceedingly complex phenomena of ignition and fire spread on which to base firefighting methods and procedures, nor of the strength and flammability of materials on which to base the rational design of fire resistant structures.

In addition to the support afforded the work of the Fire Research Committee, NSF has sponsored research projects concerned with specific phases of the fire problem.

Although understanding of the propagation of flame through premixed gases is reasonably satisfactory, the much more complicated phenomena associated with the spread of fire through a solid, across the surface of a combustible liquid, or through the discontinuous fuel bed provided by a building or a forest are only imperfectly understood. Hoyt C. Hottel and Glen C. Williams at M.I.T. have a NSF grant to support propagation studies through discontinuous solid fuels. Specifically they are looking at two cases; a ground fire burning through compacted leaves and debris, and a brush fire. The effects of wind velocity—both tail and headwinds—and fuel moisture content have been measured, and mathematical models derived which make possible more accurate predictions concerning the effect of these variables on fire spread. These projects are continuing and will yield more refined models as more experimental data are accumulated.

Large fires, both urban and forest, may be spread, not only by simple propagation, but also by firebrands carried high into the air and deposited long distances from the original fire by powerful air currents generated by the fire itself. This is a particularly important problem when major fires are fought by backburning to create burned out areas which serve as firebreaks. The meeting of the two fires may generate powerful updrafts of sufficient strength to allow jumping of the newly created firebreak by firebrands.

The trajectory of the firebrands will depend, in the absence of strong ambient winds, on the nature of the flow field in the natural convection plume above the fire. One particularly troublesome phenomenon is a violently swirling plume which can scatter burning material over a wide area resulting in many new fires. This phenomenon, called fire whirl, is under study by Dr. Emmons at Harvard and Richard S. L. Lee at the State University of New York at Stony Brook, both with grants from NSF. In his most recent reports, Dr. Lee has described the experimental production for the first time of multiple fire whirls generated by a line fire. These multiple fire whirls are now being investigated in more detail both experimentally and theoretically by Lee and his group at Stony Brook.

The Emmons and Lee projects have each involved both analytical studies and experiments in an effort to identify the important parameters controlling the formation of fire whirls, and in particular the part played by initial vorticity in the ambient air. The final objective is sufficient understanding of the phenomena to permit predictions concerning the development of fire whirls, and methods for preventing their formation.

All of these projects have in common the fact that they are fundamental studies directed toward a more complete understanding of the phenomena involved. Although substantial sums are expended on fire research in the United States each year, only a small fraction is devoted to fundamental studies of the type discussed; yet these basic projects hold the best hope for breakthroughs that will permit eventual substantial reductions in the large annual fire losses experienced in this country and throughout the world.

SOCIAL SCIENCES

There has been an increasing awareness in the physical, engineering, and biological sciences of the role of human beings and their effect on their natural environment. Thus when ecologists and atmospheric scientists approach their studies, they are concerned with the interaction of man with his environment and are aware that it is not possible to concentrate, for example, on the physical aspects of a given problem such as grasslands without taking into account what man's activities do to such areas and the repercussions of that interaction.

The social sciences, of course, always start with man as the focus of study. Human beings, and the structure and functioning of the institutions they have established, are the central concern. But in making their studies social scientists collaborate with other scientists in many areas of research. For instance, they bring to the study of such problems as construction an orientation toward the human element. Engineers have progressed beyond concentrating on the structure of a building for example to take into consideration some of the needs of the people who will use the facility. The contribution of the social scientist results because he begins with the consideration of the user. With an outlook toward optimization of the physical structure for the human being, rather than adding him at a later point of consideration, he may be able to contribute to a better integrated total design. The examples of work which follow illustrate some of the variety of problems on which social scientists are working.

Rural Economic Development

The growing interest of society in alleviating rural poverty has not as yet been matched by scholarly investigations of its origins and cures. However, some highly significant research to gauge the role of education in rural development is underway at Oklahoma State University under the direction of Luther Tweeten. In one study, Professor Tweeten has formalized the interaction of education, income, and attitudes in an econometric model of rural economic development.

To test the model, data have been obtained on the education costs, attitudes, future educational and occupational plans and biographic characteristics of a sample of primary and secondary students from eastern Oklahoma. Additional data have been secured from the parents, as well as from other sources, regarding parental income, occupation, education, and selected attitudes.

Professor Tweeten's findings emphasize the impact of education on the earnings and mobility of farm people. Specifically, a consistent positive relationship was found to exist between education and income. In the 35–54 age brackets, the lowest earning group of farmers had approximately an elementary education; the highest income group had a median education of slightly over the high school level. The heavy concentration of farm operators and hired workers in the lower education brackets helps to explain, though it does not completely do so, the prevalence of low farm income.

Professor Tweeten's data also bring out the twofold effect which education has on rural poverty. In the first place, education increases skills of persons, potentially raising their level of farm management and their suitability for nonfarm jobs. Secondly, as it broadens the outlook of people, it enhances their motivation and aspirations for higher income and living standards. This contributes to the "push" and "pull" effect to which data on migration testify. Among older individuals, migration rates are highest among the least educated. According to the theory, these individuals are pushed by declining job opportunities from depressed to more prosperous regions. In the category of younger individuals, migration rates are highest among the most educated. These data accord with the hypotheses that farm individuals are "pulled" from a slow growing or stagnant region to more lucrative jobs elsewhere. When people in the young, most educated group move, they carry with them a substantial investment of public funds in education and substantial future earning power.

Studies of Frustration and Aggression

How harmful is violence on the television and movie screens of the Nation? Are viewers emotionally more aggressive or vindictive as a consequence of filmed mayhem and murder?

In a series of laboratory experiments, a University of Wisconsin social psychologist, Leonard Berkowitz, has been investigating circumstances which may lead to aggression, including exposure to violence on films and the physical presence or absence of weapons. In most of his experiments, students, serving as experimental subjects, are angered or frustrated by another person (who is actually a confederate of the experimenter). Following this, the student is given an opportunity to punish the person who caused his anger or frustration (i.e., the confederate) by administering one or several electric shocks to him. Actually, the confederate, who is in another room, is not shocked, though the apparatus is present and the subject believes he is giving shocks, ostensibly for poor performance in a learning task. Individuals who have been angered give a greater average number of shocks than nonangered subjects.

In the studies on the effects of filmed violence, following the first portion of the experiment in which the individual was either angered or treated in a neutral manner by the confederate, a 7-minute film clip of a violent prize fight scene from the film "The Champions" was shown to some of the subjects. The effects of the following situations were assessed in a series of studies: the violent film clip compared to a neutral, nonviolent scene; the violent film in which the experimenter's introductory synopsis either depicted the film victim as a villain who presumably deserved the beating he received (justified aggression), or an innocent victim of circumstances (unjustified aggression); various degrees of similarity between the victim in the film and the insulting confederate.

The results of the study appear to indicate that film violence does not necessarily lead to open aggression against anyone. Persons who were angry at another person and were later given an opportunity to hurt him, did so whether they had seen a violent film or a neutral film. They did so to an even greater extent, however, after exposure to a violent film in which violence was described as deserved rather than undeserved. They also were more aggressive if the victim in the film was in some way associated with the object of their own anger. In these experiments, the association was by same first names or similar roles for the film victim and the other person.

While these experiments do not demonstrate that film violence necessarily leads to aggression, though it leads to an *increase* in aggression in certain special circumstances, they demonstrate that film violence does not *reduce* the chances of aggressive behavior by allowing the viewer a vicarious release from tension and anger, an argument often advanced by those who claim a positive function of viewing violence in the movie and on TV. Angry individuals remained angry and behaved aggressively after viewing either film.

In considering these findings, it must be remembered that the subjects in these laboratory experiments were given an opportunity to express sanctioned aggression, a factor which is not often present in normal social settings. The principal investigator also has expressed the view that the possibly harmful effects of filmed violence, given the right circumstances, are short-lived.

The Balance of Payments and International Economics

In view of the prolonged balance of payments difficulties which the United States has been experiencing, this aspect of international economics has become an increasingly significant area of research. The Foundation has supported an appreciable and growing volume of work which is concerned with this problem and a number of promising studies are currently in progress. One of these, a basic empirical investigation of international prices, is now nearing completion under the direction of Irving B. Kravis of the University of Pennsylvania and Robert E. Lipsey of the National Bureau of Economic Research. The object of their investigation has been to develop methods of measuring price competitiveness in international trade and to use these to construct improved indexes of comparative prices and price trends in the international trade of the United States and its main foreign competitors.

Besides the United States, the study covers the United Kingdom, the European Common Market, and Japan. Improved price indexes have been calculated for machinery, transport equipment, metals and metal products for selected years from 1953 to 1964. These new measures should prove to be extremely valuable for analyzing the effects of price changes on trade flows and on balance of payments adjustments. Previously, analysis has been hampered by the lack of measures of relative price levels and because existing measures of price changes—such as foreign trade unit value indexes and domestic wholesale or consumer price indexes—have not been adequate for the task.

According to the study, U.S. export prices for the products mentioned were, on the average, 5 to 10 percent higher than those of its principal foreign competitors. In general, however, the price competitiveness of the United States relative to the European countries did not change much over this period. In fact, one of the most striking results of the study is the similarity in magnitude and timing of the movement of international price indexes of the several countries for all of the commodities taken together. Thus, the change in the ratio of foreign to U.S. prices, the Lipsey-Kravis index of price competitiveness, stayed within a range of 5 percentage points. Within that range, U.S. price competitiveness fell relative to all countries between 1953 and 1961 and then recovered all or part of the loss by 1964.

In periods of price instability the traditional wholesale price indexes and export unit value indexes appear to be especially misleading as indicators of international price competitiveness. A major conclusion of the study is that it is feasible to collect a great variety of more reliable data relevant to the measurement of international price competitiveness which have never been collected before. It is hoped that the outcome of this investigation will encourage government and international agencies to pursue the measurement of international price relations on a more comprehensive basis that the study pioneered.

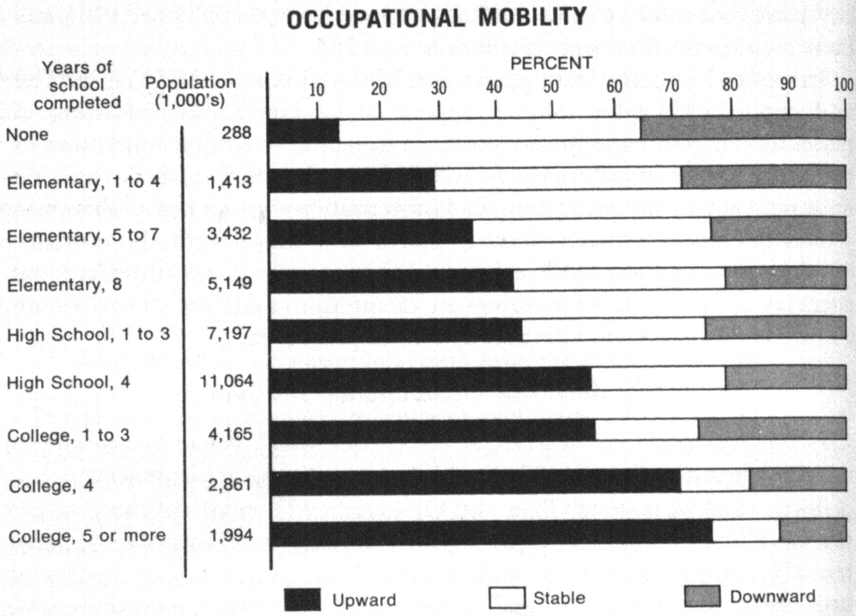
The American Occupational Structure

Is the United States still a land of opportunity? What factors determine or limit the degree of individual occupational achievement?

Two sociologists, Peter Blau and Otis Dudley Duncan (of the University of Chicago and the University of Michigan, respectively), have recently completed a nationwide study of the American occupational structure and of occupational achievement between generations and within career histories. (*The American Occupational Structure,* New York: John Wiley and Sons, Inc., 1967.) The patterns and probable determinants of occupational achievement are identified and analyzed using data collected by the U.S. Bureau of the Census, during a special national survey, from more than 20,000 American men between the ages of 20 and 64. New analytical techniques permit the researchers to assess the relative importance of various social and economic factors in determining occupational status and mobility. Their study is regarded by some experts as the most comprehensive and methodologically sophisticated work to date on occupation and social stratification in the United States.

Is the American occupational structure of today as open as it was earlier in our century? Is there still appreciable opportunity for occupational mobility between generations and within a career? The authors find no indication of increasing rigidity in the system during the last 40 years. The rates of upward social mobility in the United States today are relatively high and compare favorably with those in other industrialized societies. But although the study presents some analysis of historical trends and cross-national comparisons of rates of occupational mobility, the main thrust of the research is the analysis of the social determinants of occupational mobility.

Three factors, from among many examined, account for nearly as much of the variance in occupational achievement as all other factors together. These are: the individual's social origin, his education, and the level of his first job. Education exerts the strongest direct influence on occupational achievement, while the level on which a man starts his



career is the second strongest influence. Father's education influences his own occupation and this, in turn, influences his son's educational advantages and first job. Although most of the influence of social origins is mediated by education and early job experiences, some influence remains even when differences in schooling and first job are statistically controlled.

Youths from lower class backgrounds who manage to obtain a high school or college diploma do almost as well as youths from higher social classes with equivalent levels of education. The investigators find that there is an important exception to this, however, in the case of Negroes. According to the study, a Negro's chances of occupational success in the United States are inferior to those of a Caucasian. Like whites who have lower social origins, Negroes have fewer opportunities for obtaining a good education. When Negroes and whites of the same educational level are compared, however, the data indicate that the former start their job careers at lower levels. Furthermore, their occupational achievement is lower than that of whites even if social origins, education, and first job are statistically controlled. Finally, even within the same occupation the income of Negroes is lower than that for whites.

The difference between occupational achievement for Negroes and whites is twice as great for men who have had a high school education or better than for those who have not gone beyond the eighth grade of school. Thus, though some Negroes may make sacrifices to remain in school, they may have fewer economic incentives than whites for doing so. The authors believe that this accounts for the relatively weak motivation of Negroes to remain in school and advance their educations and, indirectly, for the "vicious circle of poverty" in which many of them are trapped. Southern Negroes suffer from even greater disadvantages than Northern Negroes.

An interesting contrast group is the sons of immigrants, who also start out with disadvantages in their backgrounds. For this group, occupational achievements are as high as those of the majority American group, even without controls on initial background differences. The authors believe that this may be attributable to high achievement by some members of the white minority groups (especially those from Northern and Western Europe) which may obscure the effects of disadvantages of others, and to the possibility that immigrant parents, already a selected group who displayed unusual courage and initiative in migrating to a new culture, have instilled these achievement-related motives into their sons.

Early Man in America

It is generally believed that the first men to enter the Americas came from Asia via the Arctic. But a great deal remains to be known about the length of time man has lived in the Western Hemisphere, the physical and cultural characteristics of early human inhabitants of the New World and possible links between these people and particular populations and regions in Asia. Important new evidence pertaining to these problems has been produced by recent anthropological research in the northwestern United States and Alaska.

Human remains believed to be the oldest yet found in the Western Hemisphere have been discovered in Southeastern Washington in an area about to be flooded by waters of the Lower Monumental Reservoir. Remnants of this ancient man in the New World include charred and shattered parts of a skull, a few pieces of rib, long bone, vertebrae and bones from the wrist. In addition a pointed bone artifact has been recovered.

These specimens are estimated to be between 11,000 and 13,000 years old. They were found in place, in undisturbed sediments beneath a thick layer of rockfall fragments. Mussel shells from the overlying rockfall layer have been dated by the radiocarbon method as 10,000–11,000 years old, and the human remains must be older than that age. Since a lake occupied the canyon in which the find occurs until 12,000–13,000 years ago, this Early Man site, called the Marmes Rockshelte rsite, must represent occupation after the lake was drained.

The remains, apparently those of a young individual in the late teens or early 20's with some Mongoloid characteristics, were discovered by Roald Fryxell, a geologist on the staff of the Department of Anthropology at Washington State University, during excavations at the site. Richard D. Daugherty of the university directed the archaeological research in the area.

322-215 O—68——11

Photo Washington State University

General view of the Marmes site showing excavators at work. The first skull was discovered in the pit in the foreground.

Despite a century of intensive search by archaeologists, few discoveries of even fragmentary remains of the earliest inhabitants of the New World have been made, and previously these had been found under circumstances which made estimates of their age problematical. The find at the Marmes Rockshelter, documented by 6 years of earlier archaeological and geological research at the site, can be dated on a firmer basis than any of the prior discoveries.

Following the discoveries described above, and reported in fiscal year 1968, subsequent work in July and August produced findings of additional scientific significance. These included two more ancient skulls, 11,000 or more years old, one of a child aged about 10 and the other of a young adult. The three crania—designated Marmes I, Marmes II, and Marmes III—now represent the earliest well-documented remains in the Western Hemisphere.

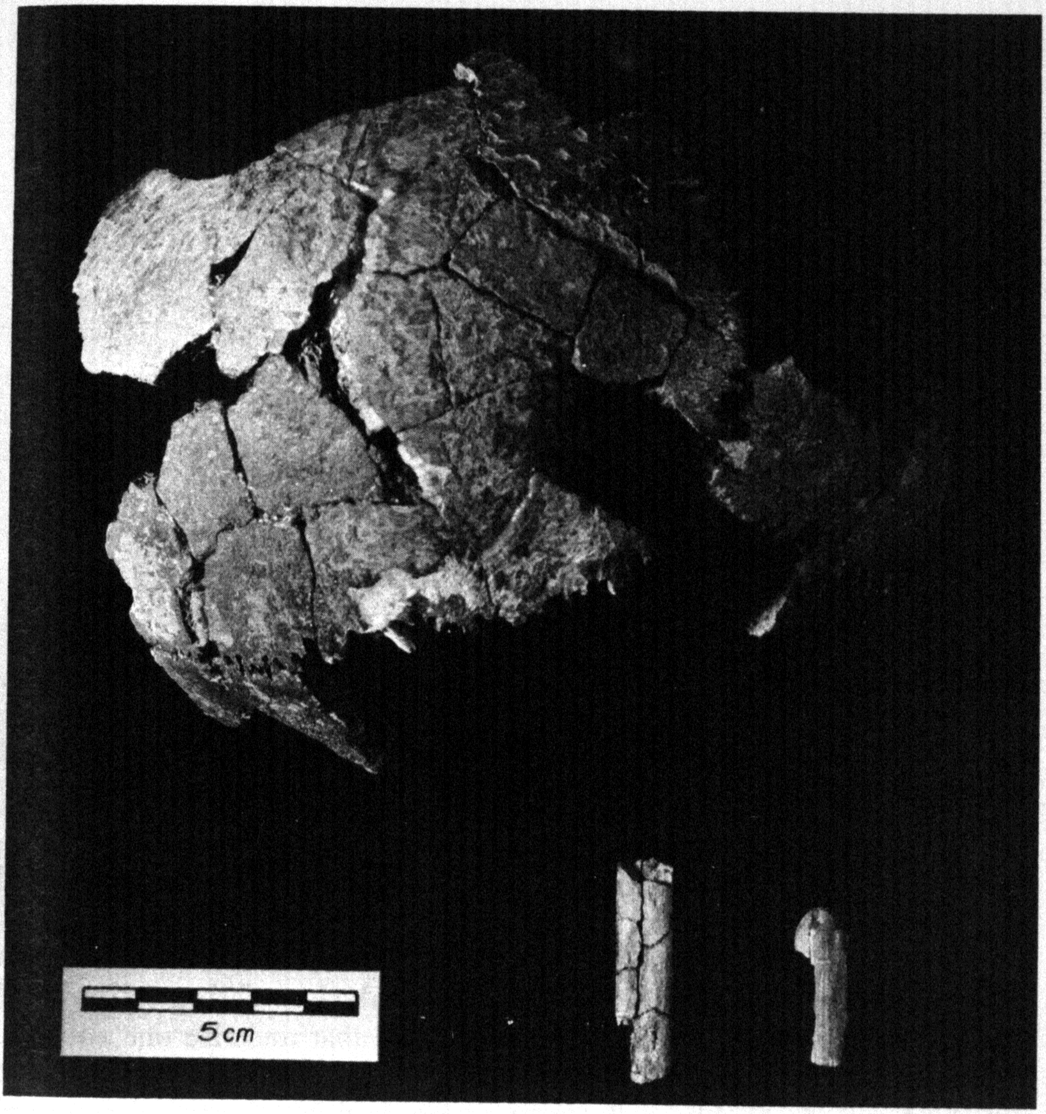


Photo Washington State University

Fragments of the first Marmes skull as pieced together by scientists. At bottom are two tiny pieces of bone artifacts found with the skull.

Of equal interest are a beautifully fashioned bone needle and other artifacts of the same period. The needle, found about 20 feet from where the remains of the original Marmes man were discovered, is probably the oldest artifact ever discovered in the United States, and is described by scientists as a "remarkable engineering achievement." It was probably used for every fine stitching and very close seams—perhaps for waterproof clothing.

Farther north, archaeological excavations at the Onion Portage site in northwestern Alaska have uncovered early cultural remains that closely resemble stone artifacts found in Northeastern Asia.

Until excavations at Onion Portage, there were few known traces of man in the Arctic area closest to Asia that could be dated before 3,000 B.C. As a result of research at the site, substantial evidence of human

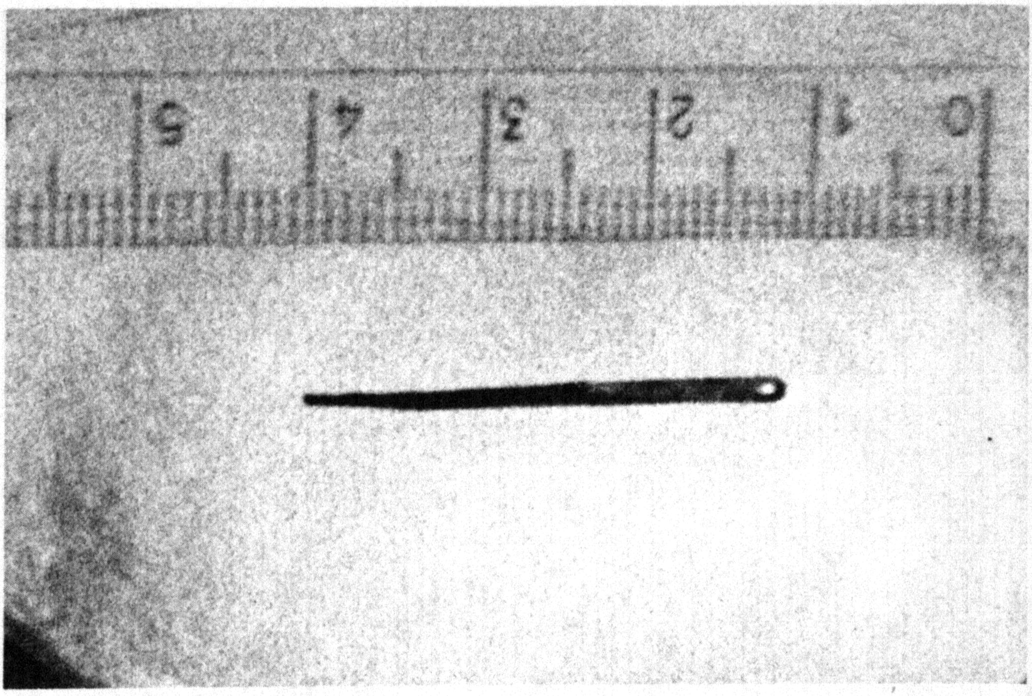


Photo Washington State University

This delicate bone needle is probably the oldest artifact discovered in the United States. It was probably used for very fine stitching such as might be necessary in the fabrication of waterproof clothing.

occupation of the area at least 8,500 years ago has been uncovered, and the site may have been occupied as early as 15,000 years ago.

The Onion Portage site is unusual in the Arctic interior because it is deeply stratified, permitting relative and absolute dating of cultural materials embedded in distinct layers of soil that underlie one another. The older the layer, the deeper it is in the column. The site was discovered by the late J. L. Giddings, Jr., who recognized its exceptional potential in an area where special features of the Arctic environment generally have prevented the accumulation of this kind of deep stratigraphic column. Since Giddings' death, research at the site has been under the direction of Douglas D. Anderson of Brown University, with support from the Foundation.

A succession of stone artifacts going back at least 8,500 years has been recovered from strata at the site, the tools and weapons of hunting peoples who lived in the area at one time or another in the past. Carbon-14 dating indicates that the earliest of these hunting groups were occupying the site by at least 6,500 B.C., and perhaps even 6,000 years earlier. Among the stone tools they made were bifacial implements shaped in the form of a disk. No implements like these have been found in Alaska before. The tools most similar to them come from sites around Lake Baikal in Siberia and are between 12,000 and 15,000 years old. The earliest occupants of the Onion Portage site also made blades from stone microcores of a type that has been found in other parts of Alaska and in Siberia, Mongolia, and Japan.

SCIENCE EDUCATION

Science education undergirds the Nation's scientific potential and serves as a key to progress in science and technology. Its role in helping to solve the problems of society grows as social and economic changes create new challenges for modern man. To be effective, however, science education must keep pace with advances in scientific knowledge and must be responsive to contemporary needs.

The National Science Foundation is charged by act of Congress with specific responsibility for strengthening education in the sciences. In carrying out this mandate the Foundation strives to improve significantly the quality of science instruction at all educational levels in U.S. academic institutions. This effort is necessarily linked to the availability of Federal funds for science education. Currently NSF seeks to maintain the stability of its educational activities and still encourage beneficial changes. While mindful of the value of continuing support for activities that have been clearly established as essential to improvement of science education, the Foundation recognizes also the importance of supporting experimental approaches to science education and the implementation of new developments.

The major educational efforts receiving continued NSF support are designed to:

- Bring about improvement in the quality of instructional programs through the development of better courses and instructional materials, including partial support of instructional equipment to implement improved courses in colleges;
- Improve the competence of elementary school, secondary school, and college teachers through specially designed instructional programs;
- Provide for the identification of high ability senior high school students, upper division college students and graduate students and appropriately support them in meaningful, enriched educational experiences in science;
- Support cooperative projects designed to help elementary and secondary schools and school systems to install improved instructional programs as regular parts of their curricula;
- Include a more extensive involvement of junior colleges and technical institutes in relevant existing programs;
- Support graduate students enrolled in advanced degree programs and more advanced individuals who seek to further upgrade their scientific capabilities; and

- Accelerate the development of science capabilities of predominantly undergraduate institutions.

In the areas of experimentation the Foundation is especially interested in doing more about (1) bettering the initial preparation of science teachers (pre-service training), in order to minimize the need for immediate updating or upgrading; (2) increasing the effective use of computers, television, and other aids for educational purposes; (3) identifying the educational problems of junior colleges and technical institutes that may be amenable to solution; (4) demonstrating ways in which successful developments in science education can be brought to bear on the problems of educating and training the educationally disadvantaged; and (5) understanding the learning process, so that the necessity for costly trial-and-error may be reduced.

The National Science Foundation's total effort in education is very small as compared with both the national and Federal efforts. Hence, in order to have a significant impact on education in science, NSF educational support must be directed in varying degrees to specific needs of the different academic levels.

At the graduate and advanced level the emphasis is on direct support of the most talented science students. From 1952 to the end of fiscal year 1968, the Foundation invested more than $302 million in fellowships and traineeships for advanced-level training. This represents a total of 48,784 fellowship awards offered to the most highly qualified individuals identified from among 174,782 applicants, and 20,791 traineeships for award by the 209 institutions receiving grants.

Opportunities for advanced scientific training are also made available through NSF-supported research projects. A substantial number of graduate students, serving as research assistants, receive skilled guidance and training while working under the leadership of principal investigators of research projects. Indeed, graduate education is so intimately related to research that the Foundation considers its support of academic research to be a major contribution to the system of graduate education.

Other NSF programs which are directly or indirectly beneficial to instruction in the sciences at the higher education level are the University Science Development Program, the Departmental Science Development Program, the College Science Improvement Program, and the National Sea Grant Program. These activities support the strengthening of science in broad terms, except that the College Science Improvement Program emphasizes the instructional aspect. Each program is making a significant contribution to the Nation's scientific capability and to a broader geographical distribution of Federal resources for science.

The College Science Improvement Program was initiated in October 1966 to assist mainly 4-year colleges in improving some major segment of their instructional programs in science. These institutions have received only a small fraction of NSF funds over the years; most of this support has been for individual projects concerned with supplementary teacher training, curriculum improvement, instructional equipment, and the like. Many colleges need to take a comprehensive approach to upgrading science education in order to effectively strengthen their science capabilities. Accordingly, the Foundation encourages undergraduate institutions to develop broad improvement plans which are tailored to meet the individual needs of the particular institution. These plans may cover a single department, or any number of departments, and any combination of specific projects within or among these departments.

In addition, the Foundation continues to support individual projects for the improvement of undergraduate science education, including college teacher programs, science curriculum improvement, undergraduate research participation, instructional equipment, and special projects. The Nation's constantly expanding college enrollments and growing number of institutions offering science instruction at this level make the problem of Federal assistance extremely complex.

At the pre-college level the Foundation stresses support for supplementary training for teachers and course content improvement. Instruction for teachers is provided mainly through institutes which are organized and conducted by colleges and universities with the aid of NSF grants. Better science courses for elementary and secondary school students are developed and produced by national groups of scientists, in cooperation with educators, psychologists, media experts and others.

Since the introduction of NSF-supported summer institutes in 1953, an estimated 125,000 secondary school teachers of science and mathematics have been provided supplementary instruction in their respective fields through such institutes. Fiscal year 1968 grants for institutes afford training opportunities for approximately 20,000 participants in summer institutes, nearly 1,450 in academic year institutes, and about 14,300 participants in in-service institutes.

Progress in the improvement of course content and materials for science and mathematics instruction at the pre-college level has been most gratifying. Thus far the Foundation has invested about $60 million for elementary and secondary school curricular reform, which began in 1954. The new courses and curricula are widely used in the schools. For example, materials produced by the School Mathematics Study Group, initiated in 1958, have been used by more than 9 million elementary and secondary school children. Some 1.7 million elementary school children are using the materials developed by the Commission on Science Education, American Association for the Advancement of Science, with the total elementary school population using new elementary science project materials being well over 2.5 million. Some 80,000 secondary school students are currently using the trial versions of the new social science materials developed by four Foundation-supported projects. At the junior high school level, 500,000 students are using the interdisciplinary *Introductory Physical Science* course, and another 300,000 students are receiving instruction in the course, *Investigating the Earth*, developed by the Earth Science Curriculum Project, American Geological Institute. Approximately 2 million secondary school students have been introduced to biology through texts, laboratory materials, and audiovisual aids developed by the Biological Sciences Curriculum Study. In addition, another 1 million secondary school students have been exposed to courses in chemistry and physics developed by groups receiving Foundation support.

NSF widely disseminates information about the new instructional materials; however, commercial sources produce and make such materials available for school use.

To facilitate the implementation of materials in the classrooms, the Foundation supports institutes and projects which provide teachers with the necessary training. Especially helpful in this respect are cooperative college-school science projects in which, under the guidance of a nearby college or university, a school system can offer teacher retraining that will assist in the transition from the old courses to the new.

This year the Foundation has supported some experimental projects for the upgrading of teachers of disadvantaged students at both the precollege and college levels. A few NSF projects in curriculum improvement and special training for able science students also have been directed toward the educational needs of the disadvantaged.

For a number of years the Foundation has been concerned about the initial training of science and mathematics teachers-to-be (pre-service training). Many institutions, particularly the smaller colleges, are not prepared to provide training that is based on new instructional materials reflecting current scientific knowledge and contemporary approaches to science teaching. This year NSF has given increased attention to the preservice training problem and has provided some support for experimental projects directed toward improving science education for college students who plan to teach science or mathematics in secondary schools. The Foundation's aim is to establish at a few institutions the kinds of preservice programs that not only provide a reasonable mix of understanding of subject matter and of pedagogical principles, but also establish familiarity with newly developed course materials and provide direct experience in the development of such materials.

The Foundation continues to study its role in relation to science education problems of junior colleges. Considerable NSF staff time and attention have been devoted to this subject. In addition, the Foundation has supported a variety of studies bearing on problems connected with science and technology at 2-year institutions. An example is an Inventory Conference sponsored by the American Society for Engineering Education. The report of this conference, released March 21, 1968, takes up, among other matters, "Engineering Related Occupational Education in the Community College." Another study, conducted by the American Association for the Advancement of Science, involves a survey of teachers of science on junior college faculties. The report indicates that there are very serious weaknesses in the subject-matter preparation of teachers of science at the 2-year institutions. The Foundation is helping a small fraction of the junior college teachers through its College Teacher Programs, but this is by no means the answer to a problem of such magnitude.

Detailed information about the various NSF educational activities follows. Table 8 below shows NSF support for science education activities at the three major educational levels in fiscal year 1968.

Table 8.—*Education in Science—Fiscal Year 1968*

	Number of proposals received	Dollar amount requested	Number of awards made	Net obligations
Graduate:				$48, 665, 161
1. Fellowships	[1] 11, 518	$76, 907, 059	[2] 2, 963	(14, 764, 964)
2. Traineeships and other grants	461	101, 861, 743	290	(33, 900, 197)
Undergraduate [3]	3, 528	79, 882, 256	1, 423	31, 137, 468
Pre-College	1, 807	88, 379, 353	1, 260	54, 653, 538
Total	17, 314	347, 030, 411	5, 936	134, 456, 167

[1] Applications.

[2] Fellowships.

[3] Includes College Science Improvement Program: column 1—102; column 2—$19,201,214; column 3—55; column 4—$9,623,600.

GRADUATE EDUCATION IN SCIENCE

Science education at the graduate level concerns a broad spectrum of National Science Foundation activities. Direct support is provided through programs of fellowships and traineeships, institutional grants, and curriculum and faculty improvement. Indirect support comes from basic research projects in which many graduate students further their educational goals by active participation.

NSF programs specifically in the category of graduate education activities emphasize individual support of science graduate students, career scientists, and science faculty. In fiscal year 1968, through fellowship and traineeship programs, approximately 9,520 U.S. citizens were offered opportunities for appropriate study and research at institutions in the United States and abroad. (Table 9 summarizes data on applicants, awardees, and obligations for fiscal year 1968). Fellowships and traineeships, awarded competitively on the basis of merit, help the award recipients to advance in knowledge and skill in their chosen fields of scientific specialization.

Table 9.—NSF Fellowship and Traineeship Programs—Fiscal Year 1968

	Awards requested by institutions	Individuals involved in applications	Awards offered	Net obligations
Graduate traineeships	16, 123 (209)[1]		5, 656 (209)[1]	$30, 229, 305
Summer traineeships for graduate teaching assistants	7, 857 (196)[1]		965 (193)[1]	1, 063, 102
Graduate fellowships		8, 814	2, 500	9, 912, 363
Postdoctoral fellowships		1, 162	120	663, 500
Senior postdoctoral fellowships		384	55	537, 901
Science faculty fellowships		1, 083	223	2, 864, 768
Senior foreign scientist fellowships		75	65	786, 432
Total	23, 980	11, 518	9, 584	46, 057, 371

[1] Number of institutions involved.

Other NSF educational efforts focused on graduate and advanced levels seek to: improve course content and instructional materials in the sciences and assist in the development of new curricula; provide educational opportunities in specialized or frontier areas of science for graduate and postdoctoral students; and encourage university graduate departments of science to experiment with unusual or innovative educational programs.

A major challenge that confronts graduate education in science today is finding the best way to cope with the expanding graduate enrollments in science and engineering and the rising cost of graduate education per student. Adding to the complexity of this problem is the effect of the Selective Service Act on graduate student enrollments. The present military draft policies may have a significant impact on the education of future scientists and engineers. The effect is not yet predictable. Meanwhile, in concert with other Federal agencies, the Foundation has broadened its long-standing policy of holding graduate fellowships for Fellows who are called into the Armed Forces to now include those entering service voluntarily, and also those conscientious objectors who serve as non-combatants or in an approved civilian capacity.

Graduate Traineeships

In the Graduate Traineeship Program the role of the Foundation is to select academic institutions or departments which are to receive grants. Selection of the individual trainees is left to the university or department. The aim of the program is to increase the number of qualified individuals who pursue and complete advanced study leading to master's and doctoral degrees in any field of science supported by the National Science Foundation. Recipients of traineeship grants are primarily those institutions with existing facilities and staff to accommodate additional first-year graduate students in strong programs, or whose students can progress more rapidly toward an advanced degree with the aid of traineeships. "Traineeships" are different from the traditional NSF fellowships which are awarded directly by the Foundation to individual applicants.

Grants awarded in fiscal year 1968 provided for the support of 5,656 Graduate Traineeships (tenable for 9 or 12 months) awarded to 209 universities as compared with 5,077 traineeships awarded to 206 universities for academic year 1967–68. In addition, Summer Traineeships for Graduate Teaching Assistants, formerly administered as Summer Fellowships for Graduate Teaching Assistants, were awarded to 965 individuals (69 more than the number receiving summer traineeships last year). Of the 196 universities requesting Summer Traineeships this year, 193 were granted support.

Graduate Fellowships

Through the Graduate Fellowship Program, now in its 17th year, the Foundation provides support to unusually able students who are studying for an advanced degree in science, mathematics, or engineering. The awards help the fellows to complete their studies with the least possible delay. Before the Foundation makes its selection of students to be offered awards, all applications are reviewed and evaluated by panels of eminent scientists appointed by the National Research Council.

In 1968 there were 8,814 applications for graduate fellowships; 2,500 awards were offered, representing an increase of 50 over the number offered last year.

Predoctoral students again were selected to receive the largest number of the Foundation's fellowship and traineeship awards. Thees awards in fiscal year 1968 totaled 9,121 in the three graduate student programs (Graduate Fellowships—2,500 awardees; Graduate Traineeships—5,656 recipients, and Summer Traineeships for Graduate Teaching Assistants—965 recipients).

Fellowships for Advanced Scholars in Science

The leadership and knowledge of advanced scholars in science contribute importantly to the national scientific enterprise. In fiscal year 1968 the Foundation offered 463 fellowship awards to established scientists to enable them to pursue highly specialized areas of science (55 Senior Postdoctoral Fellowships, 120 Postdoctoral Fellowships, and 223 Science Faculty Fellowships—all tenable at institutions of the individual's choice—and 65 Senior Foreign Scientist Fellowships—tenable at U.S. colleges and universities only).

This year there were 1,083 applications for Science Faculty Fellowships, the largest number ever received in the program's 12-year history. Many of the college teachers who received awards are on the faculties of the smaller colleges and universities. In the Postdoctoral Fellowship Program also a record high number of applications (1,162) was received in fiscal year 1968.

Since 1959 the North Atlantic Treaty Organization has supported (from NATO funds) a number of international fellowships in science as a means of promoting scientific progress and obtaining closer collaboration among scientists of the member nations. At the request of the Department of State, the Foundation was appointed the National Center in this country for the administration of NATO programs, including the selection of Fellows.

Currently NATO supports two fellowship programs. NATO Postdoctoral Fellowships in Science are similar in terms and conditions to the NSF Postdoctoral Program. NATO Senior Fellowships in Science provide support for senior staff of U.S. institutions to study new scientific developments in other NATO countries. These fellowships were offered to 52 U.S. scientists in fiscal year 1968 for study in other NATO countries and those associated with NATO.

Advanced Science Education Activities

Special needs at the graduate or advanced level are met through NSF-supported advanced science education activities: advanced science seminars, special projects in graduate education, and travel to international scientific meetings. The overall objective of these efforts is to promote the development of excellence in graduate science education. Projects oriented toward the individual offer science instruction or activity of a highly specialized nature; institution-oriented projects seek to improve the quality of science training provided by universities and colleges. In fiscal year 1968 the Foundation made about $2.7 million available for these activities.

Advanced Science Seminars

Supplementing graduate school curricula, Advanced Science Seminars provide training which enables participants to pursue science subjects in greater depth. Support for 44 such projects was awarded in fiscal year 1968; 16 of the projects were in the social sciences.

Photo University of Arizona

A graduate student at the University of Arizona uses an optical pyrometer to measure the temperature of a sample being prepared in an RF generator.

Among the efforts funded were: summer instruction in the quantitative approach to analysis of data in political science, conducted by the University of Michigan, for 150 participants (graduate faculty, recent postdoctorals, and graduate students); and research training in physical oceanography, including land-based course work and experience at sea, conducted by the University of Alaska, for 16 graduate students selected on a national basis. Another current project of significance to graduate education is an advanced-level training program in specialized areas of algebra for graduate students and recent postdoctorals, sponsored by Bowdoin College, Maine.

Special Projects in Graduate Education

This activity encourages the development and testing of new approaches to graduate science education. Rapid advances of science and technology create educational needs that in many instances cannot be met in traditional ways. Hence the Foundation allows considerable flexibility in the type of experimental efforts that may be considered for support. Particularly welcomed are proposed projects which have the potential for helping graduate institutions solve common problems. Institutions that have conducted successful projects under Foundation grants are encouraged to disseminate information about them widely so that such projects may serve as prototypes for other institutions seeking to initiate efforts with similar aims.

A growing tendency to use computers and mathematical models was evident in the projects funded this year. For example, the University of California, Berkeley, is developing training materials for computer methods in demography; Case Western Reserve, Ohio, in its "Program in Graduate Mathematical Approaches to Ceramics," seeks to replace today's largely empirical approach to ceramics with the use of mathematical models; Colorado State University seeks to improve the quantitative relationship between organisms and their environment by the implementation and the use of mathematics, statistical and computer sciences in quantitative ecology, and Stanford University has developed simulation models of the hydrologic cycle that closely reproduce physical behavior.

Other new approaches receiving support this year include Colorado State University's development of a series of videotapes which are being used to present graduate engineering courses on an in-house basis to employees of a number of engineering firms, and the University of Nevada's development of an interdisciplinary program in the philosophy of science.

Fiscal year 1968 grants for special projects totaled 24; these were awarded to 20 universities, one consortium, and one professional society.

UNDERGRADUATE EDUCATION IN SCIENCE

Colleges and undergraduate components of universities play a key role in educating future scientists and engineers and in generally preparing students for effective citizenship in a science-oriented age. Many of these institutions, faced with constantly increasing student enrollments and inadequate financial resources among other problems, find it most difficult to offer science education that keeps pace with modern times. To help them to meet critical needs the National Science Foundation supports efforts for improving the quality of science instruction, strengthening academic institutions themselves, and providing special training opportunities for the ablest students.

During the past 15 years Foundation support for science education at the undergraduate level has grown from about $16,000 in fiscal year 1952 to approximately $31 million in fiscal year 1968. Current NSF undergraduate education activities focus on:

- upgrading the college teachers' knowledge of subject matter in the sciences;
- developing modern courses and teaching materials, taking into account the pressures brought about by NSF and other support of pre-college curricular improvements, the demands of graduate schools, and the demands for a firm base of training for research-support personnel (technicians);
- providing more definitive research experiences and advanced undergraduate science training to a select number of well qualified undergraduates, while experimenting with unique educational approaches to determine ways of providing opportunities for the educationally disadvantaged, many of whom have the potential capacity for advanced training in the sciences;
- assisting colleges and universities to upgrade their undergraduate programs and capabilities in science education to a state of excellence, and to maintain strength in science education where it already exists.

The vast number of undergraduate colleges now in existence (2,252 in 1966–67) [1] makes the question of appropriate Federal assistance extremely complex. These institutions range in size from small colleges with total enrollments of less than 100 students to major multiuniversities enrolling tens of thousands. The fall 1967 undergraduate student enrollment totaled approximately 5,770,000.[2] A wide variety of science-oriented career choices are open to these students—for example, instructorships in technical schools or pre-college science teaching, positions in industry for which the baccalaureate in science constitutes adequate preparation, or careers in academia or in industry for which further work at the graduate level is a requirement.

The Foundation is constantly seeking ways to better utilize its limited support for the improvement of undergraduate science education. New or modified efforts will be based on its accumulated knowledge and insight gained through the administration of current programs.

---

[1] Education Directory, 1966–1967, Part 3, Dept. of HEW, U.S. Office of Education, p. 11.

[2] Opening Fall Enrollment in Higher Education, 1967, Dept. of HEW, U.S. Office of Education, p. 8.

College Teacher Programs

To improve the professional competence of teachers of undergraduate science the Foundation supports specially designed supplementary training, which is ordinarily not available in the regular offerings of graduate schools. Such training is directed toward the underprepared teachers who seek to have their subject-matter knowledge increased, the initially well-prepared teachers who desire updating in their fields, and the advanced teachers who need further knowledge in some specialized area having particular relevance to current advances in their disciplines.

More than $8 million was awarded in fiscal year 1968 for the various college teacher activities, thus providing training opportunities for 4,448 teacher-participants. (These participants represent a geographical distribution covering all 50 States.) In addition, 223 college teachers were awarded Science Faculty Fellowships under the Foundation's fellowship support program, which provides financial assistance to in-service college teachers of science to enable them to undertake further scientific study or work that meets their individual needs. (See table 10, NSF Programs for College Teachers, fiscal year 1968.)

As 2-year colleges increase in number, a greater fraction of the Nation's undergraduate students attend these institutions. It is important to assure that their science teachers are equal to the task of giving the students good initial preparation for possible careers in science. In this connection, approximately one quarter of the training opportunities available under the College Teacher Programs is currently earmarked for junior college teachers. The problems of 2-year colleges in providing adequate science instruction and in preparing technicians and paraprofessionals of various types are of growing interest and concern to the Foundation.

Teacher Institutes

Instruction offered in institutes is specially designed for groups of teachers with similar subject-matter backgrounds and training needs. Included are remedial programs that emphasize basic subject matter, refresher programs that concentrate on new scientific knowledge of the last decade or two, and advanced programs that cover specialized areas of science and concentrate on relatively narrow subjects. Thus, depending upon the nature of the institute, participants range from less experienced to long-established junior college and college teachers.

Academic Year Institutes

Academic Year Institutes provide college teachers with opportunities to pursue studies on a full-time basis in a university environment during regular sessions. The general pattern of these institutes has been to combine a core of special course work, tailored to the selected group, with such choices from among regular graduate course offerings as will form a supplement appropriately suited to the individual participant's needs.

Fiscal year 1968 grants for conducting Academic Year Institutes totaled $723,908. These awards will pay for the operating costs of 10 institutes and provide support for 123 participants, including stipends. Among the institutes supported are one in engineering at The Pennsylvania State University, one in chemistry at Wellesley College, Mass., and one in mathematics at the North Carolina State University at Raleigh; they are specially designed for individuals who wish to prepare for college teaching after early retirement from other careers.

Summer Institutes

Summer Institutes have proven to be a most effective mechanism for providing supplementary training for teachers. They answer a variety of needs, and many now offer instruction which incorporates new course materials and approaches representing both new scholarship and ways of learning in science that go beyond the mere amassing of new facts. Examples of such projects are institutes on Desert Biology (Arizona State University), Systems Programing (The Pennsylvania State University), Matrix Methods of Structural Analysis (University of Wisconsin) and Experimental Solid State Physics (Massachusetts Institute of Technology). Financial assistance from the Foundation makes possible the attendance of many teachers who would otherwise need to supplement their income from summer occupations.

Fiscal year 1968 grants provided support for about 2,055 teacher-participants at 68 institutions conducting Summer Institutes. More than one third of the participants selected were junior college teachers.

In-Service Seminars

In-service Seminars, conducted on Saturdays or at other convenient times, provide part-time training to college teachers who continue to work full time at their regular teaching duties. They offer instruction in scientific subject matter or opportunities for teachers to become acquainted with new textbooks and laboratory equipment and new or alternative instructional techniques. Meetings can be few in number or many, and may be scheduled to take advantage of times when laboratories at the host institutions are most likely to be available to seminar participants. No stipends are authorized for this program. In recent years some seminars have enabled large groups of participants to assemble at special conference-type projects of short duration.

As a result of grants made in fiscal year 1968, totaling $74,627, In-Service Seminars will provide training for 657 college teachers.

322-215 O—68——12

Table 10.—*NSF Programs for College Teachers—Fiscal Year 1968*

	Proposals received			Grants awarded		
	Number	Participants	Amount	Number	Participants	Net obligations
College teacher institutes	(265)	(8, 753)	($12, 081, 698)	(122)	(3, 839)	($4, 103, 020)
Academic year institutes	20	316	2, 247, 211	10	123	723, 908
Summer institutes	183	6, 064	8, 758, 089	68	2, 056	2, 726, 801
In-service seminars	12	757	154, 740	8	657	74, 627
Short courses	50	1, 616	921, 658	36	1, 003	577, 684
Research participation [1]	352	1, 007	2, 458, 805	230	609	1, 420, 889
Science Faculty Fellowships [2]		1, 083	14, 632, 000		223	2, 864, 768
Total	617	10, 843	29, 172, 503	352	4, 671	8, 388, 677

[1] Includes 256 requested and 176 granted Academic Year Extensions.
[2] Also included in statistics on fellowship programs.

Short Courses

Short Courses, usually of 1 to 4 weeks' duration, cover selected areas of scientific fields and provide intensive instruction for participants with advanced backgrounds in particular disciplines. Subventions are authorized for participants.

Among the topics for Short Courses supported under fiscal year 1968 grants are:

- Astrogeology (Northern Arizona University),
- Servo-Instrumentation (University of Illinois),
- Human Engineering (North Carolina State University),
- Neutron Activation Analysis (University of California, San Diego),
- Water Resources (New Mexico State University).

A comparatively new development is represented by modest experimentation with a type of "sequential short course" that involves the same participant group over a series of three summers. An example is a project in Linear Algebra at the University of California at Santa Barbara, which entails a modest amount of "home study" over intervening winter terms. This approach applies a multiplier effect to a project that otherwise is supported only over short periods of time in the summer.

Including the 36 Short Courses awarded grants this year, 300 such courses or conference projects have been supported since fiscal year 1956.

Research Participation

Through the program of Research Participation for College Teachers the Foundation provides opportunities for college teachers to engage in full-time research activities during the summer and, in some cases, extended participation on a part-time basis during the academic year. An important aspiration of this program is to enliven science teaching at the smaller colleges by providing participation in ongoing research to teachers from institutions with limited research facilities or heavy teaching loads.

Often faculty members who provide the summer training at major universities become involved in a unique relationship with small colleges. This is particularly likely to happen when teacher-participants have been awarded Academic-Year Extension support for continuing their research activities. It is common for participants to be selected from the region in which the university is located and a prolonged and rewarding association between participants and their research mentors can develop as the research progresses. This comes about in various ways: for example, the participant may be made to feel at home in the university's laboratories long after the formal research participation period has terminated; or he may invite his former research supervisor to his own institution where the latter may act as a consultant in such matters as course content, laboratory layout, etc., in addition to giving his advice on specific aspects of the participant's ongoing research.

Photo University of Texas

Through the program of Research Participation for College Teachers, opportunities are provided for teaches to participate in full-time research activities during the summer.

In fiscal year 1968 a total of 66 basic grants were made to major research centers; these provided for 446 teacher-participants. In the Academic Year Extension phase there were 164 grants made to 145 institutions—primarily small colleges—located in 39 States.

Instructional Improvement

Extensive improvement of pre-college science courses and new demands of graduate education in science have emphasized the need for strengthening science instruction at the undergraduate level. Many concerned institutions want to take steps to upgrade their undergraduate science curricula but find themselves hampered by the lack of modern instructional equipment. The Foundation, well aware of the various institutional problems, continues to support activities that will provide for some degree of remedial action, both in curriculum improvement and in acquisition of equipment.

Science Curriculum Improvement

The Foundation's efforts for improving science curricula at the undergraduate level are directed toward supporting qualified scientists and teachers in the planning and preparation of instructional materials which reflect not only newly discovered knowledge in science but new techniques and attitudes in teaching science. This approach to assuring a higher quality of science instruction involves the development of specific course material (textbooks, monographs, laboratory programs, auxiliary teaching aids, etc.) and the support of "College Commissions."

The College Commissions, groups of prominent scientists representing basic science disciplines, are charged with the responsibility of examining the teaching situation in their fields and of providing the leadership and stimuli necessary for making the required improvements. These groups function in agriculture and natural resources, biology, chemistry, engineering, geography, geology, mathematics, and physics. The academic scientists comprising each group have been generally useful in focusing attention on problem areas and in collecting and disseminating information about effective ways of improving undergraduate instruction.

One of the projects supported under the Science Curriculum Improvement Program came to completion in January 1968 with the publication of *Goals of Engineering Education,* the final report of the Goals Committee of the American Society for Engineering Education. The most significant achievement of this project may be its stimulation of extensive and deep self-analysis by engineering educators to improve engineering education.

Examples of noteworthy curriculum improvement activities supported by fiscal year 1968 grants are:

- Production of fluid mechanics films (Education Development Center);
- Application of computers to instructional problems in calculus (Case Western Reserve University, Ohio), in electrical engineering (Purdue University) and in science for professionally uncommitted students (Hofstra University, New York);
- An historical approach to teaching physics, especially to students in pre-service teacher training programs (Columbia University);
- Development of laser techniques suitable for use in undergraduate instruction (Texas Technological University);
- Social Science projects in group dynamics (Yale University), in political science (University of Minnesota), in psychology (Claremont Men's College, California); and films on archaeology of the Maidu (University of California at Los Angeles).

Grants for college science curriculum improvement amounted to $6,045,054 in fiscal year 1968. These funds were in support of 45 projects, including the College Commissions.

Instructional Scientific Equipment

The Instructional Scientific Equipment Program supports the upgrading of subject-matter content of undergraduate science curricula by providing 50–50 matching funds for the purchase of necessary equipment. The Foundation has discovered that in many instances an institution's progress in implementing plans for new or improved instructional programs depends largely upon the acquisition of up-to-date equipment; often even a modest amount of financial assistance will solve the problem. Other benefits that an institution derives from this equipment include greater efficiency in science teaching, enhancement of the research potential, and an overall strengthening of the institution's instructional laboratories and the work performed in them.

Since the initiation of this program in 1962, more than $46 million has been awarded through 5,214 equipment grants to 1,048 institutions. Fiscal year 1968 grants totaled 536, amounting to $4,335,789; this represents approximately 23 percent of the amount requested in the 2,084 proposals submitted to the Foundation this year. The pressing institutional need for modern equipment that will assist in curriculum improvement represents a continuing problem in undergraduate science education.

Special Projects for Undergraduate Education

Projects supported under this program are largely concerned with research and development efforts for upgrading undergraduate science education. Current activities focus on (a) investigating new approaches for improving undergraduate education in science and identifying those that offer promise for enhancing the educational programs of many colleges and universities if applied on a broad scale, and (b) experimenting with projects so identified—examining variations and alternatives, developing guidelines and administrative procedures, testing the devices over a range of institutions so as to define their limits of effectiveness, and the like. In fiscal year 1968 the Foundation made 28 grants, totaling $1,306,296, for such special projects (this does not include Visiting Scientists or College Science Improvement projects, which are discussed separately).

A brief discussion of a few projects awarded grants this year will illustrate the scope and variety of activities receiving assistance.

By providing support to a group led by Grambling College, Louisiana, the Foundation is fostering cooperation between Brookhaven National Laboratory and ten small, predominantly Negro colleges to determine whether the help of a national laboratory can be instrumental in improving undergraduate instruction in chemistry, physics, mathematics and biology at such schools. The project involves an exchange of staff between Brookhaven and the participating schools, as well as student participation at Brookhaven.

A project at Tennessee Agricultural and Industrial State University, a predominantly Negro institution graduating a significant portion of the Nation's Negro engineers, will conduct a computer-assisted instruction program in mathematics. The project will permit 1,200 students at Tennessee A&I State University to converse by computer with another computer at Stanford University in California which contains specially prepared curriculum materials.

The NSF-supported Massachusetts Biological Conference, sponsored by the State College at Fitchburg, was attended by representatives from junior colleges, colleges, and universities. Its main purpose was to stimulate an interchange of ideas and plans between the 2-year and 4-year institutions, to allow influential teachers from the two groups to become acquainted with each other, and to open lines of communication between them.

Several projects concerned with pre-service teacher education are noteworthy. A statewide cooperative program in Nebraska involves the faculty of the five junior colleges, the four State colleges, and the University of Omaha in a curriculum improvement plan in biology that forms the initial step toward upgrading the preparation of prospective science teachers in that State. A project in mathematics at Illinois State University provides supplemental seminars and workshops for both student teachers and their supervising teachers, and is aimed at their involvement in the modern curricular approaches. At the State University of New York-College at Plattsburg, a comprehensive program in several disciplines will involve second-through-fifth-year students in classroom assignments, independent study, and student experience in materials development and curricular research, under individual advisors and master teachers.

Six institutions in Georgia, with the University of Georgia acting as grantee and coordinator, will experiment with programs of recruitment, curriculum revision, and development of teaching materials in the various science disciplines. At this stage each school will follow its own way in attempting to counteract its own weaknesses; thus a wide variety of avenues will be explored. Those efforts which prove to be effective will become part of the institution's regular program of pre-service teacher preparation and results will be made available to other institutions in the system; thus each institution will serve as a demonstration center for programs that, after careful evaluation, are judged to be effective. Additional institutions in the system will be encouraged to become active as the project develops. Three of the participating institutions are currently graduating over 50 percent of those who receive initial certification to teach in the State, two are recently established institutions and one is a junior college. This diversity of schools should produce a varied array of approaches.

Under its Visiting Scientists (College) Program the Foundation awards grants to the various professional societies to assist in sending competent scientists to undergraduate colleges (including junior colleges) for visits of one or two days' duration. The visiting scientists help the science faculty members who are not in the forefront of science to keep abreast of developments in their respective fields of science, to obtain the perspective needed for the solution of their research and teaching problems, to spark desirable changes in curricula and laboratory arrangements, and to stimulate interest in scientific fields among undergraduates.

Fiscal year 1968 grants for Visiting Scientists (College) activities provide for 1,466 visits, totaling 2,789 days, at a cost of $284,905.

College Science Improvement Program

The College Science Improvement Program (COSIP), which began in fiscal year 1967, is a comprehensive program to improve the science capabilities of predominantly undergraduate level educational institutions. This program, which complements the University Science Development and Departmnetal Science Development Programs (see pp. 186–192), extends the institutional science development concept across almost the full spectrum of higher education.

The predominantly undergraduate institutions which make up the target group of COSIP constitute an important component of academic science in the United States. These institutions granted almost 50 percent of the baccalaureate degrees in science during academic years 1962–63 through 1964–65, and it is estimated that about two-thirds of the teachers of science and mathematics in secondary schools are graduates of such undergraduate institutions.

Because of the importance of these institutions, the increasingly difficult problems that they are experiencing are cause for national concern. These institutions have been faced with increasing competition for scientific personnel from many sectors, at the same time that enrollments have sharply risen. To help colleges and universities overcome these problems, COSIP was undertaken to provide support for such activities as: opportunities for faculty members to obtain additional or refresher training and to engage in research; the planning of local course and curricular improvement; student-oriented efforts, including research participation; part of the costs for laboratory equipment; and visiting professors, faculty travel, and special consultants.

For details on the implementation of this program during fiscal year 1968, see page 191 in the chapter on Institutional Programs.

Undergraduate Research Participation

In 1958 the Foundation established the Undergraduate Research Participation Program to encourage the development of able undergraduate students into competent and independent scientific investigators. Experience with the program has confirmed the position that talented students who engage in essentially independent scientific research as junior colleagues of experienced scientists will develop rapidly in scientific maturity and scholarly competence. Further, these students will be better equipped for graduate study than their peers. The Foundation thus views undergraduate research participation as an effective means of increasing both the Nation's scientific capability and its strength in science education.

Also, through this program the faculty members gain a fuller awareness of the fact that science teaching has a greater impact if it includes student experience in the practical side of science—the exploration of the unknown—research. As a result of an initial experience supported by an Undergraduate Research Participation grant, many institutions have added some provision for research participation to their regular curriculum for upper division students.

It is widely acknowledged that the Undergraduate Research Participation Program makes a contribution to faculty members as well as to students. In these days of oversubscribed classes, it is refreshing for a teacher to be able to work on a one-to-one basis with an eager, inquiring young mind. Furthermore, in many of the smaller institutions a substantial part of the external research support for the summer work of faculty members is provided through this program.

In fiscal year 1968 there were 538 grants, amounting to $4,487,530, awarded for undergraduate research participation. These funds provide training for 3,711 undergraduate students.

PRE-COLLEGE EDUCATION IN SCIENCE

Improvement of the quality of science education at the pre-college level continues to receive considerable attention and support from the National Science Foundation. Over the years the various NSF educational activities for strengthening science instruction in the Nation's schools have made substantial progress, but much more remains to be accomplished.

Coupled with the readily identified needs are the emerging needs in pre-college science education that often call for new or modified approaches. For more than 15 years the Foundation has supported activities which assist individual teachers, both elementary and secondary school, in improving their knowledge of the subject matter of the sciences, and activities which assist in the development of modern courses and teaching materials. These efforts primarily bring about changes and improvements in actual classroom practices. To effect instructional reform on a broader scale the Foundation has more recently supported, under its Cooperative College-School Science Program, specially designed projects which help schools and school systems improve their science education programs. Current NSF activities for increasing the effectiveness of science teaching at the pre-college level include institutes and conferences, course content improvement projects, cooperative college-school science efforts, and various unique supplementary training projects.

The Foundation also provides modest support for special training opportunities for high school students; these efforts are aimed at identifying talented science students and encouraging and preparing those of high ability to pursue further scientific study. A few projects to assist students with limited educational opportunities to obtain a better grasp of science are supported on an experimental basis.

In awarding fiscal year 1968 funds for support of projects devoted to the reform of pre-college science curriculum, the Foundation took into consideration certain specific aspects of proposed projects. These included the degree to which modern advances in science or mathematics were reflected and then combined with the best of instructional techniques; the needs of school systems in implementing curricular improvements, based on new materials, in such a way as to assure a significant impact; and the prevailing need for experimental efforts in the implementation of unique school-wide reforms in science education.

Improvement of Instructional Materials

Sound teaching and learning require good instructional materials. Hence the Foundation supports collaborative efforts of a variety of specialists in developing and producing effective up-to-date course materials which are especially designed for science and mathematics instruction at the pre-college level.

As a result of NSF-supported projects, junior high school and high school texts which can be appropriately used in the standard curriculum now exist in mathematics, interdisciplinary science, chemistry, physics, biology, and earth science. Publication plans for high school texts in technology, geography, anthropology, and social science are well on the way. At the elementary school level, where course work was initiated somewhat later, parts of three separate elementary science curricula as well as a considerable number of mathematics texts are in definitive editions. Many pamphlets, monographs and other supplementary reading materials in a wide variety of scientific fields are now commercially available. Currently there are more than 400 such separate instructional items (excluding foreign adaptations and translations which number over 200) ready for classroom use. This number will be greatly increased in the next several years. Nearly 400 film items are now on the open market; other audio-visual aids bring the total to well over 600 items available to teachers and students. The National Science Foundation widely disseminates information about the new instructional materials; however, commercial sources produce and make such materials available for school use.

The educational community's strong interest in the new course materials is indicated by its ready adoption of two texts which first became available for school use in the 1967–1968 school year. They are *Introductory Physical Science,* a junior high school interdisciplinary text which will be used by more than 500,000 students in 1968–1969, and *Investigating the Earth,* a senior high school text on earth science which may serve about 300,000 students in the same period.

During fiscal year 1968 significant progress was made toward completing course content projects of long standing and making way for a second generation of curriculum development. Among the projects nearing completion are the Biological Sciences Curriculum Study (University of Colorado); the Elementary Science Study (Education Development Center, Newton, Mass.); and the Anthropology Study Project (American Anthropological Association).

Among the recipients of fiscal year 1968 grants for new curriculum improvement projects are:

- The Social Studies Education Consortium, Boulder, Colo—for coordinating curriculum improvement efforts, assisting in teacher education, and disseminating information on social and behavioral sciences.
- The University of California, Berkeley—for conducting preliminary studies on a biomedical technician curriculum.
- A number of organizations, including the Regional Education Laboratories whose basic support is provided by the U.S. Office of Education—for the implementation of curriculum project materials.

A recent study [3] provides convincing evidence that NSF course content improvement efforts are effectively stimulating curriculum reform in the Nation's high schools. Findings show that seven out of eight outstanding innovative curriculum practices adopted by the high schools that were covered in the survey (72 percent of the accredited high schools of the 50 States) had been developed by NSF-supported study groups for pre-college science education. The Foundation projects and the percentage of their adoption among schools surveyed range from 3.5 percent for the *Secondary School Science Project* to 43.2 percent for the *Physical Science Study Committee,* materials (secondary school physics).

The time is fast approaching for the new generation of scientists and educators to develop the next generation of curricular materials, taking into full account the role of computers, television and other means of communication, new ideas on the reorganization of classroom activities (team teaching, individualized instruction, laboratory activities, etc.) and new knowledge of the learning process.

---

[3] Special Study: *How High Schools Innovate Nation's Schools,* April 1967, North Central Association of Colleges and Secondary Schools.

Cooperation in School System Improvement

The Cooperative College-School Science Program (CCSS) supports projects in which colleges, universities, and similar institutions collaborate with school systems to bring about improvements in elementary and secondary school science and mathematics programs. These projects effect changes in the schools through sequences of carefully designed activities which may include, for example, the subject-matter training of teachers and administrative personnel, the adaptation of courses and curricula to local needs, and arrangements by which college personnel assist teachers through visits to school classrooms. Often the projects are related to the introduction of new curricula which have been developed by groups of scientists and educators. The schools are committed to effect in their science and mathematics programs the reforms which are developed as a result of the collaboration, and the colleges are committed to assist the schools in this endeavor.

Most projects involve a college and a single school system or a limited number of schools in the accomplishment of desired school improvements; however, an entire State or a larger geographical region can be involved. For example, a relatively large region will be served by a Foundation-supported project in the earth sciences being conducted by the University of Colorado. The Earth Science Curriculum Project has developed a secondary school science course which is ready for adoption and as a means of introducing it into cooperating schools of five inter-mountain States, the University of Colorado will train 80 teachers from six population centers of those States.

An elementary school curriculum effort that is geographically broad in scope is the mathematics project being conducted by Webster College (Missouri). This project provides supplementary training for a substantial number of teachers in several large city school systems, and focuses on the Madison Project mathematics materials and instructional methodologies at the elementary level. The materials have special applications in instructing educationally disadvantaged students. This project has been in operation for several years; NSF funds awarded in fiscal year 1968 support activities in Los Angeles, Chicago, New York, and Philadelphia.

Currently the Cooperative College-School Science Program is the only NSF activity that provides training in modern science and mathematics for elementary school teachers. Having discontinued support for institutes for elementary school personnel, the Foundation has endeavored to increase the funds for projects at this level in the CCSS Program.

In fiscal year 1968 there were 88 grants, totaling $3,386,732, awarded in the Cooperative College-School Science Program. This represents an increase of about 50 percent over last year's support (56 grants, totaling $2,296,295).

Activities for Secondary School Students

NSF activities directed to secondary school students are primarily focused on identifying the select, high-ability students who have the qualifications needed to become scientists, mathematicians, and engineers; and having identified them, to strengthen their interest in science and increase their motivation toward pursuing science careers. This is done by providing opportunities for these students to experience close intellectual contact with competent and dedicated scientists.

In 1968, through its Student Science Training Program (Pre-College), the Foundation afforded opportunities for 5,300 high school students to spend from 5 to 10 weeks during the summer on college campuses or in qualified research institutions. In these settings, the students receive college-level instruction; and, in many cases, work on the research projects of experienced scientists who provide close direction so that students are integrated in a meaningful and substantial way in an ongoing research effort. Approximately 850 additional students receive comparable training on a commuting basis during the academic year.

The Student Science Training Program (SSTP) is the only broad-scale activity in the United States providing a sustained instructional effort which concentrates on students who are succeeding in secondary school and, in particular, in secondary school science. Intentionally the intellectual level of projects receiving support is high and the participants chosen are expected to be able to respond successfully to the challenge of sophisticated work in mathematics and science. The program thus stands in sharp contrast to the many activities instituted by school systems which provide summer remedial work in science and in other disciplines for students whose progress is viewed as marginal.

Other NSF-supported activities for pre-college students include: a few student seminars in science, each providing for science-oriented students a series of eight to ten lectures during the academic year; assistance provided to junior academies of science to help defray costs of bringing outstanding students to State-wide meetings to present reports on scientific projects on which they have worked; and the Holiday Science Lectures, which make it possible for audiences of 300 to 500 students to attend series of lectures presented by outstanding scientists during the spring and winter holidays in various cities across the country.

The history of one student project deserves special comment. For several years the Foundation supported a mathematics talent search conducted by the University of Wisconsin. This provided for the distribution of a series of challenging mathematical problems to high schools throughout the State of Wisconsin. Students mailed in their solutions, and those with the best records were brought to the university campus at the end of the academic year for a day of conferences with the mathematics faculty. In 1966 the University of Wisconsin cooperated with Stillman College, a predominantly Negro school in Alabama, in initiating a similar project in Alabama. This activity has continued through 1968. Results have been so satisfactory that the University of Alabama is now planning to participate with Stillman College in the project, thus allowing the University of Wisconsin to attempt to extend the project to other States where interest is developing.

Systematic studies designed to evaluate aspects of the Student Science Training Program have been made and have shown that substantially all SSTP participants ultimately enter college, where a high percentage major in science and aim toward careers in the sciences. A study completed in 1968 reports on the SSTP students of 1960 at the point of their college graduation. It shows that 73 percent of the young men were majoring in physical sciences, engineering, mathematics, or biological sciences. An additional 12 percent were majoring in the social sciences or the health professions. Furthermore, "science" was a first occupational choice of 69 percent of the young men and 50 percent of the young women.

Data such as these cannot demonstrate the validity of the SSTP as a force contributing to the supply of scientists in the United States; yet they are compatible with objectives of the SSTP experience and lend support to the intuitive judgment of college teachers who have worked in these projects that they are significant in increasing the interest of high-ability students in science, encouraging them to further study of the science disciplines and motivating them to make career choices in the sciences.

In fiscal year 1968, support for 139 projects, totaling $1.9 million, was awarded in the Student Science Training Program.

Pre-College Teacher Education Activities

The quality of instruction provided by the Nation's schools is dependent to a large extent upon the competence of teachers. Rapid changes in scientific knowledge, coupled with initial training which emphasized teaching techniques rather than the substance of science, have created serious problems for many teachers of science and mathematics. Consequently the National Science Foundation places strong emphasis on the supplementary training of teachers of these subjects, particularly at the secondary school level.

Teacher-training institutes have been the most notable of the Foundation's support efforts for upgrading the subject-matter knowledge of pre-college science and mathematics teachers. These group training activities, specially designed for meeting the needs of groups of teachers with similar professional backgrounds, are organized and conducted by universities and colleges throughout the United States. The earliest NSF-supported institutes (summer institutes of 6 to 8 weeks' duration) date back to 1953.

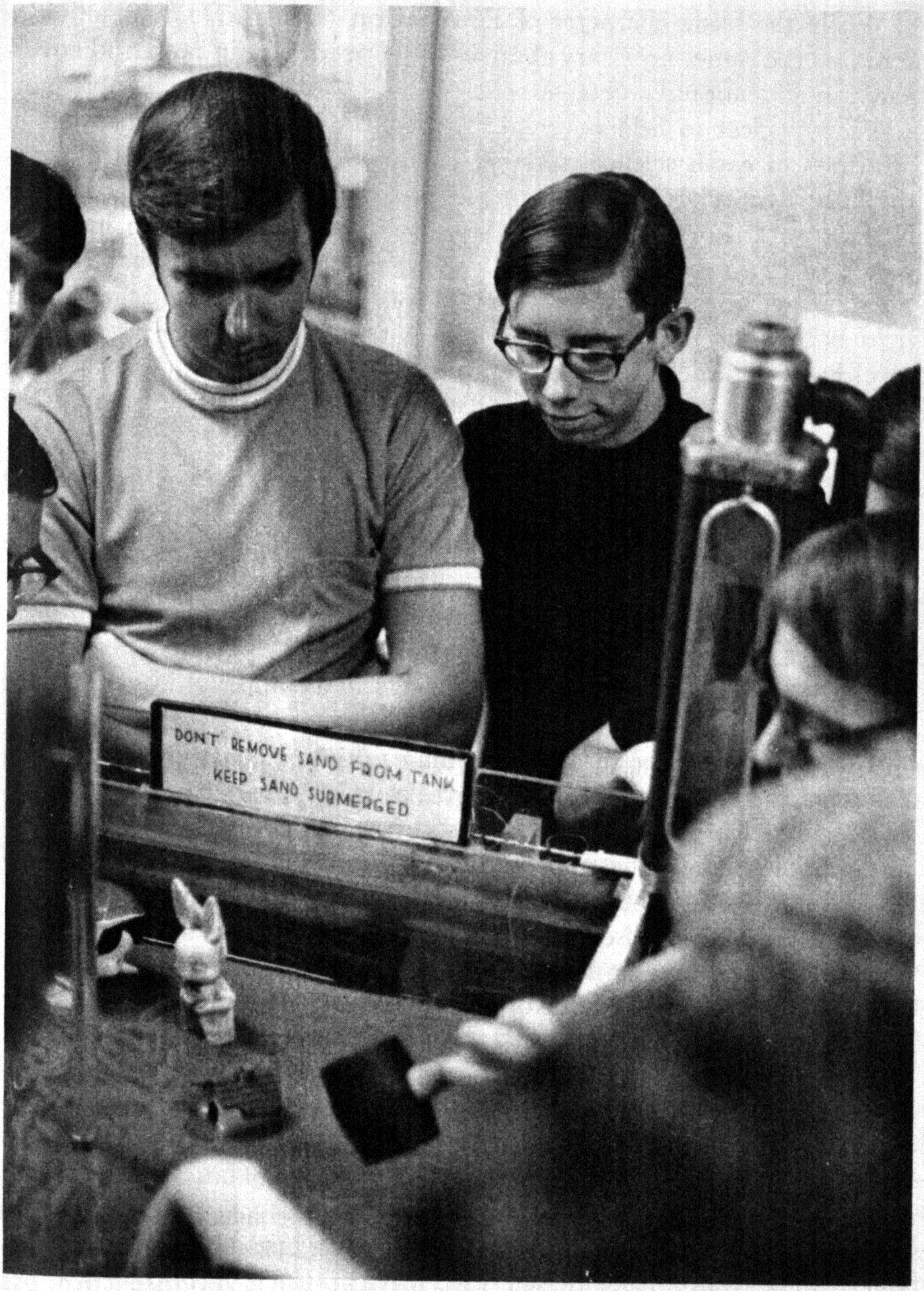


Photo Northwestern University

High school seniors attending a summer institute at Northwestern University study the characteristics of quicksand and how it can develop in wet, sandy soils. Using a rubber mallet, the lecturer demonstrates how shock waves from a pile-driver will affect nearby objects on sandy soils where quicksand conditions exist.

While the basic character of Foundation teacher-education activities remains the same, necessary changes have been made in both field coverage and educational objectives.

With respect to field coverage, there have been increases this year in offerings in earth science, physics, engineering science, and sociology—the latter two relate directly to new curricular materials developed under NSF grants. Correspondingly, there has been a decrease in institutes which offer a mixture of sciences, to correspond with a national trend of greater specialization by secondary school teachers. Overall, the subject field balance of the programs continues to approximate very closely the teaching assignments of the Nation's teachers. Within the major fields the increase in institutes and projects in computer science, from 30 last year to 51 this year, is specially noteworthy.

The educational objectives of a majority of the teacher-participants continue to emphasize both remedial training and updating in science, and these needs are principally met by Summer Institutes and In-Service Institutes. This year the In-Service Institutes program made a major effort to involve more of the teachers who have never attended institutes; the program has been increased by more than 10 percent in both participants and institutes, including projects in a number of local areas not previously reached.

In earlier years the in-depth training which culminated frequently in the teacher's earning a master's degree in science teaching was principally conducted in Academic Year Institutes. These institutes gave secondary school teachers the opportunity to study intensively, on a full-time basis for 9 to 12 months, an appropriate sequence of courses in the subject matter of their disciplines. Currently, however, the sequential component of the Summer Institutes is being enlarged to fill this function, while an increasing number of the Academic Year Institutes are being redesigned to provide advanced, specialized training for potential leaders in secondary school science. At the same time, other Academic Year Institutes are able to upgrade the academic level of their programs because their participants have improved their prerequisites in Summer or In-Service Institutes.

Approximately 450 Summer Institutes for secondary school teachers were awarded NSF support in fiscal year 1968 (18 of these received partial support from other sources). One institute will be conducted in Japan and one in Germany for the teachers of U.S. dependents.

Of the 61 Academic Year Institutes receiving support this year, 22 explicitly include instruction in the effective use of new course content materials, and 11 will train teachers for work with advanced placement courses in their school systems. A few institutes will prepare already competent science teachers for supervisory positions in the schools.

The In-Service Institutes, which offer instruction on a part-time basis during the academic year at colleges or universities, or at off-campus

Photo Duke University

Secondary school teachers attending a summer institute in biology at Duke University examine specimens gathered during a week-long field trip covering every part of the State.

centers, are much in demand. Classes are held on Saturdays or during after-school hours so that teachers may attend while still teaching full-time in their schools. In the 1968–69 school year the 307 NSF-supported In-Service Institutes will involve over 14,000 participants. This includes, at off-campus centers or regional campuses, over 3,000 teachers who do not have university instruction immediately accessible.

Institutes which provide specific background training for teaching the new curriculum materials will enroll more than 6,500 teachers, most of whom are committed to introducing these new materials in their classrooms. The subject-field trend of such institutes is toward the new projects each year, and this year gives substantial introduction to sociology, engineering science, physical science (junior high school), earth science, and physics.

In a continued effort to afford full flexibility in teacher education the Foundation is currently supporting 30 special projects for pre-college teachers and supervisors. These include summer conferences on elementary school science and mathematics materials for secondary school teachers and supervisors who are already well qualified in secondary school science and who, as a result of this training, will become resource persons in their school districts and will present local in-service training

322-215 O—68——13

Table 11.—*Pre-college Teacher Education Activities—Fiscal Year 1968*

Program	Proposals received			Grants awarded		
	Number	Participants	Amount	Number	Participants	Net obligations
Institutes for secondary school teachers:						
Academic year institutes	77	1, 837	$12, 321, 106	61	1, 446	$8, 449, 385
Summer institutes	667	28, 357	34, 859, 948	450	19, 718	21, 959, 585
In-service institutes	366	16, 674	5, 079, 936	307	14, 285	3, 653, 456
Summer conferences	25	1, 109	558, 659	14	433	162, 301
Subtotal	1, 135	47, 977	52, 819, 649	832	35, 882	34, 224, 727
Research participation for high school teachers	73	560	1, 266, 135	62	377	777, 306
Supplemental projects for secondary school personnel	32	3, 219	608, 016	22	1, 430	274, 101
Supplemental projects for other pre-college personnel	27	3, 342	205, 592	15	1, 252	183, 565
Subtotal	132	7, 121	2, 079, 743	99	3, 059	1, 234, 972
Total	1, 267	55, 098	54, 899, 392	931	38, 941	35, 459, 699

NOTE.—Total number of proposals received and grants awarded include double count on combined activities: i.e., 28 combined summer-inservice institutes, 2 combined academic-year institutes and supplemental projects, 3 combined summer institutes and supplemental projects, 1 combined conference and supplemental project, and 5 combined supplemental projects.

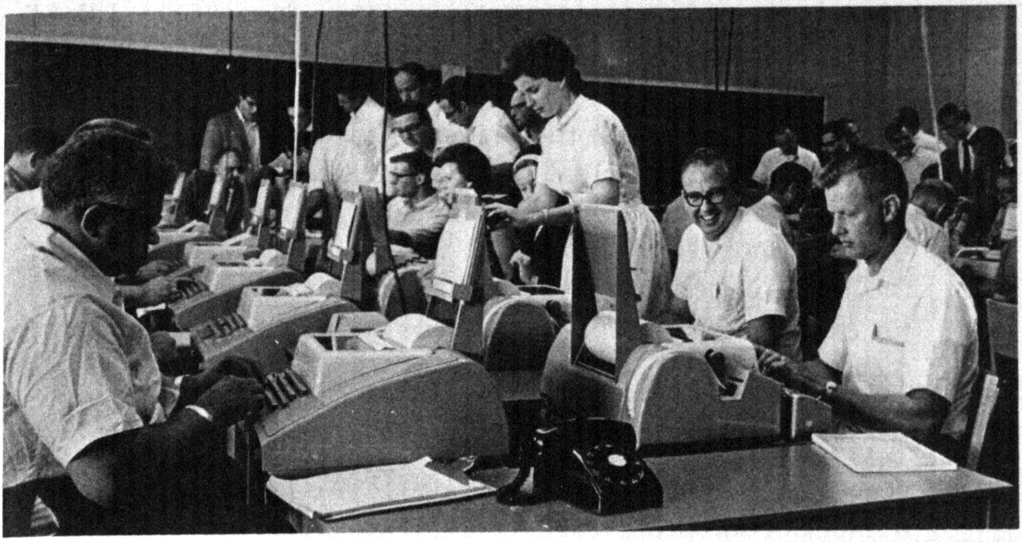


Photo Polytechnic Institute of Brooklyn

High school teachers from Suffolk County, N.Y., are taking part in a 6-week training course at the Long Island Graduate Center of the Polytechnic Institute of Brooklyn. The program is training participants in the use of time-sharing computer terminals for teaching of physics, biology, chemistry, mathematics, and social studies at local schools in the fall of 1968.

for their elementary school colleagues. Another effort provides training for a group of teachers from small colleges in Georgia. These teachers will in turn conduct, under Title I of the Elementary and Secondary School Education Act, in-service training centers in mathematics for elementary school teachers throughout the State of Georgia.

For science and mathematics teachers whose primary responsibilities involve the teaching of educationally disadvantaged students, 81 projects, offering 2,800 training opportunities, were awarded support in fiscal year 1968. This instruction benefits local teachers in Puerto Rico and the Virgin Islands, Negro teachers attending projects conducted at predominantly Negro colleges, Appalachian area teachers attending projects conducted at colleges in that area, local Spanish-speaking teachers attending programs conducted in southernmost Texas, and teachers in ghetto schools of Chicago, Detroit, and Washington, D.C. (In addition, teachers of educationally disadvantaged students are included in hundreds of other NSF-supported training projects designed for science and mathematics teachers in general.)

Special Projects in Pre-College Science Education

The Special Projects in Pre-College Science Education program was developed 2 years ago to support small-scale experimental projects, usually one-of-a-kind efforts. This year 14 such projects were supported for a total of $480,765.

To illustrate the character and diversity of these special activities the following projects are cited:

- A joint effort involving the Delaware State Department of Public Instruction and the University of Delaware is designed to implement the curriculum program "AAAS Science—a Process Approach" throughout the State of Delaware. This is being done by training the principal or a key teacher in each elementary school who will then develop programs to instruct other teachers in the school. The pilot project was started with resources from the State of Delaware. Now the Foundation is supporting a major extension of this pilot endeavor in order to give this implementation technique the broadest distribution possible across the State.
- A project being conducted at the Lawrence Hall of Science, University of California (Berkeley), will give training to a sizeable number of substitute teachers of science so that they may provide more effective secondary school instruction in science when serving as substitutes. With a cadre of substitutes so trained, the project will focus on its primary objective which is to bring entire science departments from selected San Francisco Bay area schools to work and study for 2-week periods at the Lawrence Hall. While these professional teachers are away from their normal teaching duties as a result of this activity, their places in the classrooms will be taken by the previously trained substitute teachers. The training of the professional teachers will continue after the initial 2-week intensive experience through periodic follow-up sessions also to be held at the Hall.

Table 11 provides a statistical summary of the Pre-College Teacher Education Activities, Fiscal Year 1968.

PUBLIC UNDERSTANDING OF SCIENCE

Projects directed toward increasing the public's knowledge of scientific facts and the role of science in contemporary times are supported under this activity. Among the various approaches are projects designed to enhance the subject-matter knowledge of professional communicators, who in turn can transmit knowledge and understanding to others; projects aimed at reaching a large number of people through educational television programs; and other kinds of efforts which are supported usually on an experimental basis.

Fiscal year 1968 grants for public understanding of science totaled 13, amounting to $295,255.

In a very real sense all NSF educational activities contribute to public understanding of science because the improvement of science education inherently makes for better informed scientists, teachers, students, and consequently citizens in general.

INSTITUTIONAL PROGRAMS

Federal programs of institutional support for academic science—as distinct from support for scientific activities of specific individuals—have in recent years assumed a variety of forms. One of the broadest of these is to provide assistance for the general ongoing activities of the institution, to be used at the discretion of those charged with responsibility for its management. Other programs may be for construction of instructional and research facilities, or for block support of graduate student stipends and general institutional costs associated with the training of graduate students. Still others may be for more specifically defined institutional purposes such as development of one or more departments or areas of science or engineering.

With the introduction of new programs to meet the growing needs of academic science, there has been an increasing recognition of the desirability of expanded institutional support from agencies of the Federal Government. While this has been expressed in a variety of ways, there has been rising interest, in recent years particularly, in the concept of broad formula-based institutional grants to help institutions meet critical financial needs generated by mounting student enrollments, ever-increasing demands for service to the community, and pressures created by rising costs of all kinds.

Evidence of growing concern for the problems of academic institutions is found in such proposals as that of the so-called Miller Bill (H.R. 875), which was introduced for consideration in the second session of the 90th Congress. At the end of fiscal year 1968, congressional hearings were initiated on this proposal to establish a "national institutional grants program" to be administered by the Foundation. The draft bill proposes authorization for distribution of $150 million annually to be allocated among institutions of higher education on various statistical bases. While action was incomplete as of the close of the fiscal year, the proposal is considered worthy of mention as an indicator of current interest in many quarters in large, broadly based institutional support programs.

In recognition of the need for institutional support, the Foundation has, over the years since 1960, established a variety of institutionally oriented programs in response to the dynamic needs of science and science education in institutions of higher education.

A number of these, although fundamentally aimed at broad institutional needs, are not classified as institutional programs within the Foundation and, accordingly, discussion of these will be found in other sections of this report. Examples are the Traineeship Program, the institutional portion of the Sea Grants Program, and the Computer Science Support Program. This section is confined to those areas of support specifically classified as institutional programs within the Foundation. These include two directed at maintenance of institutional strength in science; namely, the Institutional Grants for Science Program and the Graduate Science Facilities Program. Also included are three principal efforts directed toward assistance in the development and improvement of capability for scientific research and education. These are the University Science Development Program, the Departmental Science Development Program and the College Science Improvement Program.

During fiscal year 1968, the Foundation continued the institutional programs enumerated immediately above, obligating a total of $83.2 million for grants aimed at the broad goals of institutional assistance of education and research in the sciences. These obligations were distributed among the several programs as shown in the following table. The operations of the individual programs during the past year are discussed in the following sections.

Table 12.—*Obligations for Fiscal Year 1968*

[Millions of dollars]

Program	Amount	Number of grants	Number of institutions	Number of States
Maintenance of Institutional Strength:				
Institutional Grants for Science	$14.2	497	497	[1] 50
Graduate Science Facilities	17.8	50	38	25
Development of Science Capability:				
University Science Development	29.6	9	9	9
Departmental Science Development	12.0	22	22	17
College Science Improvement	9.6	55	55	28

[1] Grants were also made to institutions in the District of Columbia and Puerto Rico.

INSTITUTIONAL GRANTS FOR SCIENCE

The maintenance of strong university and college science programs requires that educational institutions have funds available for use according to their own judgment and discretion. Such discretionary funds provide institutional administrators a modest but essential margin of control over their research and instructional activities and permit these officials to adjust to particular changing circumstances of the institution. The Foundation's Program of Institutional Grants for Science is designed to help meet this need.

Through its Institutional Grants for Science Program the Foundation, in fiscal year 1968, awarded $14.2 million in such grants to 497 colleges and universities in all 50 States, the District of Columbia, and Puerto Rico. The grants ranged in amount from $1,500 to $137,623. Grants of more than $100,000 went to 49 institutions, and 76 institutions participated in the program for the first time.

As in prior years, the amount of awards in 1968 was determined by applying a graduated arithmetical formula to the total amount of the grants the university or college received during the period April 1, 1967, to March 31, 1968, under the Foundation's programs of support for basic research, undergraduate research participation, and research participation for college teachers. The formula matched the first $10,000 of these grants. The 1968 formula was the same as that used in the 2 preceding years. However, due to limited funds, the Foundation was unable to award the full tapered amount above the matching portion, and it was necessary to reduce each award by 15 percent of the portion above $10,000, so that the largest Institutional Grant amounted to somewhat less than $138,000. Although all institutions receive grants proportional to the amount of Foundation research and research-training support, the graduated formula gives greatest relative benefits to colleges and universities in the middle and lower dollar ranges of such support.

The annual reports which are received from institutions receiving the grants continue to show that the funds are used for a broad range of purposes even among institutions of the same general type and size. About half of the expenditures are for the purchase of research and instructional equipment. Other frequent uses are for the initiation for faculty research projects, especially of younger faculty members in the lower academic ranks; payment of stipends to student research and teaching assistants; acquisition of books and periodicals for science libraries; payment of charges for the operation of computers; renovation or construction of laboratory facilities; and the bringing of visiting lecturers and consultants to the campus.

Institutional officials continue to emphasize the value of Institutional Grants for Science because of the flexibility they afford in assisting in the fulfillment of scientific research and education responsibilities. Since the grants may be applied at the discretion of the institutional administration to any direct cost of scientific activities, they provide resources for financing unique needs of a particular university or college.

GRADUATE SCIENCE FACILITIES

The Graduate Science Facilities (GSF) Program supports the construction and renovation of graduate academic facilities for research and graduate education in all fields of science and engineering, excepting the clinical sciences. The program, established by the Foundation in fiscal

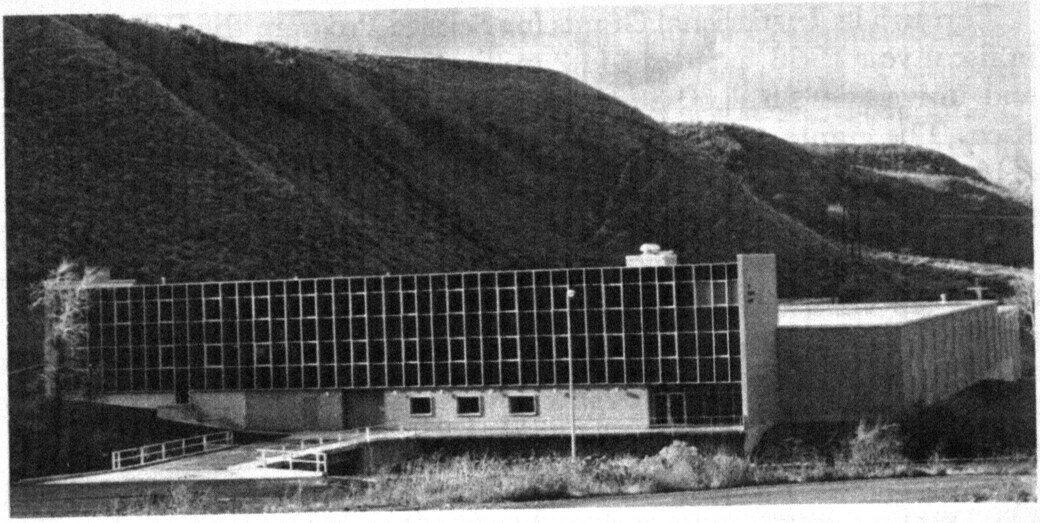


Photo Utah State University

Water Research Laboratory at Utah State University.

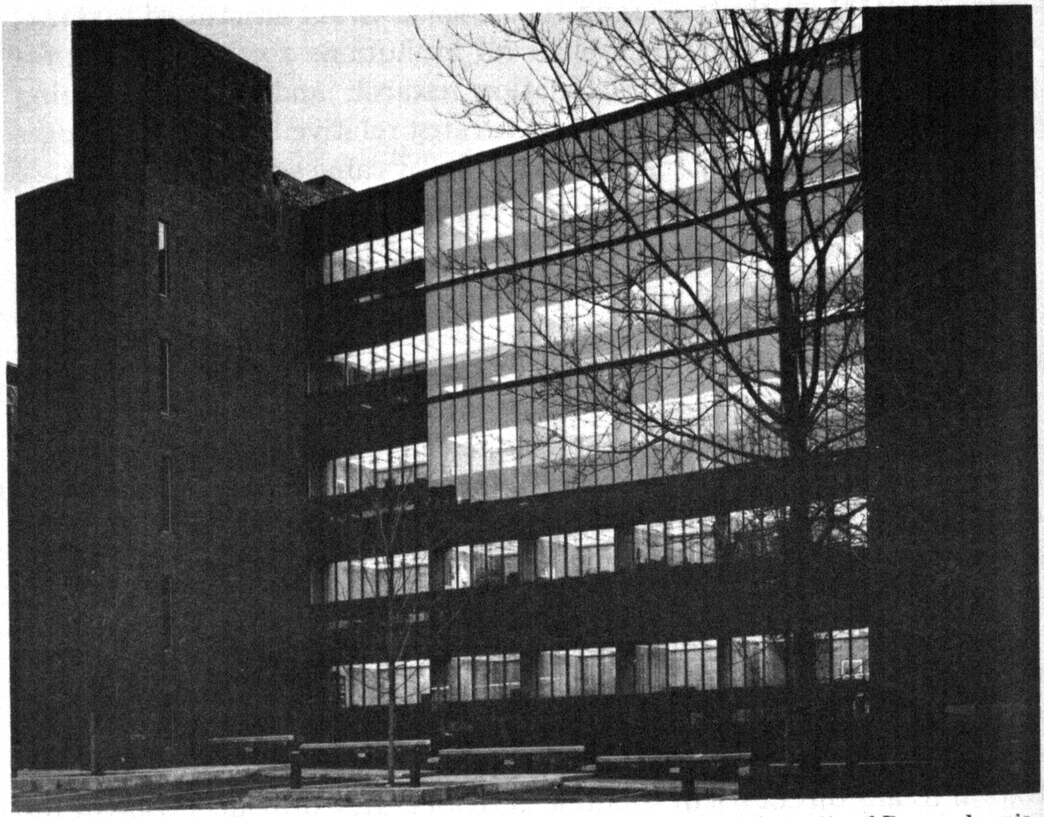


Photo University of Pennsylvania

Electrical Engineering Building at the University of Pennsylvania.

year 1960 to help maintain and strengthen academic institutions of established merit, has provided $178.9 million for facilities costing approximately one-half billion dollars. While other Foundation programs also support facilities, they do so only in connection with specialized program objectives. The Graduate Science Facilities Program provides support up to 50 percent of the cost for those institutional science areas that

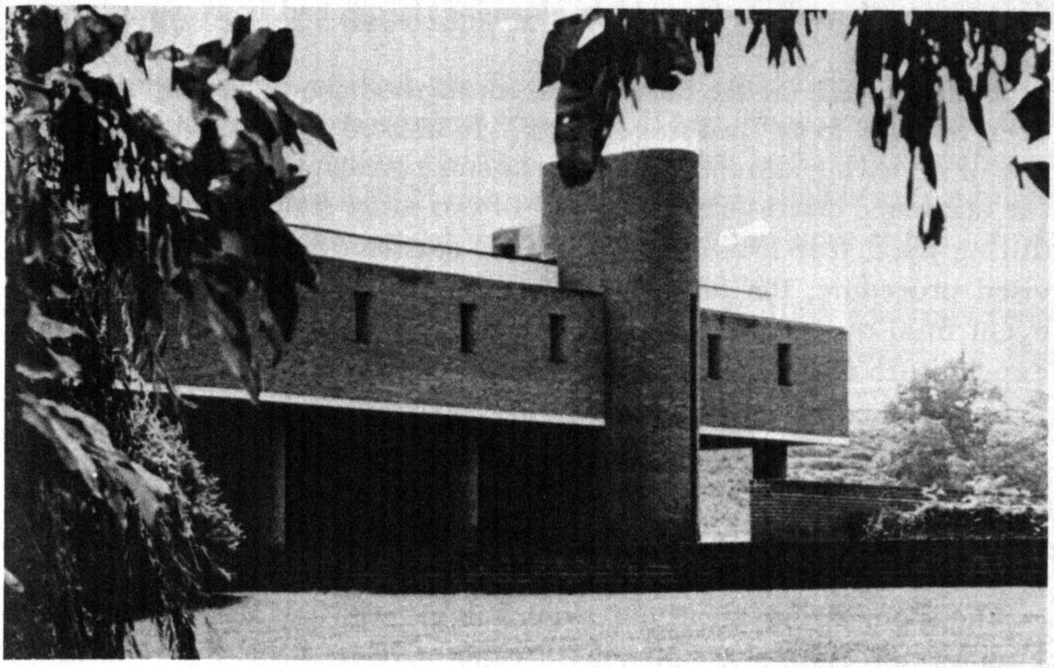


Photo Hollins College

Psychology Building at Hollins College, Virginia.

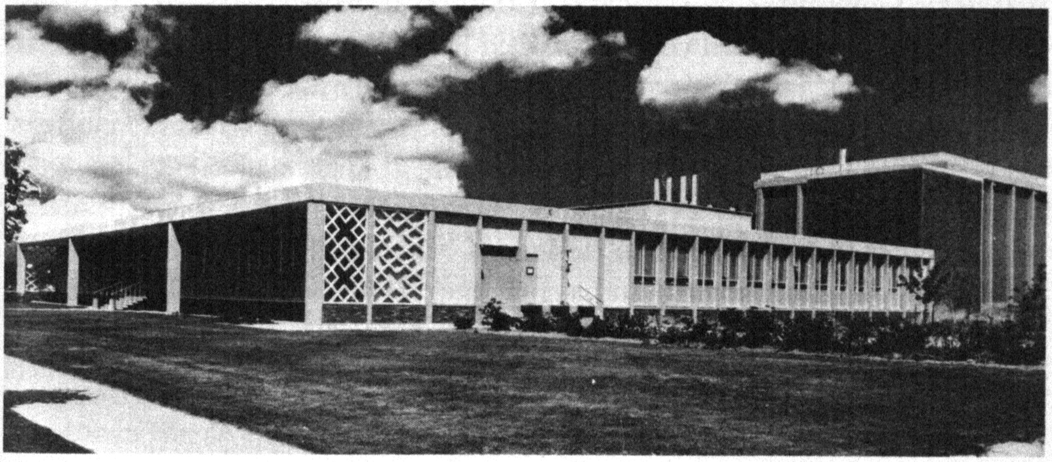


Photo Oregon State University

Nuclear Research Facility at Oregon State University.

have already achieved high levels of quality and where graduate training in science is an important aspect of institutional activity. Due to limitations of funding in fiscal year 1968, an administrative decision was instituted within the Foundation to limit the size of any single grant to $1.0 million. While it was recognized that in most instances such grants could be considered only "contributory" rather than "matching," it nevertheless seemed desirable, in view of the number of meritorious requests, to assist as many institutions as possible.

Awards totaling $17,830,671 for 50 grants to 38 institutions in 25 States were made. Forty-three of these were new grants. The other seven awards were made to as many institutions to proceed with the construction stage of projects for which planning funds had been awarded in prior years.

Awards made on the latter basis, mentioned above, have in the past been referred to as "two-stage grants." In accord with Foundation practice of reviewing administrative procedures to improve relationships with the academic institutions, the award of two-stage grants was reexamined during fiscal year 1968 and a simplified mechanism adopted. In the revised procedure, the full amount of the grant is awarded but, in the event final construction plans for the facility are not yet available, the expenditure of funds for construction is restricted until final plans have been reviewed by the Foundation. This procedure permits an institution to learn quite early what funds are available for its facility so that planning can proceed in an orderly and intelligent manner. Also, it provides timely support to those institutions that are restricted from planning for a facility beyond its initial stage unless construction funds are assured.

The Foundation maintains close liaison with the Health Research Facilities Program of the National Institutes of Health and the Graduate Facilities Program of the Office of Education through representation on the National Advisory Council on Health Research Facilities and the Advisory Committee on Graduate Education, respectively. In addition, the operating personnel of the facilities programs of the three agencies are in frequent and close communication to increase their effectiveness.

Through a small Architectural Services Staff, the Foundation offers assistance to universities in their planning for more efficient and safe facilities. In a number of instances, preliminary reviews have pointed out areas of improvement in design of the structure itself or of such aspects as air conditioning and ventilation systems. Hazards have been found and the attention of the institution directed toward their elimination.

SCIENCE DEVELOPMENT

Programs for University and Departmental Science Development and for College Science Improvement provide support for institutions already demonstrating strength and a potential to move toward the ranks of those having outstanding capabilities in science at the graduate and undergraduate level. Since fiscal year 1965 a total of $155.8 million has been granted by the Foundation to support implementation of institutionally generated plans for improvement in science and science education.

The accompanying map locates recipients of development-type grants awarded to date. Institutions represented are those with great potential for growth and improvement in quality. In most instances, they are located in major population centers where demands for higher education are heaviest.

University Science Development

Fiscal year 1968 marked the third complete year of operation of the University Science Development Program. Hence, those institutions that had received grants during the first year and that had made significant progress toward their initially proposed goals were eligible to apply for supplementary grants to assist them in achieving the goals of the fourth and fifth years of their development plans.

A total of $29.6 million was awarded in FY 1968 for university science development. Five institutions received initial awards in the amount of $22.9 million. These were: Florida State University, Michigan State University, University of Georgia, University of Iowa, and the University of Washington. A supplementary grant was made to Case Western Reserve University, one of the first awardees, in the amount of $2.2 million to assist the university further in achieving its long-term development goals. Also, additional funds, amounting to $4.1 million, were awarded to the Indiana University for the design and building of a 200 Mev cyclotron. This was a joint undertaking with the Foundation's Specialized Physics Facilities Program, the latter providing $2.0 million of the required funds. During the current fiscal year the Foundation also awarded two 3-year "special" development grants totaling $2.4 million to the University of Kentucky and the University of Tennessee. These special grants are similar in concept to the grants awarded under the University Science Development Program but the development objectives are more limited in scope. Thus, to date, 29 institutions have received USD awards in the sum of $126.1 million and 6 have received special development grants ($5.6 million) in response to proposals submitted to this program.

The institutions receiving grants under this program make a substantial commitment of their own funds in order to achieve the planned improvement. While the extent of their participation is an important factor in the overall determination to award a grant, there are no specific matching requirements.

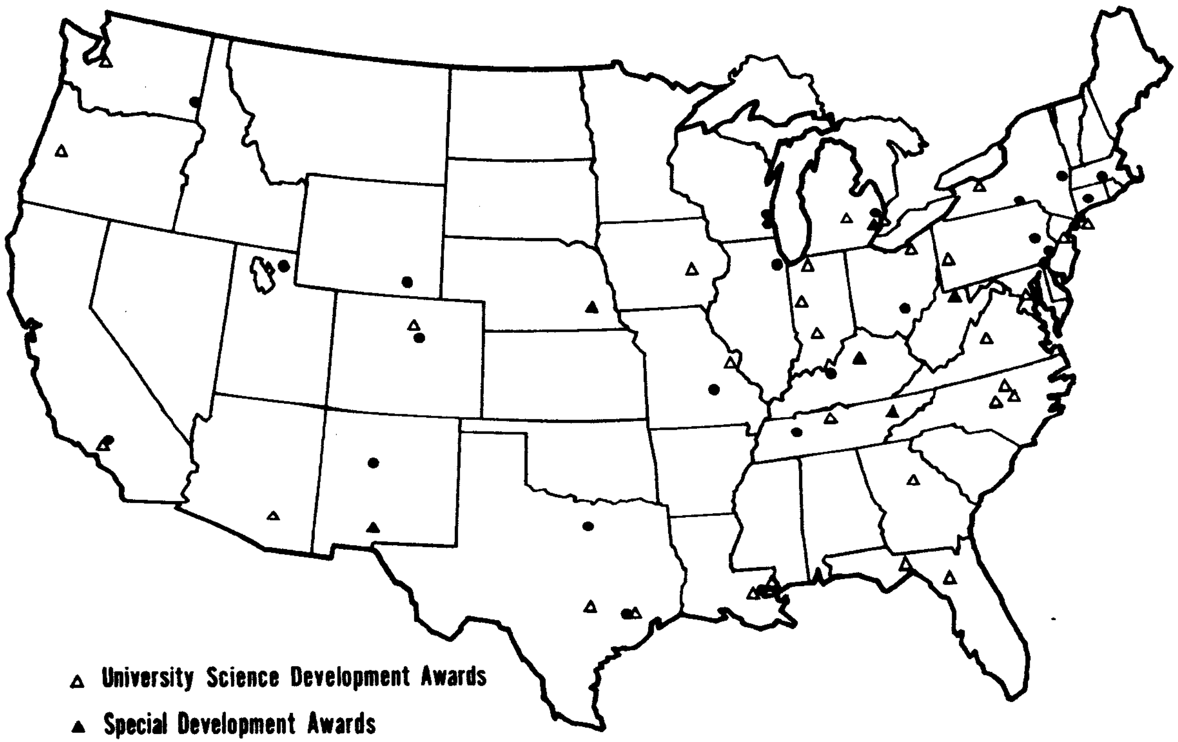
In accordance with the plans submitted by the institutions, Foundation funds made available have been allocated, in aggregate, as follows: personnel (faculty, postdoctoral students, graduate and undergraduate students, and technical and clerical staff) 39 percent; equipment and supplies, 34 percent; and facilities (renovation and new construction) 27 percent.

Annual reports furnished by recipients of the grants continue to stress the salutary effects of such aid in accelerating and extending institutional planning, not only for the areas supported by the grants, but for other parts of the universities as well. These effects include self-appraisals leading to better long-term planning, reevaluation of degree-granting programs, ability to attract funds from other sources, particularly from donors in the private sector, and increased quality of uni-

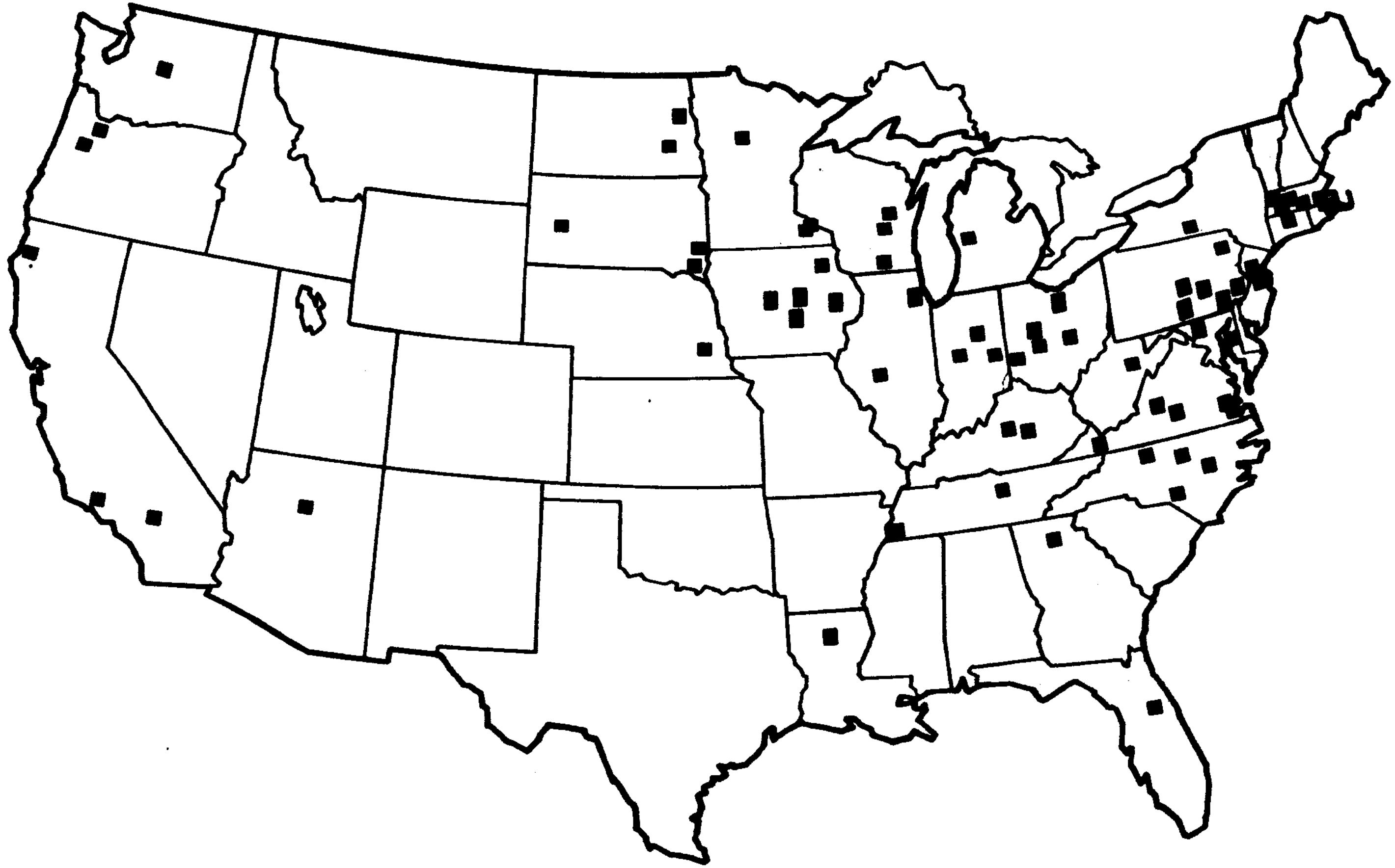
NATIONAL SCIENCE FOUNDATION

INSTITUTIONAL DEVELOPMENT AWARDS AS OF JUNE 30, 1968

Number of Institutions - 61 Total Obligations - $143.7 Million



Number of Institutions - 70   Total Obligations - $12.1 Million



■ College Science Improvement Program Awards versity faculty and graduate students—a key to the success of the improvement plans.

Understandably, it will be several years before the full impact of the program can be documented. However, several important tentative conclusions about institutional management, development, and change are already emerging:

1. There is complete agreement among recipient institutions that this type of support provides necessary and adequate flexibility to design and shape the priorities of the university for quality upgrading.
2. It is accepted that the emphasis on continuous institutional planning is requiring university administrators to reevaluate academic programs systematically and is providing an opportunity and impetus for redressment of existing imbalances. Recognition of the value of continuous institutional planning may well turn out to be the most important outcome traceable to institutional development programs.
3. Now that institutions are gaining more meaningful experience with institutional development programs and as supplementary grant requests are readied, a most useful opportunity is presented for identifying reliable institutional performance indicators. Hopefully, in these new interactions within the academic community and between it and the Foundation, more will be learned about effective and ineffective approaches to various classes of institutional problems.

Departmental Science Development

The Departmental Science Development Program became fully operative in 1968. Grants are intended for support of one department or area of science judged by the institution to have great potential for qualitative improvement. It is expected that each activity supported will catalyze other parts of the institution, thereby providing a multiplier effect on institutional development.

After several months of experience in administering the program, it became apparent that certain changes in the original guidelines were needed. Accordingly two modifications were instituted. One was to remove the $600,000 ceiling on 3-year awards. The other was to change the permissible frequency for institutional application to an annual basis rather than at the expiration of an existing 3-year award. The latter modification is intended to permit greater continuity in the development program of institutions and to encourage them to move more rapidly in the development of additional areas of scientific activity.

In response to 47 departmental science development proposals received during fiscal year 1968, the Foundation awarded 22 grants, bringing the total number of grants since inception of the program in fiscal year 1967 to 26. The 22 awards in fiscal year 1968, totaling $12.0 million, were made to institutions in 17 States. Among the recipients were 13 public and 9 private institutions. Awards were made in all principal substantive areas of science and engineering. Five of the awards were in physics; four were in engineering; three each were in biology and mathematics; two each in chemistry, environmental sciences, and interdisciplinary activities—basically chemical-physics; and one in the social sciences. All of the awards, with one exception, were made for departments granting the doctorate.

In addition to the $12 million granted by the Foundation under the program, the 22 recipient institutions obligated themselves for slightly more than $37 million of their own funds, somewhat more than three-fourths of the total committed for the 3-year development plans. These institutional commitments do not include the support anticipated from other sources, predominantly other Federal sources, estimated at $17 million. Furthermore, the institutions have obligated themselves to continue support beyond the 3-year period for the major improvements made possible by the accelerated development, chiefly those involving expansion in manpower and related program categories.

About two-thirds of Foundation DSD funds have been obligated for additional manpower. Included are added faculty, graduate students stipends and cost-of-education allowances, postdoctoral traineeships, and provisions for visiting scientists and seminar speakers. Other obligations budgeted include funds for equipment and supplies, computers, renovation of existing facilities, and library resources.

College Science Improvement

A number of useful and encouraging developments have emerged from the first full year's experience with College Science Improvement Program (COSIP), aimed at strengthening the science capabilities of predominantly undergraduate educational institutions in a comprehensive way. Institutions have been encouraged to study carefully their current science education practices, clearly identify their improvement needs, and make long-range plans for achieving selected goals through a sequential set of science improvement projects.

The general utility of the guidelines published in November 1966 have been confirmed by the receipt of a good number of carefully formulated institutionwide plans for accelerating upgrading of the applicants' science potentials. Also, NSF administrative procedures have been considerably refined so that evaluating panels are reviewing more complete, more nearly comparable submissions than before. Improved guidelines are being prepared with streamlined report forms and the elimination of unneeded forms. Progress on Phase I of this program (grants to individual institutions for comprehensive projects) has reached the point where consideration is being given to projects for interinstitutional cooperation involving groups of 4-year colleges or universities and junior college consortia.

Seventy grants, representing a total amount of $12,087,410, have been made to institutions in 28 States since the program's initiation in 1966. Of these, 55, representing a total amount of $9,623,600, were made in fiscal year 1968. Grants were awarded in fiscal year 1968 by discipline and activity as shown in the tables below.

Table 13.—*College Science Improvement Program Activities, Fiscal Year 1968*

Discipline	Grants: Number	Grants: Amount	Grants: $ as percent of total
Disciplines Affected by Awards			
			Percent
Biology	41	$2, 017, 985	21
Chemistry	37	1, 245, 874	13
Earth sciences	24	476, 287	5
Engineering	2	51, 200	1
Mathematics	32	846, 900	9
Physics	42	1, 584, 155	16
Social sciences	26	978, 706	10
Interdisciplinary	11	500, 482	5
Multidisciplinary	29	1, 922, 011	20
Total		9, 623, 600	100
Type of Activity Affected by Awards			
			Percent
Faculty research and scholarly activities	43	$2, 288, 710	24
Local course and curriculum studies	44	1, 866, 510	19
Instructional equipment	47	3, 137, 000	32
Undergraduate student activities	29	795, 100	9
Other activities	42	1, 536, 280	16
Total		9, 623, 600	100

COMPUTING ACTIVITIES IN EDUCATION AND RESEARCH

The computer's remarkable power as an amplifier of human intellect and also as a reliable, quick performer of routine tasks has made it in a very short time a necessity in research and education activities. At the same time, despite substantial achievement and greater promise, its complexity and its cost have created problems in establishing priorities and supporting progress which are national in scope. (For a discussion of some of these problems see "Computers in Higher Education"—Report of the President's Science Advisory Committee, February 1967.)

Characteristically, the educational institutions are in the forefront in recognizing the potential of computers but they are constrained from exercising their natural leadership by the high cost of participation. Because of the burden to academic institutions of their increasingly heavy investment in computers, the Foundation has been providing for several years, through its various programs, greater support for academic computational facilities and operations.

Despite this support, it became clear that significant new Federal support would be needed if the potential uses of computers in education are to be realized in the early 1970's. This need was recognized in the President's Health and Education Message to Congress on February 28, 1967, which said, "One educational resource holds exciting promise for America's classrooms: the electronic computer. Computers are already at work in educational institutions, primarily to assist the most advanced research. The computer can serve other educational purposes—if we find ways to employ it effectively and economically and if we develop practical courses to teach students how to use it.

"I have directed the National Science Foundation working with the U.S. Office of Education to establish an experimental program for developing the potential of computers in education."

Because of the growth of support by the Foundation for computers in research and education and in response to the President's directive, the Office of Computing Activities was established on July 1, 1967. The principal objectives of this program of the Foundation are:

- to explore the role of the computer in education and research;
- to help academic institutions provide adequate computing services to faculties and students;
- to strengthen and expand educational and research developments in computer science.

322-215 O—68——14

To further these goals, the Foundation is working with educational institutions, industry and other government agencies. Several advisory groups consisting of leaders in computing technology, education and research were formed to help focus attention on the most significant developments and suggest solutions to important issues. An interagency committee was formed to help coordinate the support of computing activities by the Government. The staff of the Foundation has also learned a great deal about the opportunities and problems through conversation with several thousand interested persons and groups, studying several hundred proposals, conducting several score site visits to institutions and projects, and sponsoring a number of meetings.

In fiscal year 1968, the Office of Computing Activities obligated a total of $22 million, providing a total of 173 grants and contracts in assistance to some 350 colleges, universities, secondary schools and educationally related institutions.

Curriculum Development and Training

In order to give guidance to activities which might accelerate the use of the computer in undergraduate instruction, the Foundation sponsored a conference of outstanding educators in mathematics, statistics, chemistry, and physics. The conference report contains many specific recommendations for action by scientists in these four disciplines involving the entire undergraduate curriculum. It advocates, for example, the creation of new courses which permit the student to simulate on a computer the performance of complicated, and often expensive laboratory experiments or to systematically explore at an early point in his training complicated theoretical models which otherwise must await his acquisition of powerful mathematical techniques.

The effect of such a course would be that undergraduates could see the frontiers of science as only the advanced graduate students are able to view them today. The influence of these recommendations was reflected in 14 grants which the Foundation made to develop computer based instructional materials in mathematics, statistics, the social sciences, hydrology, geology, acoustics, physics and high school science, and in four grants for development of computer programs and equipment for education in mathematics, science, and engineering.

As new curricular materials are developed it will be necessary to train teachers in these methods. Five grants involved development of computer-related materials for and training of secondary school teachers, three dealt with vocational training and assistance to the disadvantaged student, two focused on the teaching of computer programing, three provided training of college science teachers, and two addressed the instruction of the outstanding student specializing in computer science.

Computer Assisted Instruction

One method of using computers in education which is receiving national attention is computer assisted instruction (CAI). Although experiments with these techniques have shown promise in some areas, there are computer hardware and software systems problems which must be solved before CAI can be successfully and economically implemented on any large scale. Also, teaching methods and curricular materials appropriate to CAI must be developed and tested through pilot studies. Eight grants were made to study teaching and learning processes, develop computer languages for preparing CAI course materials, and develop curricular materials in mathematics, geology, and programing. Two grants will address systems and hardware problems of CAI and two grants will provide pilot projects for testing the application of CAI to secondary schools and to remedial mathematics for underprivileged students entering college. Finally, two conferences were sponsored to review the state of the art and suggest requirements for further progress.

Computing Services

Today there are many new uses of computers on campuses and the number of computer users at educational institutions is increasing rapidly. In addition to their use for the large research problems of faculty and graduate students and the administrative functions of institutions, computers are being used as tools of undergraduate teaching. Some universities now require all freshman engineering and science students to study programming and encourage those in other disciplines to do so too. These students then use computers throughout their college careers. The social sciences are turning toward quantitative studies in research and instruction and the humanities are applying computers to research in literature, history, music, and linguistics.

Nearly all universities, many 4-year colleges, some junior colleges and community colleges, and a smaller fraction of secondary schools now make available to their faculty and students some kind of computing service for educational purposes. Most institutions without any equipment of their own are struggling with the problem of how and where to begin.

Because of the large investments in hardware and staff which are necessary to provide computing services and the technical complexities involved, institutions are facing difficult problems in adjusting their resources to accommodate this demand and in establishing facilities which will provide a sufficient variety of computing services. In response to this need, the Foundation provided financial assistance to 129 colleges and universities and 23 secondary schools to expand existing computing services or offer computing service for the first time. Some grants were made to colleges and universities to enable them to install computing facilities on their own campuses. Some were to enable institutions to share facilities or to use facilities located elsewhere through remote terminals.

As part of an experiment intended to determine the value and costs to educational institutions of sharing computers and developing related activities on a regional basis, 10 regional pilot projects were undertaken involving eight major universities, 79 participating colleges and 23 secondary schools located in 25 states. These projects were designed to make effective use of the intellectual leadership available in the major universities to help colleges and secondary schools explore the merits and limitations of regional computer network concepts in education, and to develop models which other institutions may wish to adapt to their own environments.

In addition, the Foundation sponsored several studies concerning the areas of computers and communications, university information systems, and university computing services. A survey by the Southern Regional Education Board was sponsored to examine the computing activities and investments of institutions throughout the country.

Computer Sciences

One of the most critical problems in computing is the shortage of qualified computer scientists to staff the faculties of educational institutions. The Foundation supported the development of academic computer sicence programs with grants to Colgate University, Johns Hopkins University, New York University, and Ohio State University. In addition, 21 grants were made to support activities in computer science for research and to train advanced graduate students.

Through these activities the Foundation has begun an integrated set of programs to help educational institutions explore and develop the full potential of computers in education.

SEA GRANT PROGRAMS

The National Science Foundation Sea Grant Program, as defined by the National Sea Grant College and Program Act of 1966 (Public Law 89–688), has as its mission the support of research and development, education and training, and advisory services which will enhance the nation's efforts to develop and effectively utilize marine resources. Two types of support, institutional and project, are provided under the program criteria first promulgated in September 1967. Institutional support is provided to institutions of higher education possessing the necessary facilities, staff, and experience in significant marine-related activities to conduct a program encompassing all of the areas listed above. Project support, on the other hand, may be awarded to qualified investigators for a specific activity in any one of the above areas.

In fiscal year 1968, $4,999,900 were obligated by the Foundation in the two major program categories. The following table is a summary of the types of grants awarded and the total amount of funding in each.

Table 14.—*National Science Foundation Sea Grant Program Awards, Fiscal Year 1968*

Category of grant	Number	Amount
Institutional	6	$2, 545, 600
Project grants:		
Coherent [1] projects	2	509, 000
Education and training	12	931, 100
Applied research and development	11	979, 000
Planning	2	35, 200
Total	33	$4, 999, 900

[1] Multidisciplinary studies.

During fiscal year 1968, 78 proposals were received which represented a wide variety of types, disciplines, institutions, etc. These proposals were submitted by more than 55 institutions in 28 States, including 22 coastal States and four bordering on the Great Lakes. Subject areas most frequently covered in the proposals were in the fields of food from the sea, engineering, ocean engineering curriculum development, marine technician training resource planning, and advisory services. By contrast,

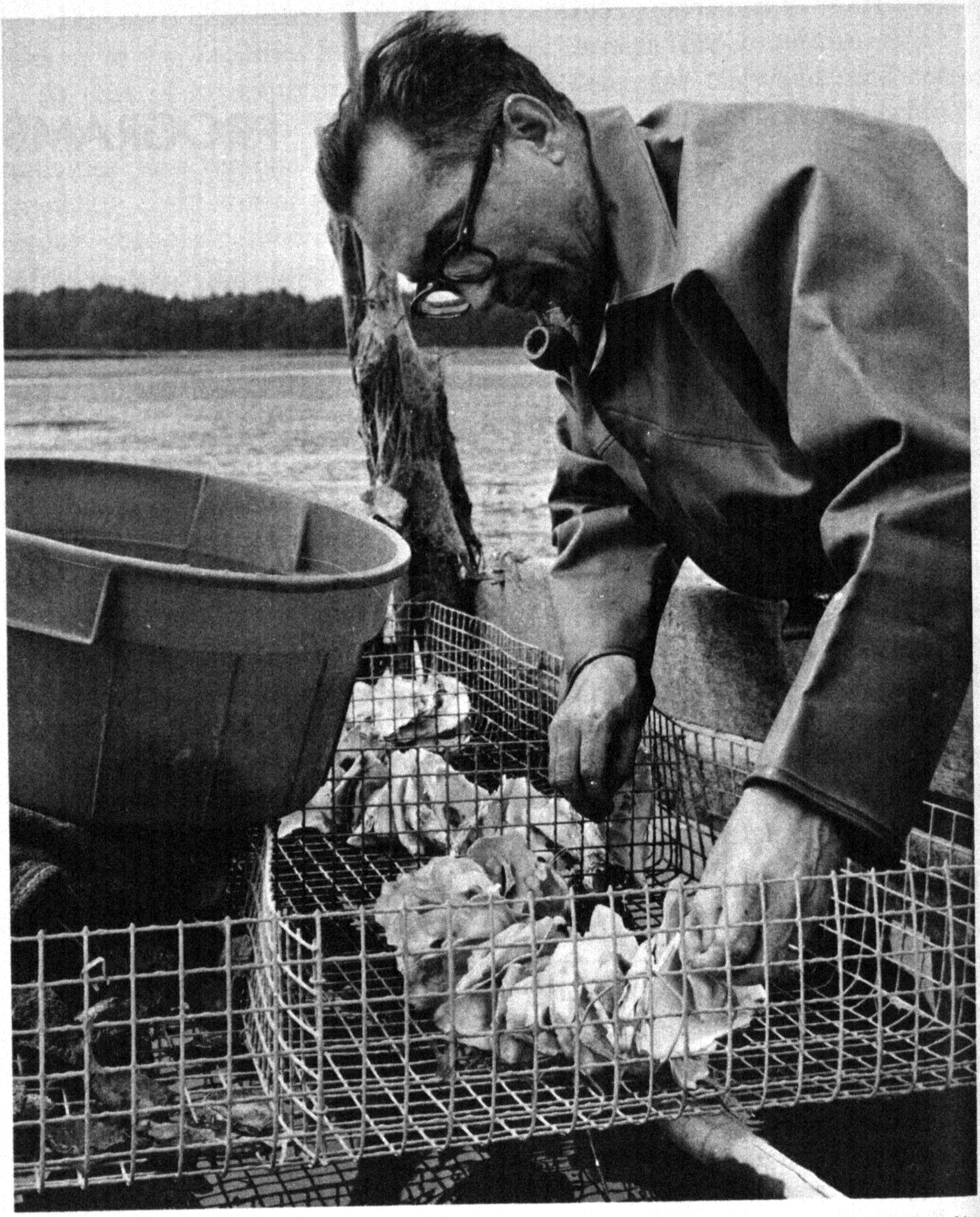


Photo Oregon State University

European oysters are prepared for planting as part of an aquaculture research project at Oregon State University. The oysters were spawned and hatched in the OSU Marine Science Center and planted in local waters for growth and survival studies. (Right) OSU researchers on the oyster flats gather samples in study of problems related to competition from shrimp and other invertebrates to the oyster bed.

very few proposals were received in the fields of minerals from the sea, drugs from the sea, economics, political science, and recreation.

Institutional Support

The following named six universities were awarded Sea Grant Institutional support: the University of Washington, Oregon State University, the University of Rhode Island, the University of Hawaii, the University of Wisconsin, and Texas A. & M. University.

The Sea Grant Program at each of these institutions consists of research, as well as education and advisory service activities, with the research varying from the use of acoustical techniques in marine resource location at the University of Washington to the development of precious coral as a resource at the University of Hawaii. The program at the University of Wisconsin will concentrate on the problems associated with resource development and preservation in the Great Lakes.

The Sea Grant program at Oregon State University includes a study of ocean law to be conducted by the University of Oregon School of Law and a training program for marine technicians at Clatsop Community College in Astoria. In addition to a wide variety of research projects, the University of Rhode Island will expand the advisory services provided to the region by its New England Marine Resources Information Program and supply training for needed technicians through its 2-year program in fisheries and marine technology. As part of its Sea Grant program aimed primarily at the marine resources of the Gulf of Mexico, Texas A. & M. University will develop two new technician training programs in cooperation with the Texas Maritime Academy, the James Connally Institute and Galveston Junior College. In most in-

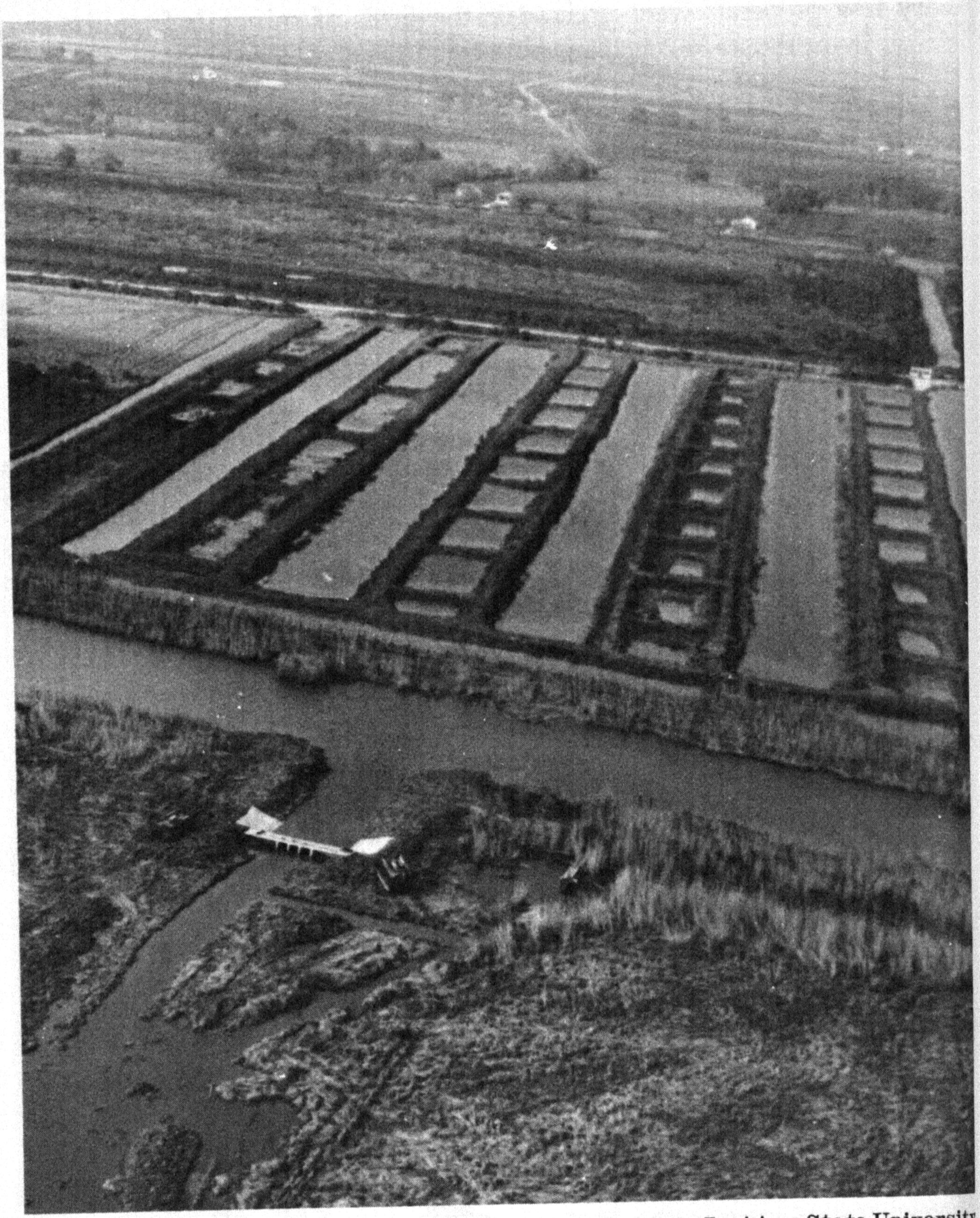


Photo Louisiana State University

At Louisiana State University the culture of redfish and pompano in brackish water ponds is being studied on the Rockefeller Refuge, Cameron Parish. Additional studies are being conducted in the brackish and fresh water marshes of the Louisiana coastal region. These waters are rich nursing grounds for shrimp, blue crab, and other fauna of economic significance.

stances, the educational portion of the programs will include support for additional faculty members to teach new courses on marine resources and support for graduate students on research or teaching assistantships.

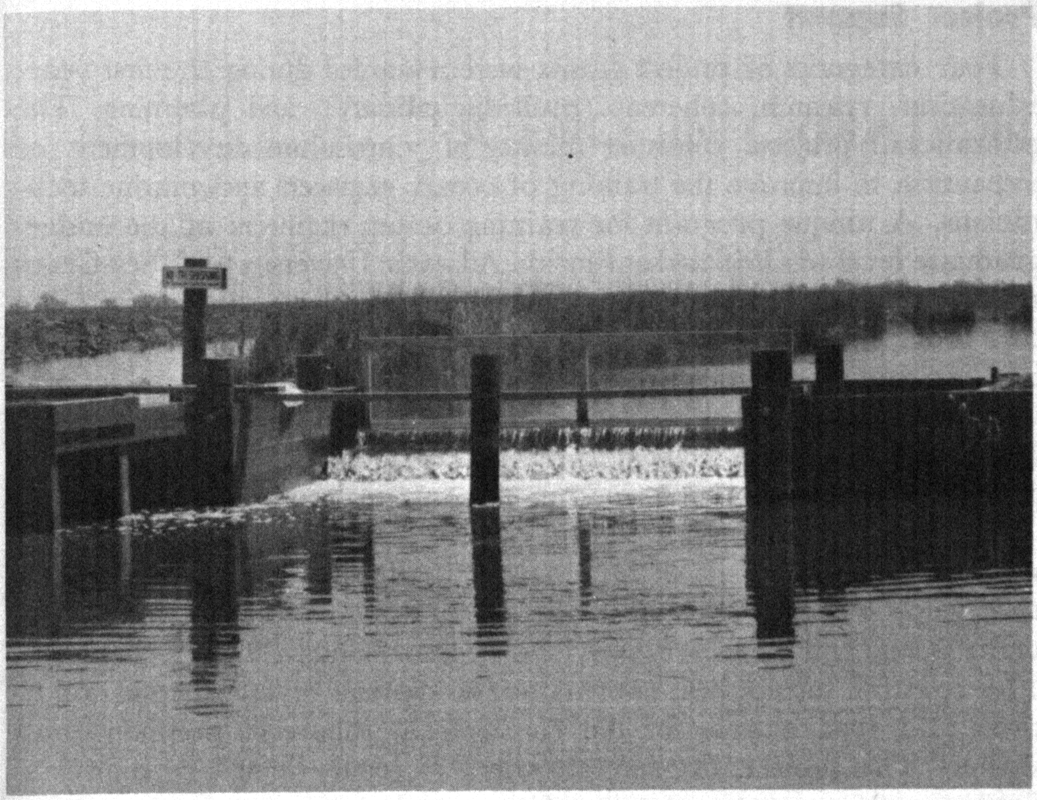


Photo Francis T. Nicholls State College

Research by biologists at Francis T. Nicholls State College, Louisiana, seeks to prove the feasibility of shrimp farming in impounded marshes and lagoons. Nicholls State staff and students observe the harvest of adult shrimp gathered by the net as upper level of water is drained.

Project Support

Four categories of project grants were awarded during the first year; education, research, coherent (multidisciplinary), and planning. The educational projects consisted mainly of curriculum development or expansion to improve the training of ocean engineers and marine technicians. A unique program for training ocean engineers at the undergraduate level was initiated at Florida Atlantic University with Sea Grant support. Having completed their first 2 years of college, students entering this program will spend alternate 6-month periods between academic training and employment in a cooperating industrial or Federal laboratory. When the student has successfully completed the 3-year program, he will receive his bachelor's degree and will additionally have a background of actual experience working in ocean engineering.

Many different subject areas will be investigated with research project support. The University of Miami will conduct a series of experiments to develop techniques for the artificial rearing of shrimp and pompano, using ponds and a hatchery provided by the Florida Power & Light Co. This research should yield information on optimal environmental conditions and food sources for the commercial culture of pompano and shrimp. This project, like several others, is jointly funded by industrial firms. In this case, the Armour Corp. and the United Fruit Co. are both providing partial support.

Development and utilization of marine resources is affected in varying degrees by State laws and other regulations. The University of Maine School of Law will study statutes, court decisions, administrative regulations, and policies of the State of Maine having a bearing on marine resources, and will examine their environmental and economic impact. This interdisciplinary study will be directed by the School of Law, but will involve experts in the sciences and economics from other organizations, including Bowdoin College and the State Department of Sea and Shore Fisheries.

Two coherent project grants were awarded in fiscal year 1968; one to Louisiana State University for a broad study of intensive aquaculture in local salt-water marshes, and the other to the University of Delaware for a study of the application of systems engineering to estuarine resource development.

The Sea Grant Program has already demonstrated a promising potential for promoting coordination and cooperation among institutional components and between institutions, industry, and State agencies. Several industrial organizations are exploring the possibility of alliances with academic institutions in pursuit of applied projects that will benefit both the academic and industrial communities. In several States, two or more universities are working out arrangements, usually in concert with an appropriate State agency, to combine their facilities and staffs into a program having more extensive capabilities than could be attained by a single institution acting independently.

SCIENCE INFORMATION

This is the 10th anniversary of the Office of Science Information Service (OSIS). The Foundation's Science Information Service was instituted under the provisions of Title IX, National Defense Education Act of 1958. OSIS was established in recognition of the importance of information to the health of the nation's science and engineerng efforts and the need to help scientists and engineers cope with the rising tide of information. That scientific and technical literature increases in volume along an exponential curve with a doubling time of 8 to 15 years is a well established phenomenon. Some examples of literature growth for biology and chemistry over the last 10 years will emphasize this point. In 1958, *Biological Abstracts* (BA) produced 43,000 abstracts; in 1968, BA will publish about 130,000 abstracts (an increase of 202 percent). During this period BA produced 1,248,000 abstracts (including over 232,000 entries in Bio Research Index). In 1958, Chemical Abstracts Service (CAS) published about 95,000 abstracts; in 1968, CAS will publish about 216,000 (an increase of 127 percent). During this period 1,753,000 chemical abstracts were added to the literature. The volume of literature for other fields of science and engineering is growing at rates similar to that given for these two fields.

The increased production of scientific literature is the result of at least three interacting factors: (1) The increase in the numbers of producers of information; (2) the motivation of scientists and engineers to contribute to knowledge; and (3) the publishing activities of scientific societies, research organizations, and commercial and industrial companies in response to producers of information, e.g., establishing new journals, increasing size of regular journals, publishing special issues, repetitive publication of the same material in different journals, and the publication of technical reports and conference papers that are not subject to review by peers of the authors. The last two factors interact to cause the production of large amounts of duplicated, unreviewed, and incompleted scientific and technical literature. This material is added to the information sources which the scientists and engineers need to consult.

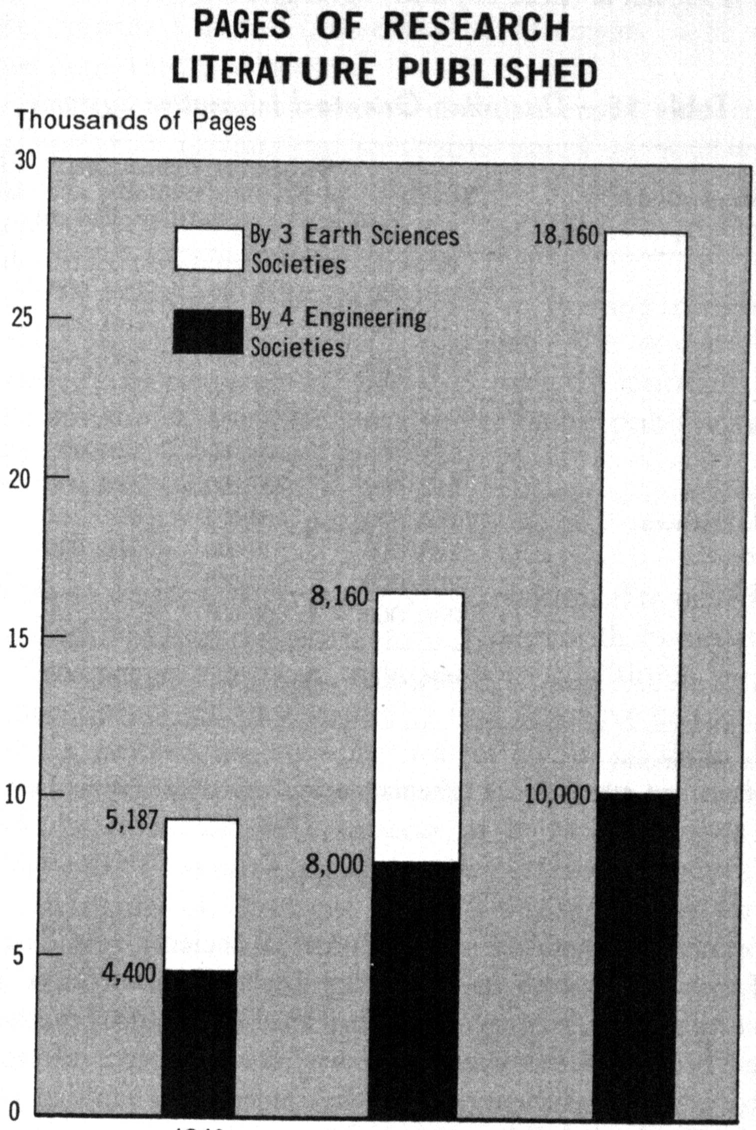
The increase in research and development activities related to each discipline results in a greater volume of literature, which encourages specialization in narrowly defined subdisciplines and fields. The results of specialization are: (1) A trend toward the fragmentation of sciences; (2) the expression of need to preselect, condense, and organize information in a form responsive to the user's requirements; and finally (3) recognition of the urgency to harness new communication technologies, including the computer, to serve science and engineering.

The individual user is interested in information pertaining to his specific interests, i.e., organized in blocks or parts appropriate to the user's requirements. The trend toward the development of modern science information systems based on the responsible representative societies, emerges from the recognition that the mass of information available on a given subject is never used in its entirety by the total community of users of science information. In addition, the volume, diversity, and complexity of information for the many scientific and engineering fields mitigates against a single collection which serves all scientists and engineers. It follows, therefore, that the development of discipline-oriented science information systems for the major disciplines is a necessary and efficient way of managing "blocks" of information. Each discipline-oriented science information system is relatively independent, but each is exploring cooperative projects with other information systems in order to create a network that will make its information files accessible to all scientists and engineers.

The Foundation, sensitive to trends in science information needs, continued to support three major areas of emphasis in science information: (1) *Discipline-Oriented Information Activities*—support for present information activities and development of comprehensive information systems within the major scientific disciplines; (2) *Federal Science Information Activities*—support for and coordination of science information functions of interest and benefit to Federal agencies; (3) *General Science Information Activities*—support of activities, services, and information science research which serve more than a single scientific discipline or group.

Progress toward the goal of comprehensive information systems for the major disciplines is discussed below. The principal objective of the support program for discipline-oriented information systems is the development and exploitation of a computer-based comprehensive science information system which is user-oriented for each major scientific discipline. In addition, funds now provided by the Foundation permit planning in these developing systems for eventual access to large files of machine-readable information and data.

The scientific fields listed in table 17 represent an estimated 1½ million scientists and engineers who, as members of the scientific community, may be better served through the information systems now being developed. In fiscal year 1968, the Foundation awarded 154 grants and contracts, amounting to $14.5 million, in support of scientific information activities. These awards were distributed among 32 scientific societies, 26 academic institutions, eight research institutes, eight commercial organizations, four museums, five Federal agencies, seven foreign organizations (for translations and other science information projects) and to one individual.



DISCIPLINE-ORIENTED INFORMATION SYSTEMS

During fiscal year 1968, $10.0 million was obligated to support the science information systems of professional societies, compared to $7.7 million in fiscal year 1967. NSF channels its support for discipline-oriented information primarily through the scientific societies because: (1) A scientific society usually includes the majority of active research personnel in a given scientific field; (2) societies have traditionally provided information products for the scientific community; (3) the society can respond to the expressed information requirements of its members; and (4) active scientists and engineers become involved in the development of a science information system(s) which serves their needs through their respective professional societies. Foundation support for the development of discipline-oriented information systems for 9 fields of science is shown in table 15, and highlights for each field are discussed below.

Table 15.—*Discipline-Oriented Information Systems*

Fields of science	Totals	Support of publications and services	Systems development and improvement	Research and studies
Mathematics	$465, 000	$258, 000	$152, 000	$55, 000
Physics [1]	1, 314, 000	10, 000	1, 180, 000	124, 000
Chemistry	4, 430, 000	24, 000	4, 236, 000	170, 000
Biology	433, 000	187, 000	246, 000	....
Social sciences	184, 100	117, 100	67, 000	....
Psychology	558, 900	108, 900	450, 000	....
Engineering	517, 000	307, 000	210, 000	....
Atmospheric sciences	160, 000	160, 000	....	....
Earth sciences	728, 000	510, 000	218, 000	....
Oceanography	204, 000	159, 000	....	....
	[2] 1, 000, 000	[2] 1, 000, 000	....	....
Total	9, 994, 000	2, 841, 000	6, 759, 000	349, 000

[1] Includes astromomy.

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

Chemistry

Development of the American Chemical Society's (ACS) computer-based information system in chemistry included three major activities: (1) The establishment of two experimental information centers to introduce more broadly the concepts of computer produced information and services to a wider audience; (2) the initiation of unified publication procedures (for both full length articles as well as abstracts) to capitalize on one preparation for input to the total system; and (3) the successful completion of experimental cooperative projects with other government agency information systems as well as the initiation of other cooperative activities. At the same time, discussions were initiated with OECD countries of Western Europe for pooling of efforts in the acquisition and processing of chemical information.

Build up of the computer store of the Chemical Abstracts Service Chemical Compound Registry continued. The Registry now contains about 900,000 chemical compound structures. Research and development continued at Chemical Abstracts Service on special problems such as processing information on polymers, mixtures, and other substances by computer. Display techniques for computer output of chemical structures were investigated at the University of Pennsylvania. Computerized comparison of four kinds of spectral data to identify new compounds was demonstrated by the Illinois Institute of Technology Research Institute. Graph theory applications, to chemical structure analysis by computer were examined at the University of Michigan. The university projects mentioned are experimental.

Advanced research on translation of chemical names into connection tables (an inventory of chemical structures based on atomic bonding characteristics) by computer was undertaken. Connection table techniques have reached the point where an estimated 65 percent of the compounds can be registered by this process.

The ACS established a Planning Office to develop comprehensive plans for the total chemical information system. The objectives are, by 1971, to publish by computer all 20 ACS primary journals, after the intermediate goal of a completely computer-based publication system for Chemical Abstracts is achieved in 1970.

Physics

The American Institute of Physics (AIP), continued to develop a program for a National Physics Information System with Foundation support. The development program includes both traditional methods of the communication of physics knowledge and "creative condensations," such as indexes, reviews, and compilations of evaluated data. AIP also assumed the responsibility for maintaining a machine readable bibliographical file, developed with NSF support, at the Massachusetts Institute of Technology (MIT) as part of a mechanized reference retrieval system. AIP is continuing its development of an indexing system for physics and, in cooperation with other groups, is conducting a series of indexing and searching experiments. Stanford University continued development of an operational on-line reference-retrieval system for faculty scientists as well as those at the Stanford Linear Accelerator Center. This project also includes a study of the information-seeking behavior of physicists in this setting.

Social Sciences

During fiscal year 1968 the Center for Applied Linguistics (CAL) pursued a program toward development of a Language Information Network and Clearinghouse System. To date the CAL has produced analyses of the characteristics of the user community, of the existing information services in the language sciences, and of available computerized file management technology. By 1970 CAL is expected to have a detailed design and implementation plan for a system which will ultimately provide comprehensive information services throughout the language science community. The Econometric Society, in cooperation with the International Association for Research in Income and Wealth, began a 2-year project to mechanize bibliographic and biographical files to serve virtually the entire econometric community.

Psychology

The American Psychological Association started a 2-year project to (a) prepare a long-range developmental plan for scientific communication programs in psychology, (b) establish a managerial and technical cadre for the execution of that plan, and (c) augment the capabilities of the APA's computer-based secondary service, *Psychological Abstracts* (a service also receiving operational support from the Foundation).

Earth Sciences

The American Geological Institute's (AGI) Committee on Science Information began development of a concept for a national information system in the earth sciences, with the corresponding definition of general policy and long-range goals, and the formulation of a three-year plan for earth sciences information activities. Foundation support will enable AGI to establish the capability for the U.S. geological community to initiate an information system program, maintain liaison, hold meetings, and obtain expertise and services required to accomplish its objectives. In one specific area, liaison activities have facilitated cooperative, coordinated work by diverse groups on a micropaleontological information retrieval system.

Engineering

The Tripartite Committee (United Engineering Trustees, Engineers Joint Council, and Engineering Index, Incorporated) is preparing long-term plans, with Foundation support, for development of a United Engineering Information System and an objective assessment of its viability. The Committee hopes to obtain industry support for further development of the system.

The conventional engineering information services of Engineering Index, Inc. (the Annual Index, Card Service, and Monthly Bulletin) reached a level in fiscal year 1968 where subscription and sales income was sufficient to cover production costs. No further Foundation support is required for these services.

Mathematics

With NSF funding, the American Mathematical Society (AMS) held a conference on communication problems in the mathematical sciences which provided the impetus for organizing a comprehensive system program for mathematics comparable with that being defined in physics (see page 207).

The AMS, with partial support from NSF, has initiated a project designed to distribute selected mathematical articles from about 60 participating journals to mathematicians according to their subject-interest profiles. This is a new form of subscription service to selected articles as opposed to a subscription to an entire journal. Among significant abstracting and indexing journals receiving NSF publication support is *Mathematics Reviews,* which in the course of fiscal year 1968 achieved self-supporting status and no further financial assistance was required from the Foundation. AMS has also entered the final phase of its development of a computer-controlled photocomposition system for the publication of its journals in which it will "debug," test, and conduct experimental production operations. The capability to be achieved will form the nucleus of a comprehensive information system for mathematics.

Biological Sciences

As part of NSF's support of new modes of primary publication utilizing computer technology to speed up the publication and distribution process, Johns Hopkins University started a new computerized journal, *Communications in Behavioral Biology.* Full financial support for the production and distribution of *Mycological Abstracts,* initiated by Bio-Sciences Information Service of Biological Abstracts (BIOSIS) with NSF funding, was assumed by BIOSIS during fiscal year 1968. BIOSIS also began the development of a guide to the vocabulary of biological information which is expected to make a basic contribution to the evolution of a comprehensive information system in the field of biology. The American Museum of Natural History, in cooperation with BIOSIS, initiated bibliographic services in ichthyology and herpetology.

Oceanography

The Foundation provided funds for co-support of "A Comprehensive Study on a National Marine Science Data Program" sponsored by the Office of Naval Research and the National Council on Marine Resources and Engineering Development. The first part of the study, completed in December 1967, provided an overview of marine science activities, and presented a plan for the design of "a national data management system for the marine environment."

Atmospheric Sciences

The American Meteorological Society, under a contract with the Foundation, continued the preparation, publication and distribution of *Meteorological and Geoastrophysical Abstracts* (MGA) for calendar year 1968. The current contract concludes a 4-year Government program attempting to place MGA on a sound financial base which would require no further Government subsidy.

The management analysis study, undertaken by the Society in fiscal year 1967, was completed during fiscal year 1968. The results of the study are now being used by the Society to plan possible improvements in information services for atmospheric scientists.

322-215 O—68——15

FEDERAL SCIENCE INFORMATION ACTIVITIES

During fiscal year 1968, the Foundation provided financial support to the Smithsonian Institution for the operation of the Science Information Exchange. SIE is a centralized interagency exchange mechanism which records about 90 percent of all available Federal tasks in basic and applied research. About 130,000 research task resumés (including proposed tasks) will be received and recorded by SIE in 1968 (85 percent Federal and 15 percent non-Federal research tasks).

Linking the work of Federal agencies and that of the scientific community outside of Government, NSF also continued backing the Committee on Scientific and Technical Communication (SATCOM) of the National Academy of Sciences-National Academy of Engineering. SATCOM is preparing a report on scientific and technical information which will cover primary publications, reference services, new technologies, national planning, international cooperation, and other subjects. In addition, other Academy groups such as the Council on Biological Sciences Information received continued support.

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

A joint OST/SATCOM *ad hoc* Task Group on Interchange of Scientific and Technical Information in Machine Language (ISTIM) received support from NSF through the National Bureau of Standards. The firm of Peat, Marwick, Livingston & Company, under an NSF contract monitored by OST, began a study of Government-wide research and development project-reporting.

Cooperative financing by NSF, the National Library of Medicine, and the Office of Education permitted the University of Maryland to commence a study of requirements, educational preparation, and utilization of manpower in library and information science work.

A National Serials Data Program, located at the Library of Congress (and sponsored by the three national libraries) was partially supported by the Foundation through the Joint Committee on the Union List of Serials, Inc.

GENERAL SCIENCE INFORMATION ACTIVITIES

These activities include a wide variety of science information programs to serve the needs of more than one scientific or technical field. Examples of these activities include (a) the operation of organizations that foster international cooperation in the exchange of science information as well as efforts to ensure the acquisition and availability of foreign scientific and technical publications, (b) measures to improve the basic organization and information handling capabilities of the research libraries in the United States, and (3) research on information science.

International Science Information Activities

The adequate availability of significant foreign science information, whether communicated in oral or written form, is an important concern of the Foundation. In fiscal year 1968, the Foundation continued to support U.S. participation in the science information activities of international organizations and meetings, international travel for science information meetings, the exchange of personnel, the provision of reference and information aids (for example, *International Directory of Psychologists*), and arranging for the translation of 78,000 pages of foreign literature. In addition, the heightened international interest in scientific and technical information required the financial and staff support by the Foundation in the activities of the International Council of Scientific Unions Abstracting Board, the Organization for Economic Cooperation and Development, the International Federation of Documentation, and others.

Research Libraries

New methods for efficient text representation, file searching, and retrieval, developed at Lehigh University, received Foundation support for continued development as a prototype system. The project will (1) permit operational tests of the methods of text representation and file searching; (2) serve as a research tool in information retrieval; and (3) be used to support the instructional functions of the University.

A framework for collaboration on library systems development will link the work being done at Columbia University, the University of Chicago, and Stanford University. Each is engaged in a project for the design and integration of computer-based library sub-systems for traditional processing functions. The Collaborative Program in Library System Development, funded by the Foundation, will permit coordination of this work among the three libraries.

NSF support helped initiate a long-range science improvement program for the Texas Gulf Coast at Rice University. The objective is to develop a centralized bibliographic reference and intra-network location and transfer service for 18 academic institutions in the area.

Research in Information Science

In addition to the activities reported above, the Foundation supports research projects in information science, the results of which contribute to basic understanding of functions involved in the total scientific information exchange process. Research support in this area is provided primarily to individual investigators and to university-based science information research centers. Examples of individual studies currently under way include a behavioral study of scientific communication by Johns Hopkins University; the role of information in parallel research and development projects by MIT; statistical studies of information networks through analysis of citations in scientific papers by Yale University; and science information exchange among communication researchers at Stanford University.

Exploratory development began on the establishment of prototype information systems expected to influence operational systems of the future. Examples are (1) an effort to design, develop, and evaluate an unconventional library catalogue at MIT; (2) research on automatic document retrieval system procedures at Cornell University; and (3) work on real-time video console indexing at the University of Pennsylvania.

The Georgia Institute of Technology and the Ohio State University continued, with Foundation assistance, to develop a research center in information science. At Ohio State, six information science research areas have been established and a Distinguished Lecture Series in the information sciences was also supported.

Automatic and Computer Indexing

Using the accumulated literature of statistics and probability for periods of more than 30 years and up to 1966, science information research at Princeton University continues on the preparation of automatic and computed indexing techniques which will provide better access to these fields. The literature of statistics and probability is widely scattered and of interest to a small group of mathematicians. At the same time, statistics and probability are extensively used in many other disciplines by scientists and engineers who have difficulty locating literature pertinent to their efforts. During fiscal year 1968, work concentrated on a citation index, an improved index to titles organized for more effective retrieval purposes, and a means of identifying journals from the diverse abbreviations occasionally used by authors.

With the advent of computer composition, a likely outgrowth of this research will be the automation of the difficult and time consuming task of preparing indexes to books. Automated indexes will be more complete than those prepared conventionally. They will also be more effective because the key words or work groups can be arranged and printed in bold face type in a permuted manner, i.e., arranged so that the user's attention is directed to key words of word groups.

INTERNATIONAL SCIENCE ACTIVITIES

The international scientific activities of the Foundation are divided into two categories: (1) those which strengthen science, scientists, and science education in the United States, and (2) those for which the National Science Foundation is especially qualified to serve the interests of the Federal Government. Examples of the first include research carried out abroad by U.S. scientists, travel abroad of U.S. scientists to pursue fellowship activities and to attend international scientific meetings, and translations into English of foreign scientific literature. Among NSF-supported activities at foreign sites, a notable example is the Cerro Tololo Inter-American Observatory in Chile, where U.S. scientists may study the southern sky. The second is exemplified by the science education program now being carried out in India by the Foundation, with financial support being supplied by the Agency for International Development of the U.S. Department of State. Many NSF activities carried out in conjunction with international science activities fall into one or sometimes both of the above categories.

STRENGTHENING U.S. SCIENCE

International cooperation in science is increasing. Stemming from the earlier International Geophysical Year, the Foundation's Antarctic Research Program supports scientists from United States institutions to carry out a wide variety of research in the Antarctic, including exchanges of personnel and other collaboration among scientists of nations adhering to the Antarctic Treaty. Newer examples of the increasing tendency for scientists to mount a concerted approach to scientific problems of broad significance are the International Biological Program and the Global Atmospheric Research Program. A simultaneous but highly diversified approach to solving scientific problems, with scientists from one country profiting by the experience of scientists from another country, will yield greatly increased dividends over a single-country approach.

The Foundation administers two formal bilateral programs, one with Japan and another with Italy, which are discussed below. There is also an increasing number of informal inter-university cooperative programs, with NSF supporting the U.S. participants, and the foreign scientists receiving support from their own governments.

In terms of manpower and financing, the above types of activities comprise the great bulk of science-related international activities of the

Foundation. The substantive results of these activities are reported under their respective disciplines elsewhere in this report.

The Foundation provides funds to support U.S. scientists for research which may be conducted abroad, for attendance at international scientific meetings, for science information exchanges between cooperating nations, and for educational and training programs. The Foundation makes very few direct grants to foreign institutions, and only when such grants can be justified with respect to their importance to science in the United States and the necessity of their being conducted abroad by a foreign institution. In fiscal year 1968 there were 12 research grants to foreign institutions, totaling $344,400.

The United States-Japan Cooperative Science Program, established in 1961, has been notably effective in establishing cooperation and fostering communication between scientists of the two countries. Projects under the program are funded cooperatively, with each country supporting its own scientists. The Foundation is the implementing agency in the United States and works closely with two implementing agencies in Japan. NSF maintains representation in Japan through a small office in Tokyo.

Activities conducted under this program include cooperative research, visits by scientists of one country to the other, scientific meetings, and exchange of educational materials. The official fiscal year for this program follows the Japanese custom with the fiscal year ending on March 31 rather than June 30. As of March 31, there were 45 on-going cooperative research projects, of which 23 were funded during the period of this report. Fifteen U.S. scientists visited Japan for various periods of time, and 25 scientific meetings were held, 14 in this country involving 229 U.S. scientists. During the year, a total of 491 scientists from both countries took part in scientific meetings. Altogether, a total of 992 scientists from both countries took part in all activities of the program this year.

The United States-Italy Program, which was initiated in June of 1967, encompasses in general the same activities as the United States-Japan Program. The Foundation is the implementing agency for the United States, and the *Consiglio Nazionale delle Richerche* (CNR) is the implementing agency for Italy. During the first year of the program, 16 cooperative research projects were approved. These cooperative projects cover many areas of science, including a cooperative program on linear electron accelerators; studies on plant viruses, modes of virus transmission, virus-vector and virus-host interrelationships; image processing by holography; and an exchange program in genetics and molecular biology.

The United States-India Exchange of Scientists and Engineers, which also began in 1967, calls for exchange visits for periods of 2 weeks to several months, with a total of 800 man-days per year for each country. During this year five Indian scientists came to the United States and two

Americans went to India. The visiting Indian scientists were interested in science information, solid-state physics, industrial toxicology, telecommunications, and oceanography. The Americans visiting India were interested in certain phases of medicine and in a collaborative project on the metabolism of vitamin B_{12}.

Foundation fellowship and exchange programs continue to encourage contacts between individual American and foreign scientists. Of the 2,898 fellowships awarded in fiscal year 1968 to U.S. citizens, 151 provided for tenure at a foreign institution. Under the NSF Senior Foreign Scientists Fellowship Program, visits of 65 eminent foreign scholars were made possible to as many U.S. universities for periods up to a year.

The North Atlantic Treaty Organization (NATO) conducts a postdoctoral fellowship program which is administered by the Foundation for the Department of State. This program provides for study by American scholars in institutions of NATO nations for periods of 6 to 12 months. In fiscal year 1968, 39 individuals received these awards. A second NATO program—NATO Senior Fellowships in Science—was inaugurated last year, and 13 individuals received awards in fiscal year 1968. The latter program is designed primarily to permit U.S. universities and other nonprofit scientific research organizations to send senior staff members to European countries to study new scientific techniques and developments for periods of from 1 to 3 months.

NATO also sponsors advanced study institutes in many fields. In fiscal year 1968, travel grants were provided to 77 American scientists for attendance at 40 of these institutes. These are in addition to travel grants awarded under Foundation programs for 677 American scientists to visit abroad, primarily for the purpose of participating in international meetings.

During fiscal year 1968, the Foundation continued to support exchange of scientists between the National Academy of Sciences and counterpart

Table 16.—*U.S.S.R. and East European Exchange of Scientists Programs Number and Duration of Individual Visits Initiated July 1, 1967–June 30, 1968*

	American scientists		Foreign scientists	
	Number	Duration (man-months)	Number	Duration (man-months)
Czechoslovakia	10	50	9	60
Poland	16	28	7	56
Romania	9	9	9	53
Yugoslavia	6	23	6	23
East Europe, subtotal	41	110	31	192
U.S.S.R	32	90	26	118
Total	73	200	57	310

organizations in Czechoslovakia, Poland, Romania, Yugoslavia, and the U.S.S.R. The quota established for Soviet exchanges during the calendar biennium 1966–1967 (180 man-months) was completely filled by both academies. This is the first instance of complete subscription since the beginning of the program in fiscal year 1960. Individual exchanges with other East European countries (conducted on an academic-year basis) commenced in fiscal year 1967. While the first year's exchanges were considerably below quota, the second year saw a notable increase and the number of persons whose visits commence before August 31, 1968, will approach the number planned for the 2-year period.

INTERNATIONAL NONGOVERNMENTAL SCIENTIFIC ORGANIZATIONS

International scientific unions and organizations are increasingly active in sponsorship and coordination of exchange of information through scientific meetings, publications, and information systems; in the establishment of standards, units, and nomenclature necessary for meaningful international collaboration and comparison of experimental results.

The international scientific organizations are governed by their national members. The National Academy of Sciences, the U.S. national member of nearly 30 international organizations, is supported by the Foundation for the conduct of activities with the following objectives:

- To provide an effective means for American scientists from universities, industry, and government to participate in the scientific activities, policy formulation and administration of the international nongovernmental scientific organizations.
- To provide a way for American scientists to participate effectively in the planning and conduct of international collaborative programs which are formulated and coordinated by the nongovernmental scientific organizations.
- To give the special attention necessary to assure that proposals of the U.S. scientific community receive full consideration at appropriate levels of the international nongovernmental organization.
- To assure that information of the activities of these nongovernmental organizations reaches not only interested American scientists but also officials of the Department of State, the National Science Foundation, and the Office of Science and Technology who are responsible for American participation in the scientific affairs of intergovernmental bodies.
- To maximize U.S. benefit from participation in the international scientific organizations by strengthening and improving the international bodies as mechanisms for advancing scientific cooperation.

In the summer of 1967 there were 12 major congresses and general assemblies of international scientific organizations attended by 14,102 participants from about 50 countries; 2,970 Americans participated in these meetings, of whom 93 were empowered by the National Academy of Sciences to vote in representation of the American scientific community in the governing bodies of the organizations.

DEVELOPMENT ASSISTANCE PROGRAMS

India

The National Science Foundation continued its efforts to assist the AID Mission and the Government of India with the operation of a Science Education Improvement Program for India. Again, as in 1967, the major activity was in the conduct of summer institutes for teachers of science, engineering, and technology. In 1968, using funds transferred from AID, the Foundation provided 178 short-term consultants to assist with the conduct of these institutes as teachers, visiting lecturers, and part-time supervisors. The Government of India approved and supported a total of 136 institutes under this joint program.

The U.S. personnel on the NSF Science Liaison Staff in New Delhi was increased to 12 (10 scientific, two administrative). This increase allowed more staff time for activities beyond the summer institute program. Members of the staff traveled extensively throughout India to become better acquainted with on-going projects to improve scientific and technical education in India, to provide advisory service and technical assistance to such projects, and to enhance communication within the academic and governmental scientific community.

Latin America

Since 1963 the Foundation and the Agency for International Development (AID) have been cooperating in a technical assistance program for the improvement of science and mathematics teaching at the undergraduate level in the five national universities of Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua. In 1966 the national university of Panama was also incorporated into the program. All activities are coordinated through the Superior Council of Central American Universities (CSUCA) with headquarters in San Jose, Costa Rica.

The program in Central America is directed toward qualitative improvements in the teaching of science and mathematics through services of U.S. specialists in the fields of biology, chemistry, mathematics, physics, and science materials development. During this year the major activities have been consultation in curriculum improvement, selection of laboratory equipment, development of improved laboratory instruction, assistance in the design of buildings, and selection of books. Supplementing these efforts, there was a series of seminars and workshops for teachers on the use of audiovisual materials, the design of simple laboratory equipment, and the use of locally available materials in equipment construction. The program has also contributed to the training of Central American university staff in the use of modern techniques for chemical analysis and in the use of electronic equipment in physics teaching and research.

U.S. EXHIBIT IN BRAZIL

In the fall of 1967, the Foundation participated in a novel and highly successful project in international science. At the request of the Government of Brazil, and with the endorsement of the U.S. Department of State, NSF assumed responsibility for planning, assembly, and operational management of the U.S. Exhibit at the First Biennial of the Sciences and Humanism held from October 17 to December 3, 1967, at São Paulo, Brazil.

With the cooperation of other Federal agencies and assistance from a number of universities and science-oriented industries, an exhibit, based on the theme Progress Through Science, was presented which illustrated many important current advances in science and technology.

Among the features of the exhibit attracting particular interest among visitors were three operating lasers, accompanied by extensive illustrative material explaining the laser principle. Actual demonstration of their use before the eyes of viewers graphically illustrated some of the current and potential uses of laser, including the promise it offers in surgery. Other features of the exhibit included a model of the Apollo capsule and the Lunar Orbiter satellite, a model of a desalinization plant, as well as motion pictures and a number of audiovisual displays designed for operation by the viewers themselves.

A particularly noteworthy feature of the exhibit was the active participation by science students from the University of São Paulo. These students, after a period of training by NSF representatives, served as lecturer-demonstrators, operating the equipment and explaining the various features of the exhibit to visitors.

During the 6 weeks of its operation, the U.S. portion of the exhibit was visited by more than 40,000 persons, including a number of Brazilian public officials and members of the U.S. House of Representatives. Upon its conclusion, the NSF equipment was transferred to the São Paulo office of the U.S. Information Service, and this equipment continues to be used in other areas of Brazil.

SCIENCE PLANNING AND POLICY STUDIES

The National Science Board and Director are directed by statute "to recommend and encourage the pursuit of national policies for the promotion of basic research and education in the sciences." Also, the Foundation is directed "to evaluate the status and needs of the various sciences." These responsibilities are being carried out on a broad national basis not only for the benefit of all segments of our society, but also for the development and implementation of plans and policies of the NSF. Since these assessments and evaluations are vital to the operation of all NSF activities, they are carried out in many organizational elements of the Foundation, as well as in units specializing in planning and policy development. The results of these activities provide the bases for policy formulation.

Policy formulations for the Foundation itself are made by the Director and the National Science Board and are reflected in the implementation of the various NSF programs. Consequently, NSF policies and policy changes are summarized in the Director's Statement, the Introduction and Summary chapter, and are interwoven in the reports on the various NSF programmatic activities. Many of these policy decisions are based on data, analyses, and recommendations evolved from the NSF program of planning and policy studies.

Science policy determination, whether it is related solely to Foundation activities or is national in scope, is generally preceded by three, often closely interrelated steps:

- Identification of current and future issues requiring policy decisions.
- Evaluation of the needs of science and the role of science in society.
- Development of the basic tools for science planning and policy making, such as data banks and methodology.

With the information developed by these steps, it then becomes possible to assess alternative courses of action and to arrive at the most appropriate policy determination.

NSF planning and policy study activities, as highlighted below, cover each of these steps. These activities have been carried out either through direct NSF staff efforts, through contracts and grants to groups working in institutions of higher education, nonprofit institutions and other Government agencies, or frequently through the combined efforts of NSF personnel and those working under grants or contracts in other institutions.

IDENTIFICATION OF CURRENT AND FUTURE ISSUES REQUIRING POLICY DECISIONS

Broad general studies and day-by-day interaction with various segments of the scientific estate provide a focus for the identification of special current policy issues. Frequently, these require further investigation, including surveys and data compilations.

Since the Foundation has a major involvement with the academic community, major efforts have gone into the identification of academically related issues. For example, studies are carried out to analyze the impact of national budgetary and other policy decisions on academic science. One such study, to be completed in fiscal year 1969, is to ascertain whether and to what extent young faculty members are having disproportionate difficulty in obtaining research support. It is evident that different types of institutions (new or well established) and different disciplines (with or without an old established tradition of research) are experiencing problems of research support for young faculty members to different degrees. Consequently, a broad survey of 800 department chairmen was designed to obtain further information. The survey revealed that 50 percent of the faculty in the departments studied had been awarded Ph. D.'s in the last seven years and that nine out of ten of these recent Ph. D.'s were engaged in research at least 20 percent of the time. Over two-thirds of the department heads stated that the division of available research funds between "young" and "senior" investigators was appropriate; however, many believed that increases in the total funds available to all investigators were greatly needed. Those who believed that the split between young and senior investigators is appropriate were relatively evenly distributed among the different types of academic institutions.

Also during this year a study was completed which compiled and analyzed graduate education statistics received from NSF traineeship applications covering 1965–66. The report, *Graduate Student Support and Manpower Resources in Graduate Science Education,* is based on data from most of the science departments in the Ph. D.-granting institutions. It discusses the distribution of the various types of graduate student support from different sources; numbers and distributions of U.S. and foreign graduate students; graduate faculty; postdoctorals; and faculty to student ratios. Interesting trends revealed in the report include the relative decrease over the last decade in the number of foreign students and the concentration of these students in the engineering field; the fact that about three-fourths of all full-time science graduate students in doctoral departments receive stipend support from some source and that one-third are fellows or trainees, about one-fourth are teaching assistants and about one-fourth receive support as research assistants. Since these compilations provide a valuable source of graduate-education statistics, which can be obtained without additional burden on respondents, they will continue to be compiled on an annual basis.

A study of the "productivity" of various types of undergraduate institutions was carried out. Productivity was measured on the basis of: (a) bachelor degrees awarded in science and engineering; (b) baccalaureates who subsequently received doctorates in science and engineering; and (c) baccalaureates who were subsequently employed as scientists, although they had not received doctorates. The analysis shows that the undergraduate schools of universities and the 100 highest quality liberal arts colleges, chosen according to a selectivity index developed by Astin in his book, *Who Goes Where to College,* clearly have the greatest productivity and thus warrant special attention in the allocation of academic science funds.

The first in a series of reports by the Academy for Educational Development on the future of higher education was published this year. This effort is sponsored by the National Institutes of Health, National Science Foundation, Office of Education, and the Bureau of Health Manpower (PHS). The report, entitled *Present Planning for Higher Education,* summarizes the status of present planning arrangements for and coordination of higher education in each of the 50 States and the District of Columbia, and includes a master directory of agencies, institutions, and organizations involved in higher education planning. The next two reports in this series, which are expected to be available in early fiscal year 1969, will focus on probable major expansions of graduate and professional education in 1966–80, together with planning trends and the outlook for the future.

The Foundation continued to provide support for the Committee on Science and Public Policy (COSPUP) of the National Academy of Sciences (NAS) and the Committee on Public Engineering Policy (COPEP) of the National Academy of Engineering (NAE). These high-level scientific groups investigate science and public policy issues for the benefit of the scientific community, the Federal Government and the Congress. Special COSPUP studies relating to the status and needs of various fields of science also received continued support. A study of the mathematical sciences was completed during 1968, and a report is expected to be published in early 1969. Work on similar evaluations of the life sciences and the behavioral and social sciences was also continued. Both of these studies are expected to come to fruition in 1969. COPEP, which is still a relatively young organization, is in the process of reviewing engineering needs of the United States and is also involved in the establishment of a task force to examine the significant interchange between engineering manpower, development of science and technology, and national goals.

EVALUATION OF THE NEEDS OF SCIENCE AND THE ROLE OF SCIENCE IN SOCIETY

The greatly increased size and complexity of scientific activities and their growing involvement in virtually every facet of social and economic endeavor demand increased emphasis on the need for adequate analyses of the role and effect of science upon society. Since the problem is exceedingly broad, NSF efforts have been restricted to supplementing other efforts and to dealing with problems of most current interest.

University Science Planning and Policy Program

A new program, the University Science Planning and Policy Program, was announced in fiscal year 1968 to stimulate greater interdisciplinary university faculty activity and student training in the science planning and policy area. Our universities are major national intellectual centers, and it is expected that through this program their unique resources can be brought to bear in an increased fashion on the problems of science and society. Since science has become an ever-present component of everyday activities, it is also essential that more students become acquainted with science and its interaction with society. It is hoped that such broad general educational programs will stimulate increasing numbers of students to enter the area of science planning and science policy development as a professional career. Such careers require multidisciplinary training involving both the social and natural sciences. It is evident that the graduates of such an educational program are urgently needed in State, local, and Federal Governments and in other sectors of society. Thus, the new program is designed to provide funding for integrated university programs involving research, training, and possibly curriculum development on a multidisciplinary basis.

Grants have been awarded to universities with previously established programs, such as the Science Technology and Society Program at Harvard University, and to universities which were ready to initiate new broad university-wide efforts in this field, such as the University of Illinois and the University of Virginia. Research topics to be covered by grants made in fiscal year 1968 include: the use of science in international affairs; case studies of policy formulation and resource allocation involving specific scientific disciplines; the relationship of technology and the city; nuclear energy, the law and international affairs; and a broad study of the social implications of science.

Since science and technology are or should be used at various levels of government, it is important to evolve methods and mechanisms best suited for the utilization of science by State and local governments. During the past year a grant was made to support a conference, to be held in the fall of 1968 under the sponsorship of the Southern Interstate Nuclear Board, at which information will be exchanged on the experiences and potential use of science and technology at the State and local level. Representatives of Federal, State, and local governments, as well as industrial and academic groups will participate. In addition, NSF and the Department of Commerce jointly supported initiation of a number of integrated studies of science advisory mechanisms in nine States.

The role of basic research in the development of modern technology is recognized but has seldom been studied in detail. Consequently, a contract was awarded to the Illinois Institute of Technology Research Institute to investigate several case histories of the utilization of basic research results. The effort involves the tracing of the connections between end products or processes, some of which have major technological impact, and the broad underlying base of fundamental research on which the technology is based. A report, which deals with the contributions of non-mission related research to practical innovations of economic or social importance, is expected in fiscal year 1969.

Also during the last year a comprehensive report, *National Science Policies of the U.S.A., Origins, Development and Present Status,* was completed and provided to UNESCO for publication in their series of reports on science policy in various nations. The report covers: the history of the U.S. scientific and technological enterprise; the political and economic setting; the diversified system of performance and support of R. & D. and manpower; and a summary of current national science policy issues. It is expected that this report will become one of the standard reference works on U.S. science policy.

One aspect of Federal interrelation with science and technology development has been investigated in an NSF-funded study undertaken by the Denver Research Institute on *The Role of Federally Funded Research and Development Centers (FFRDC)*. The report, which will be released in early 1969, concludes that, although FFRDC's present some problems, especially with respect to the exercise of administrative controls over their operations, they provide an effective instrument for the accomplishment of important national research missions. The report notes that the use of this particular organizational mechanism has not been limited to the Federal Government, but that because of the successful operation of these centers, city and State governments are showing increased interest in utilizing the services of existing centers or by establishing similar organizations for the performance of research functions.

An aspect of the Federal-private interaction with respect to a newly emerging industrial activity is being investigated by the National Planning Association (NPA) in a study of *Methods of Government-Business Cooperation in the Field of Oceanics.* This project was initiated and supported by NSF. Subsequently, the National Council on Marine Resources and Engineering Development found it advantageous to utilize this project to obtain information needed to help develop its recommendations to the Congress. The NPA project was therefore extended to include studies of the prospects of the economic exploitation of the major marine resources. Some 15 special reports have been prepared in two general areas: (1) industry/government role and cooperation in the exploitation of marine resources and shoreline development; and (2) case studies of nonoceanic industries with substantial Federal support. These latter studies are designed to reveal possible techniques which might be applied in marine resources development. A summary of the conclusions—*A Preliminary Review of Alternative Measures of Encouraging Private Enterprise in Marine Resource Development*—is available through the Commerce Department's Clearinghouse for Federal Scientific and Technical Information.

DEVELOPMENT OF THE BASIC TOOLS FOR SCIENCE PLANNING AND POLICY FORMULATION

At least two basic tools are required to formulate science policy or plans. One is an adequate data base, including sources of funds and types of expenditures; numbers and types of educational and R. & D. institutions; scientific manpower, including students and their characteristics or types; and location of science facilities. The other involves the development of methodologies to evaluate the effects of science and technology and to aid in the allocation of science resources.

Data Compilation and Analyses

Since its establishment, the Foundation has been engaged in the compilation and analysis of science resource data. These are made available in the various NSF periodic science resources reports, examples of which are discussed below.

Federal Funds for Research, Development, and Other Scientific Activities provides, on an annual basis, information on the allocation and utilization of Federal science and technology funds. Federal R. & D. obligations totaled $16.5 billion in fiscal year 1967 and an estimated $16.2 billion in 1968. The estimated drop in fiscal year 1968 obligations is due to a decrease in obligations for development from $11.3 billion to $10.8 billion or 3.8 percent. This is the first time since 1955 that total R. & D. funding has decreased from the previous year. However, basic research obligations increased from $2,015 million in fiscal year 1967 to $2,093 million in fiscal year 1968, or 3.9 percent. It should be pointed out that this increase occurred primarily in the industrial sector and not in academic basic research support.

Research and Development in Industry provides, on an annual basis, detailed information on the R. & D. programs of industrial firms. The report issued in fiscal year 1968 showed that these companies increased their R. & D. expenditures by 10 percent from 1965 to 1966 to $15.5 billion; these expenditures accounted for approximately 70 percent of the Nation's total R. & D. spending. Federal funds to industrial firms made up more than one-half of industry's R. & D. effort and increased 7 percent between 1965 and 1966, while company-financed research and development in 1966 rose 13 percent over 1965. The latter constitutes the largest year-to-year gain registered by company-supported research and development in a decade.

The first report on the R. & D. activities of State government agencies (*R. & D. Activities in State Government Agencies, Fiscal Years 1964 and 1965*) was released in fiscal year 1968. State agencies spent $88 million in fiscal year 1965 for research and development (excluding funds made available to State universities and colleges) which represents about 10 percent of the total State government R. & D. effort. Nearly 50 percent of the total R. & D. expenditures of State agencies was reported by New York, California, New Jersey, Illinois, and Pennsylvania. State agencies received about 40 percent of their R. & D. funds from the Federal Government, and concentrated their R. & D. efforts in the areas of health and hospitals, natural resources, and highways. A companion study of local government agencies is now underway and a report will be available shortly.

These various sources of statistical information are woven into "transfer tables" which provide a two-dimensional picture of total American research and development funding and performance. An example involving basic research is shown on page 226.

A special continuous study of Federal financial aid to universities and colleges is also conducted by the Foundation. The report is prepared under the auspices of the Committee on Academic Science and Engineering (CASE) of the Federal Council for Science and Technology for the Office of Science and Technology. In 1968, a report, *Federal Support to Universities and Colleges, Fiscal Years 1963–66,* was published which showed that total Federal obligations to these institutions increased from $1.4 billion in 1963 to $3 billion in 1966; academic science support increased from $1.3 billion to $2.2 billion during this same period. However, the overall Federal academic science support growth rate—i.e., support of R. & D., R. & D. plant, science education, and other academic science activities such as those for the dissemination of science information—has dropped from an average increase of 18.1 percent per year in the 1963–66 period to 6.3 percent in fiscal year 1967 and an estimated 3.3 percent in 1968.

Oceanography is one of the most rapidly growing scientific and technological activities in the United States. Vital to future plans is the need to know detailed information on the manpower resources active in this field at this time. Consequently, a *Study of the Numbers and Characteristics of Oceanographic Personnel in the U.S. in 1967* was conducted under NSF contract by the National Oceanographic Foundation.

322-215 O—68——16

Table 17.—*Intersectoral Transfer of Funds for Performance of Basic Research, 1968 (Estimate)*[1]

[Millions of dollars]

Sources of funds used	Basic research performers: Federal Government	Basic research performers: Industry	Basic research performers: Universities and colleges: Proper[2]	Basic research performers: Universities and colleges: FFRDC's	Basic research performers: Other nonprofit	Total	Percent distribution sources
Federal Government	504	[3] 175	1, 199	248	[3] 149	2, 275	61. 6
Industry		483	31		19	533	14. 4
Universities[4] and colleges			690			690	18. 7
Other nonprofit[4]			93		102	195	5. 3
Total	504	[3] 658	2, 013	248	[3] 270	3, 693	100. 0
			2, 261				
Percent distribution:							
Performers	13. 5	17. 8	54. 5	6. 7	7. 3	100. 0	
			61. 2				

[1] All data are based on reports by the performers.

[2] Includes agriculture experiment stations.

[3] Includes funds from the Federal Government for Federally Funded Research and Development Centers (FFRDC) administered by organizations under contract with Federal agencies.

[4] Includes State and local government funds.

Source: National Science Foundation.

Since computer activities in institutions of higher education will not only play a rapidly increasing role in higher education but also provide the key to the availability of well trained personnel for future U.S. scientific and technological efforts, it is important to have good information on the extent and nature of existing activities. Another special data compilation effort involves a survey by the Southern Regional Education Board aimed at developing a complete inventory of U.S. college and university facilities and computer science degree courses and curricula. This survey is nearing completion and a report is expected to be issued in fiscal year 1969.

Methodology

Only since World War II has science been generally recognized as a major national resource. Furthermore, our national investment in R. & D., both government and private, has evolved at a very rapid rate of growth over the last two decades. This funding growth has been accompanied by a corresponding growth, in both number and complexity, in the mechanisms of R. & D. funding, and the methods used to perform R. & D. Considering all of these factors, it is not surprising that methods of dealing with science policy and resource allocation have only begun to develop significantly during the last 10 years. Constant efforts are required to develop more sophisticated methodology to deal with the numerous resource allocation questions and problems which face science and technology today. Since the system is so complex and frequently abstract, development of improved methodologies is difficult and requires long experimental endeavors which have a relatively high failure rate.

Methodological developments occur within NSF through efforts related to the implementation of the Planning, Programming and Budgeting System (PPBS). Because of the breadth of the NSF objectives—succinctly—the "health of science in the U.S.," the nature of its educational and research programming, and the importance of quality in these activities, it has proven very difficult to define simple overall "measures of output," in contrast to many Government programs where this is feasible. Nevertheless, it has been possible to take advantage of the discipline imposed by the PPBS approach in internal NSF planning activities. Constant efforts are made to provide further insights into the potentials and limitations of the PPB approach to the science resource allocation process. Thus, the Rand Corp. was commissioned for a pilot study to review the present practices and methodologies for science resource allocation and to determine the applicability of PPBS techniques in the field of chemistry. The study concludes that, within the present state of the art, the use of economic analytical methods for resource allocation presents a high order of difficulty. Moreover, significant additional methodological improvements were judged improbable at present until more theoretical work, especially model development, can be achieved.

A study by ABT Associates involves an attempt to develop a model by which it might be possible to "measure" in quantifiable terms the value or effectiveness of specific basic research projects. Two years of preliminary work have produced two such models for solid state physics. If proven valid and operationally feasible, such models could become useful tools for effectiveness judgments required for resource allocation processes. However, much more work is required to ascertain the validity, operational feasibility, and applicability to other fields of these conceptual models.

The Foundation has also funded a number of studies of university planning and accounting practices and their interrelation with university administrations in the management of education and research operations. A project to develop a system for measuring and reporting financial and resources data for institutions of higher education has been carried out by a group of universities (University of Arizona, University of Florida, Michigan State University, University of Pennsylvania, Rensselaer Polytechnic Institute, St. Louis University, Texas A. & M. University System, and the University of Washington) and a report on *Systems for Measuring and Reporting the Resources and Activities of Colleges and Universities* was published this year. This study provides a potential guide for institutions of higher education for the development of more effective resources reporting and analyses systems. The increasing importance placed by universities upon operating information for internal management purposes makes this timely study particularly useful. Similar studies of university operations included a study of a *Systems Approach to Higher Education* undertaken by Michigan State University and a Tulane University study of *A Model of the Cost Structure of a University*.

APPENDIX A

National Science Board, NSF Staff, Special Commission, Advisory Committees and Panels

NATIONAL SCIENCE BOARD

Terms Expire May 10, 1970

MARY I. BUNTING, President, Radcliffe College, Cambridge, Mass.
H. E. CARTER, Vice Chancellor for Academic Affairs, University of Illinois, Urbana, Ill.
JULIAN R. GOLDSMITH, Associate Dean, Division of the Physical Sciences, University of Chicago, Chicago, Ill.
WILLIAM W. HAGERTY, President, Drexel Institute of Technology, Philadelphia, Pa.
ROGER W. HEYNS, Chancellor, University of California at Berkeley, Berkeley, Calif.
HARVEY PICKER, Chairman of the Board, Picker Corporation, White Plains, N.Y.
MINA S. REES, Provost of the University Graduate Division, The City University of New York, New York, N.Y.
F. P. THIEME, Vice President, University of Washington, Seattle, Wash.

Terms Expire May 10, 1972

CLIFFORD M. HARDIN, Chancellor, University of Nebraska, Lincoln, Nebr.
CHARLES F. JONES, President, Humble Oil & Refining Co., Houston, Tex.
THOMAS F. JONES, JR., President, University of South Carolina, Columbia, S.C.
*ROBERT S. MORISON, Professor of Biology and Director, Division of Biological Sciences, Cornell University, Ithaca, N.Y.
*E. R. PIORE (Vice Chairman, National Science Board), Vice President and Chief Scientist, International Business Machines Corp., Armonk, N.Y.
JOSEPH M. REYNOLDS, Boyd Professor of Physics and Vice President for Instruction and Research, Louisiana State University, Baton Rouge, La.
ATHELSTAN F. SPILHAUS, President, The Franklin Institute, Philadelphia, Pa.
RICHARD H. SULLIVAN, President, Association of American Colleges, Washington, D.C.

Terms Expire May 10, 1974

R. H. BING, Research Professor of Mathematics, The University of Wisconsin, Madison, Wis.
*HARVEY BROOKS, Gordon McKay Professor of Applied Physics and Dean of Engineering and Applied Physics, Harvard University, Cambridge, Mass.
WILLIAM A. FOWLER, Professor of Physics, California Institute of Technology, Pasadena, Calif.
NORMAN HACKERMAN, President, The University of Texas at Austin, Austin, Tex.
*PHILIP HANDLER (Chairman, National Science Board), James B. Duke Professor and Chairman, Department of Biochemistry, Duke University Medical Center, Durham, N.C.

*Member, Executive Committee.

JAMES G. MARCH, Dean, School of Social Sciences, University of California at Irvine, Irvine, Calif.

GROVER E. MURRAY, President, Texas Technological College, Lubbock, Tex.

FREDERICK E. SMITH, Chairman, Department of Wildlife and Fisheries, School of Natural Resources, University of Michigan, Ann Arbor, Mich.

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.

NATIONAL SCIENCE FOUNDATION STAFF**

Director, Leland J. Haworth

Executive Assistant, Robert W. Johnston

Executive Associate Director, Louis Levin

OFFICE OF COMPUTING ACTIVITIES

Head, Milton E. Rose

Special Assistant for Liaison, Christof N. Schubert

INSTITUTIONAL COMPUTING SERVICES SECTION

Head, Kent Curtis

Deputy, Glenn R. Ingram

SPECIAL PROJECTS SECTION

Head, Arthur S. Melmed

COMPUTER SCIENCE PROGRAM

EDUCATION, RESEARCH, AND TRAINING SECTIONS

Head, Thomas M. Gallie, Jr.

RESEARCH

Associate Director, Randal M. Robertson

Deputy, Edward P. Todd

Special Assistant, Leonard F. Gardner

Senior Staff Associate, Raymond J. Seeger

Assistant For Special Projects, Jerome H. Fregueau

DIVISION OF ENVIRONMENTAL SCIENCES

Division Director, T. O. Jones

Deputy Division Director, A. P. Crary

Office of Antarctic Programs

Chief Scientist, Louis O. Quam

Executive Officer, G. R. Toney

SCIENCE PROGRAMS

Program Director, Antarctic Biology, George A. Llano

Program Director, Antarctic Earth Sciences, Mort D. Turner

Program Director, Antarctic Atmospheric Physics, Ray R. Heer, Jr.

FIELD REQUIREMENTS AND COORDINATION PROGRAM

Program Director, Philip M. Smith

Vessel Coordinating Officer, R. L. Dale

Logistics Coordinating Officer, Jerry W. Huffman

Logistics Liaison Officer-Eltanin, Merle R. Dawson

**As of September 1968.

Atmospheric Sciences Section

Head, Fred D. White

INTERDEPARTMENTAL COMMITTEE FOR ATMOSPHERIC SCIENCES
Executive Secretary, Sherman W. Betts
AERONOMY PROGRAM
Program Director (Acting), Albert E. Belon
METEROLOGY PROGRAM
Program Director, Eugene W. Bierly
SOLAR TERRESTRIAL RESEARCH PROGRAM
Program Director, Albert E. Belon
WEATHER MODIFICATION PROGRAM
Program Director, Peter H. Wyckoff
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
Program coordinator, Clifford J. Murino

Earth Sciences Section

Head, William E. Benson

GEOCHEMISTRY PROGRAM
Program Director, Alvin Van Valkenburg
GEOLOGY PROGRAM
Program Director, Richard G. Ray
GEOPHYSICS PROGRAM
Program Director, Roy E. Hanson

Oceanography Section

Head, Hugh McLellan

PHYSICAL OCEANOGRAPHY PROGRAM
Program Director (vacant)
OCEANOGRAPHIC FACILITIES PROGRAM
Program Director, Mary K. Johrde
SUBMARINE GEOLOGY AND GEOPHYSICS PROGRAM
Program Director, Vernon J. Henry

DIVISION OF MATHEMATICAL AND PHYSICAL SCIENCES

Division Director, William E. Wright
Executive Assistant, Andrew W. Swago

Astronomy Section

Head, Robert Fleischer

OPTICAL ASTRONOMY PROGRAM
Program Director, Harold H. Lane
RADIO ASTRONOMY PROGRAM
Program Director, Everett H. Hurlburt

Chemistry Section

Head, M. Kent Wilson

CHEMICAL DYNAMICS PROGRAM
Program Director, Donald A. Speer
CHEMICAL INSTRUMENTATION AND ANALYSIS PROGRAM
Program Director, Arthur F. Findeis
CHEMICAL THERMODYNAMICS PROGRAM
Acting Program Director, Oren F. Williams
QUANTUM CHEMISTRY PROGRAM
Program Director, William H. Cramer
STRUCTURAL CHEMISTRY PROGRAM
Program Director, Ronald E. Kagarise
SYNTHETIC CHEMISTRY PROGRAM
Program Director, Oren F. Williams

Mathematical Sciences Section

Head, William H. Pell

ALGEBRA AND TOPOLOGY PROGRAM
Program Director, Ralph M. Krause
ANALYSIS, FOUNDATIONS, AND GEOMETRY PROGRAM
Program Director, Matthew P. Gaffney, Jr.
APPLIED MATHEMATICS AND STATISTICS PROGRAM
Program Director (Acting). William H. Pell

Physics Section

Head, Wayne R. Gruner

ATOMIC AND MOLECULAR PHYSICS PROGRAM
Associate Program Director, Langdon T. Crane, Jr.
ELEMENTARY PARTICLE PHYSICS PROGRAM
Program Director, J. Howard McMillen
ELEMENTARY PARTICLE PHYSICS FACILITIES PROGRAM
Program Director (Acting), Paul F. Donovan

NUCLEAR PHYSICS PROGRAM
Program Director, William S. Rodney
SOLID STATE AND LOW TEMPERATURE PHYSICS PROGRAM
Program Director, Howard W. Etzel
THEORETICAL PHYSICS PROGRAM
Associate Program Director, Joel A. Snow

DIVISION OF BIOLOGICAL AND MEDICAL SCIENCES

Division Director, Harve J. Carlson

Deputy Division Director, John W. Mehl
Special Assistant, J. T. Spencer

Cellular Biology Section

Head, Herman W. Lewis

DEVELOPMENTAL BIOLOGY PROGRAM
Program Director, Mrs. Ursula K. Abbott

GENETIC BIOLOGY PROGRAM
Program Director (Acting), Herman W. Lewis

Environmental and Systematic Biology Section

Head, Bostwick H. Kitchum

ENVIRONMENTAL BIOLOGY PROGRAM
Program Director (Acting), Bostwick H. Kitchum
SYSTEMATIC BIOLOGY PROGRAM
Program Director, Richard F. Johnston

BIOLOGICAL OCEANOGRAPHY PROGRAM
Program Director (Acting), Edward Chin

Molecular Biology Section

Head, Eugene L. Hess

BIOCHEMISTRY PROGRAM
Program Director, Richard Y. Morita

BIOPHYSICS PROGRAM
Program Director (Acting), Eugene L. Hess

Physiological Processes Section

Head, David B. Tyler

REGULATORY BIOLOGY PROGRAM
Program Director (Acting), David B. Tyler

METABOLIC BIOLOGY PROGRAM
Program Director, Sidney Solomon

Psychobiology Program

Program Director, Henry S. Odbert

DIVISION OF ENGINEERING

Division Director, John M. Ide

ENGINEERING CHEMISTRY PROGRAM
Program Director, Lewis G. Mayfield
ENGINEERING ENERGETICS PROGRAM
Program Director (Acting), R. E. Rostenbach
ENGINEERING MATERIALS PROGRAM
Program Director, Israel Warshaw
ENGINEERING MECHANICS PROGRAM
Program Director, Michael P. Gaus
ENGINEERING SYSTEMS PROGRAM
Program Director (Acting), Elias Schutzman
SPECIAL PROGRAMS
Program Director, Lewis D. Conta

DIVISION OF SOCIAL SCIENCES

Division Director, Howard H. Hines
ANTHROPOLOGY PROGRAM
Program Director, Richard W. Lieban
ECONOMICS PROGRAM
Program Director, James H. Blackman
GEOGRAPHY PROGRAM
Program Director, Howard H. Hines
HISTORY AND PHILOSOPHY OF SCIENCE PROGRAM
Special Consultant, Dudley Shapere
Special Assistant, Mrs. Bertha W. Rubinstein
POLITICAL SCIENCE PROGRAM
Program Director, Howard H. Hines
SOCIOLOGY AND SOCIAL PSYCHOLOGY PROGRAM
Program Director, Charles R. Wright
SPECIAL PROJECTS PROGRAM
Program Director, Murray Aborn
SPECIAL COMMISSION ON THE SOCIAL SCIENCES
Staff Director, Albert Buckberg

OFFICE OF SEA GRANT PROGRAMS

Head, Robert B. Abel

Planning Officer, Harold L. Goodwin
Program Director, Arthur G. Alexiou
Program Director, Robert D. Wildman

INSTITUTIONAL RELATIONS

Acting Associate Director, Howard E. Page

Special Assistant (Planning), Mrs. Mildred C. Allen
ARCHITECTURAL SERVICES STAFF
Supervisory Architect, Harold Horowitz
Engineer, S. A. Heider

Graduate Science Facilities Section

Head, Joshua M. Leise
Staff Associates: Richard A. Carrigan, Paul G. Cheatham, Lloyd O. Herwig, Frederic A. Leonard, Harold A. Spuhler

Institutional Grants for Science Program

Program Director, J. Merton England

University Science Development Section

Head, Denzel D. Smith
Senior Staff Associate, George A. Livingston
Staff Associates: George W. Baker, Jesse C. Denton, J. Richard Mayer

Departmental Science Development Section

Head, William V. Consolazio

Staff Associates: Edward Z. Dager, Robert R. Kadesch, John F. Lance, Robert H. Linnell, Ralph H. Long, Jr.

EDUCATION

Associate Director, Thomas D. Fontaine

Deputy Associate Director, Keith R. Kelson
Executive Assistant, Albert T. Young

PLANNING AND EVALUATION UNIT
Planning Officer, William A. Jaracz

DIVISION OF UNDERGRADUATE EDUCATION IN SCIENCE

Division Director, Lyle W. Phillips

UNDERGRADUATE STUDENT PROGRAM
Program Director, Donald C. McGuire
COLLEGE TEACHER PROGRAM
Program Director, Reinhard L. Korgen
INSTRUCTIONAL SCIENTIFIC EQUIPMENT PROGRAM
Program Director (Acting), Richard C. Kolf

COLLEGE SCIENCE IMPROVEMENT PROGRAM
Program Director, Alfred F. Borg
SPECIAL PROJECTS PROGRAM
Program Director, James C. Kellett, Jr.

DIVISION OF GRADUATE EDUCATION IN SCIENCE

Division Director, Howard D. Kramer

Deputy Division Director, Francis G. O'Brien
ADVANCED SCIENCE EDUCATION PROGRAM
Program Director, Fred S. Honkala
GRADUATE FELLOWSHIPS AND TRAINEESHIPS PROGRAM
Program Director, Douglas S. Chapin

FACULTY AND POSTDOCTORAL FELLOWSHIPS PROGRAM
Program Director, Hall Taylor
SENIOR FELLOWSHIPS PROGRAM
Program Director, Mrs. Marjory R. Benedict

DIVISION OF PRE-COLLEGE EDUCATION IN SCIENCE

Acting Division Director, Charles A. Whitmer

Teacher Education Section

Head, C. Russell Phelps

SUMMER STUDY PROGRAM
Program Director, William E. Morrell

RESEARCH TRAINING AND ACADEMIC YEAR STUDY PROGRAM
Program Director, Michael M. Frodyma

Student and Curriculum Improvement Section

Head, Howard J. Hausman

PRE-COLLEGE COURSE CONTENT IMPROVEMENT PROGRAM
Program Director, Laurence O. Binder

STUDENT AND COOPERATIVE PROGRAM
Program Director, E. Allen Davis

PLANNING

Planning Director, Charles E. Falk

OFFICE OF DATA MANAGEMENT SYSTEMS

Head, Irvin V. Voltin

Deputy Head, Richard W. H. Lee

OFFICE OF PLANNING AND POLICY STUDIES

Head, Sidney G. Reed, Jr.

OFFICE OF ECONOMIC AND MANPOWER STUDIES

Head, H. E. Riley

Deputy Head, Sidney A. Jaffe

Statistical Surveys and Reports Section

Head, Kenneth Sanow

GOVERNMENT STUDIES GROUP
Study Director, Benjamin L. Olsen
UNIVERITIES AND NONPROFIT INSTITUTIONS STUDIES GROUP
Study Director, Joseph H. Schuster
INDUSTRY STUDIES GROUP
Acting Study Director, Thomas J. Hogan
ANALYTICAL STUDIES GROUP
Study Director, Lawrence Seymour

Sponsored Surveys and Studies Section

Head, Thomas J. Mills

SCIENTIFIC MANPOWER STUDIES GROUP
Study Director, Norman Seltzer
SCIENCE EDUCATION STUDIES GROUP
Study Director, Justin C. Lewis
NATIONAL REGISTER GROUP
Study Director, Milton Levine
FOREIGN STUDIES GROUP
Study Director, Joseph P. Kozlowski
SPECIAL ANALYSIS GROUP
Study Director, Robert W. Cain

OFFICE OF SCIENCE INFORMATION SERVICE

Head, Burton W. Adkinson

Deputy Head, Henry J. Dubester

Studies and Support Section

Head, William S. Barker

RESEARCH AND STUDIES PROGRAM
Program Director, Donald K. Pollock
INFORMATION SYSTEMS PROGRAM
Program Director, Harold E. Bamford, Jr.
INFORMATION SERVICES PROGRAM
Program Director, Gordon B. Ward
SPECIAL PROJECTS PROGRAM
Program Director, Edward C. Weiss
CHEMICAL INFORMATION UNIT
Head, Paul D. Olejar

Science Information Coordination Section

Head, Ernest R. Sohns

DOMESTIC SCIENCE INFORMATION PROGRAM
Program Director, Henry Tovey
FOREIGN SCIENCE INFORMATION PROGRAM
Program Director, Eugene Pronko

OFFICE OF INTERNATIONAL SCIENCE ACTIVITIES

Head, Arthur Roe

Cooperative Science Activities

Head, Max Hellman

INDIA PROGRAM
Program Director, Gordon Hiebert
LATIN AMERICA PROGRAM
Associate Program Director, Jay Davenport

U.S.-JAPAN AND U.S.-ITALY PROGRAMS
Program Director, J. E. O'Connell

Scientific Liaison

NSF Exchange Officer (State Dept.), Ray Mayhew
Acting Head, Duncan Clement

NSF/NEW DELHI, NSF SCIENCE LIAISON STAFF, USAID NEW DELHI, CARE OF AGENCY FOR INTERNATIONAL DEVELOPMENT, WASHINGTON, D.C. 20523
Head, Ray Koppelman

NSF/TOKYO, SCIENCE LIAISON STAFF, NATIONAL SCIENCE FOUNDATION, CARE OF AMERICAN EMBASSY, APO SAN FRANCISCO 96503
Head, Walter Hodge

OFFICE OF THE GENERAL COUNSEL

General Counsel, William J. Hoff

Deputy General Counsel, and Head, Legal Office, Charles F. Brown

Deputy General Counsel—Special Projects, Charles Maechling, Jr.

OFFICE OF CONGRESSIONAL AND PUBLIC AFFAIRS

Head, Clarence C. Ohlke

Publications Officer, Jack Kratchman

CONGRESSIONAL LIAISON OFFICE

Congressional Liaison Officer, Theodore W. Wirths

PUBLIC INFORMATION OFFICE

Public Information Officer, Roland D. Paine, Jr.

ADMINISTRATIVE MANAGER

Administrative Manager, F. C. Sheppard

Deputy Administrative Manager, Henry Birnbaum

OFFICE FOR EQUAL OPPORTUNITY

Head, Howard S. Schilling

CONTRACTS OFFICE

Head, Robert D. Newton

GRANTS OFFICE

Head, William E. Fee, Jr. *Deputy Head,* Robert A. Michelitch

MANAGEMENT ANALYSIS OFFICE

Head, George Pilarinos

ADMINISTRATIVE SERVICES

Administrative Services Officer, Howard Tihila

PERSONNEL OFFICE

Personnel Officer, Calvin C. Jones

COMPTROLLER

Comptroller, Aaron Rosenthal

BUDGET OFFICE

Budget Officer (Deputy Comptroller), Luther F. Schoen

FINANCE OFFICE

Finance Officer, Edward B. Garvey

INDIRECT COST (RATE) DETERMINATION OFFICE

Head, Louis Siegel

INTERNAL AUDIT OFFICE

Head, Wilford G. Kener

Special Commission on The Social Sciences

ORVILLE G. BRIM, JR. (Chairman), President, Russell Sage Foundation, New York, N.Y.

H. GUYFORD STEVER (Vice Chairman), President, Carnegie-Mellon University, Pittsburgh, Pa.

SAMUEL J. ELDERSVELD, Professor of Political Science, The University of Michigan, Ann Arbor, Mich.

MARION B. FOLSOM, Director, Eastman Kodak Co., Rochester, N.Y.

WILLIAM L. GARRISON, Director, Center for Urban Studies, University of Illinois at Chicago Circle, Chicago, Ill.

MARGARET A. HICKEY, Public Affairs Editor, *Ladies Home Journal,* St. Louis, Mo.

ADELAIDE CROMWELL HILL, African Studies Center, Boston University, Brookline, Mass.

GARDNER LINDZEY, Vice President for Academic Affairs, The University of Texas, Austin, Tex.

PAUL A. SAMUELSON, Professor of Economics, Massachusetts Institute of Technology, Cambridge, Mass.

CECIL G. SHEPS, General Director, Beth Israel Medical Center, New York, N.Y.

ALLAN F. SMITH, Vice President for Academic Affairs, The University of Michigan, Ann Arbor, Mich.

ADVISORY COMMITTEES, COUNCILS, AND PANELS

Advisory Committee for Biological and Medical Sciences

W. Frank Blair, Department of Zoology, University of Texas, Austin, Tex.

Edward W. Fager, Scripps Institution of Oceanography, La Jolla, Calif.

David M. Gates, Director, Missouri Botanical Garden, St. Louis, Mo.

J. Woodland Hastings, Biological Laboratories, Harvard University, Cambridge, Mass.

Ray D. Owen, (Chairman), Division of Biological Sciences, California Institute of Technology, Pasadena, Calif.

Carl Gottschalk (Vice Chairman), School of Medicine, University of North Carolina, Chapel Hill, N.C.

William D. Neff, Department of Psychology, Indiana University, Bloomington, Ind.

Anton Lang, Director, Atomic Energy Commission Plant Research Laboratory, Michigan State University, East Lansing, Mich.

Charles G. Sibley, Peabody Museum, Yale University, New Haven, Conn.

Edgar Zwilling, Department of Biology, Brandeis University, Waltham, Mass.

Advisory Committee for Computing Activities

Daniel Alpert (Chairman), Dean, Graduate College, University of Illinois, Urbana, Ill.

Gordon W. Blackwell, President, Furman University, Greenville, S.C.

Alan J. Perlis, Head, Department of Computer Science, Carnegie-Mellon University, Pittsburgh, Pa.

J. T. Schwartz, Courant Institute of Mathematical Sciences, New York University, New York, N.Y.

Jules I. Schwartz, Systems Development Corp., Santa Monica, Calif.

Sidney Fernbach, Head, Computation Division, Lawrence Radiation Laboratory, Livermore, Calif.

John G. Kemeny (Vice Chairman), Department of Mathematics, Dartmouth College, Hanover, N.H.

Harrison Shull, Dean of the Graduate School, Indiana University, Bloomington, Ind.

Patrick C. Suppes, Institute for Mathematical Studies in the Social Sciences, Stanford University, Stanford, Calif.

Advisory Committee for Engineering

George W. Housner (Chairman), Department of Civil Engineering, California Institute of Technology, Pasadena, Calif.

Nathan M. Newmark, Department of Civil Engineering, University of Illinois, Urbana, Ill.

Richard R. Hughes, Shell Oil Co., Norco Refinery, Norco, La.

Charles L. Miller, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Robert M. Saunders, School of Engineering, University of California, Irvine, Irvine, Calif.

Thomas L. Martin, Jr., Dean, Institute of Technology, Southern Methodist University, Dallas, Tex.

William G. Shepherd, Vice President for Academic Affairs, University of Minnesota, Minneapolis, Minn.

John G. Truxal, Provost, Polytechnic Institute of Brooklyn, Brooklyn, N.Y.

Winfield W. Tyler, Vice President for Research, Xerox Corp., Rochester, N.Y.

Richard H. Wilhelm, Department of Chemical Engineering, Princeton University, Princeton, N.J.

Advisory Committee for Environmental Sciences

A. R. CHAMBERLAIN (Chairman), Vice President, Colorado State University, Fort Collins, Colo.

JAMES R. BALSLEY, JR. (Vice Chairman), Chairman, Department of Geology, Wesleyan University, Middletown, Conn.

WAYNE V. BURT, Chairman, Department of Oceanography, Oregon State University, Corvallis, Ore.

JOHN E. CANTLON, Department of Botany, Michigan State University, East Lansing, Mich.

STIRLING A. COLGATE, President, New Mexico Institute of Mining and Technology, Campus Station, Socorro, N. Mex.

*RICHARD M. GOODY, Professor of Meteorology and Director of Blue Hills Observatory, Division of Engineering and Applied Physics, Harvard University, Cambridge, Mass.

**CHARLES M. TIEBOUT, Department of Economics, University of Washington, Seattle, Wash.

VERNON J. HURST, Chairman, Department of Geology, University of Georgia, Athens, Ga.

JOHN A. KNAUSS, Dean, The Graduate School, University of Rhode Island, Kingston, R.I.

*JAMES WARREN MCKIE, Department of Economics, Vanderbilt University, Nashville, Tenn.

ROBERT A. RAGOTSKIE, Chairman, Department of Meteorology, University of Wisconsin, Madison, Wis.

*GILBERT F. WHITE, Professor of Geography, University of Chicago, Chicago, Ill.

*New Panel Members as of February 1968. **Deceased January 1968.

Advisory Committee for Institutional Relations

HOMER D. BABBIDGE, JR. (Chairman), President, University of Connecticut, Storrs, Conn.

LOUIS T. BENEZET, President, Claremont University Center, Claremont, Calif.

JOHN A. D. COOPER, Dean of Science, Northwestern University, Evanston, Ill.

JOSEPH L. MCCARTHY, Dean of Graduate School, University of Washington, Seattle, Wash.

EMIL M. MRAK, Chancellor, University of California (Davis), Davis, Calif.

CLARENCE SCHEPS, Executive Vice President, Tulane University of Louisiana, New Orleans, La.

EDGAR F. SHANNON, JR., President, University of Virginia, Charlottesville, Va.

JOSEPH R. SMILEY, President, University of Colorado, Boulder, Colo.

Advisory Committee for Mathematical and Physical Sciences

BART J. BOK, Director, Steward Observatory, University of Arizona, Tucson, Ariz.

PAUL J. FLORY, Department of Chemistry, Stanford University, Palo Alto, Calif.

KENNETH GREISEN, Department of Physics, Cornell University, Ithaca, N.Y.

HERMAN H. GOLDSTINE, Research Division, IBM Corp., Yorktown Heights, N.Y.

*IRVING KAPLANSKY, Department of Mathematics, University of Chicago, Chicago, Ill.

VERNER SCHOMAKER (Vice Chairman), Department of Chemistry, University of Washington, Seattle, Wash.

*WILLIAM P(ENCE) SLICHTER, Bell Telephone Laboratories, Inc., Chatham, N.J.

GEORGE H. VINEYARD, Chairman, Physics Department, Brookhaven National Laboratory, Upton, L.I., N.Y.

HAROLD F. WEAVER, Director, Radio Astronomy Laboratory, University of California, Berkeley, Calif.

*Appointed: 1 July 1968 to 31 January 1969.

Advisory Committee for Planning

GERHARD COLM, Chief Economist, National Planning Association, Washington, D.C.

PAUL M. DOTY, Department of Chemistry, Harvard University, Cambridge, Mass.

WAYLAND C. GRIFFITH, Vice President for Research and Technology, Missiles and Space Co., Lockheed Aircraft Corp., Sunnyvale, Calif.

MILTON HARRIS, Chairman of the Board of Directors, American Chemical Society, Washington, D.C.

ALLYN W. KIMBALL, Dean of Arts and Sciences, Johns Hopkins University, Baltimore, Md.

EDWIN MANSFIELD, Department of Economics, University of Pennsylvania, Philadelphia, Pa.

EMMANUEL G. MESTHENE, Director, Program of Technology and Society, Harvard University, Cambridge, Mass.

DAVID Z. ROBINSON, Vice President for Academic Affairs, New York University, New York, N.Y.

M. H. TRYTTEN, Consultant to the President of the National Academy of Sciences, Washington, D.C.

CARL M. YORK, JR., Assistant Chancellor for Research, University of California, Los Angeles, Calif.

Advisory Committee for Science Education

W. GORDON WHALEY (Chairman), Dean, The Graduate School, The University of Texas, Austin, Tex.

ANNE ANASTASI, 121 East 38th Street, New York, N.Y.

SANFORD S. ATWOOD, President, Emory University, Atlanta, Ga.

GORDON S. BROWN, Dean, School of Engineering, Masssachusetts Institute of Technology, Cambridge, Mass.

BRYCE L. CRAWFORD, JR., Dean, The Graduate School, The University of Minnesota, Minneapolis, Minn.

EDWARD C. CREUTZ, Vice President for Research and Development, General Atomic, San Diego, Calif.

ROBERT W. MACVICAR, Vice President, Academic Affairs, Southern Illinois University, Carbondale, Ill.

J. W. MAUCKER, President, University of Northern Iowa, Cedar Falls, Iowa

NORMAN H. NACHTRIEB, Department of Chemistry, University of Chicago, Chicago, Ill.

JOSEPH B. PLATT (Vice Chairman), President, Harvey Mudd College, Claremont, Calif.

ARNOLD E. ROSS, Chairman Department of Mathematics, Ohio State University, Columbus, Ohio

WILLIAM A. STALLARD, President, South Florida Junior College, Avon Park, Fla.

Advisory Committee for Social Sciences

JOHN R. BORCHERT, Department of Geography, University of Minnesota, Minneapolis, Minn.

MARSHALL CLAGETT, Institute for Advanced Study, Princeton, N.J.

ROBERT E. LANE, Department of Political Science, Yale University, New Haven, Conn.

STANLEY LEBERGOTT, Department of Economics, Wesleyan University, Middletown, Conn.

JOHN C. MCKINNEY, Department of Sociology, Duke University, Durham, N.C.

M. BREWSTER SMITH, Department of Psychology, University of California, Berkeley, Calif.

ALEXANDER SPOEHR, Department of Anthropology, University of Pittsburgh, Pittsburgh, Pa.

ROBERT STROTZ, College of Arts and Sciences, Northwestern University, Evanston, Ill.

ROBIN WILLIAMS, Department of Sociology and Anthropolgy, Cornell University, Ithaca, N.Y.

BURTON W. ADKINSON, Head, Office of Science Information Service, National Science Foundation, Washington, D.C.

HERBERT BAILEY, Director, Princeton University Press, Princeton, N.J.

FREDERICK C. BARGHOORN, Department of Political Science, Yale University, New Haven, Conn.

LAMONT C. COLE, Professor of Ecology, Division of Biological Sciences, Langmuir Laboratory, Cornell University, Ithaca, N.Y.

MARTIN M. CUMMINGS, Director, National Library of Medicine, Department of Health, Education, and Welfare, Washington, D.C.

CLIFFORD GROBSTEIN, Vice Chancellor for Medicine and the Biological Sciences, Dean, School of Medicine, University of California at San Diego, La Jolla, Calif.

EDWIN HARRISON, President, Georgia Institute of Technology, Atlanta, Ga.

H. WILLIAM KOCH, Director, American Institute of Physics, New York, N.Y.

JOSEPH LICKLIDER, Visiting Professor, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

WILLIAM BEVAN, Provost, Johns Hopkins University, Baltimore, Md.

LAUNOR F. CARTER, Senior Vice-President, Research and Technology Division, System Development Corp., Santa Monica, Calif.

ROBERT COLBORN, 33 River Road, New Canaan, Conn.

W. KENNETH LOWRY, Manager, Technical Information Libraries, Bell Telephone Laboratories, Murray Hill, N.J.

L. QUINCY MUMFORD, The Librarian of Congress, Washington, D.C.

BYRON RIEGEL, Director, Chemical Research and Development, Searle & Co., Chicago, Ill.

JOHN SHERROD, Director, National Agricultural Library, U.S. Department of Agriculture, Washington, D.C.

ROBERT G. VOSPER, Librarian, University of California at Los Angeles, Los Angeles, Calif.

JOHN C. WEAVER, President, University of Missouri, Columbia, Mo.

LEO WEINS, President, The H. W. Wilson Co., Bronx, N.Y.

ADVISORY PANELS

Advisory Panel for Antarctic Programs

LAURENCE M. GOULD (Chairman) College of Mines, University of Arizona, Tucson, Ariz.

PAUL C. DANIELS, Main Street, Lakeville, Conn.

LAURENCE IRVING, Advisory Scientific Director, Institute of Artic Biology, University of Alaska, College, Alaska

HEINZ H. LETTAU, Department of Meteorology, University of Wisconsin, Madison, Wis.

ERNST STUHLINGER, Director, Research Projects Laboratory, National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Ala.

Advisory Panel for Anthropology

ROBBINS BURLING, Department of Anthropology, University of Michigan, Ann Arbor, Mich.

PEDRO CARRASCO, Department of Anthropology, State University of New York at Stony Brook, Stony Brook, L.I., N.Y.

JAMES J. F. DEETZ, Department of Sociology and Anthropology, Brown University, Providence, R.I.

JOHN L. FISCHER, Department of Anthropology, Tulane University, New Orleans, La.

322-215 O—68——17

JOHN DESMOND CLARK, Department of Anthropology, University of California, Berkeley, Calif.

ROBERT MURPHY, Department of Anthropology, Columbia University, New York, N.Y.

Advisory Panel for Astronomy

Chairman: GEORGE B. FIELD

RADIO ASTRONOMY

ALAN H. BARRETT, Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Mass.

CORNELL H. MAYER, U.S. Naval Research Laboratory, Washington, D.C.

JAMES W. WARWICK, Department of Astro-Geophysics, University of Colorado, Boulder, Colo.

GART WESTERHOUT, Astronomy Program, University of Maryland, College Park, Md.

OPTICAL ASTRONOMY

GEORGE B. FIELD, Astronomy Department, University of California, Berkeley, Calif.

JOHN T. JEFFERIES, Institute of Geophysics, University of Hawaii, Honolulu, Hawaii.

DONALD E. OSTERBROOK, Washburn Observatory, University of Wisconsin, Madison, Wis.

MAARTEN SCHMIDT, California Institute of Technology, Pasadena, Calif.

GEORGE WALLERSTEIN, Astronomy Department, University of Washington, Seattle, Wash.

Advisory Panel for Atmospheric Sciences

ALFRED K. BLACKADAR, Head, Department of Meteorology, Pennsylvania State University, University Park, Pa.

KENNETH L. BOWLES, Department of Applied Electrophysics, University of California, San Diego, LaJolla, Calif.

ROBERT L. CHASSON, Department of Physics, University of Denver, Denver, Colo.

WILLIAM E. GORDON, Department of Engineering and Science, Rice University, Houston, Tex.

NORMAN A. PHILLIPS (Chairman), Department of Meteorology, Massachusetts Institute of Technology, Cambridge, Mass.

RICHARD J. REED, Department of Atmospheric Sciences, University of Washington, Seattle, Wash.

Advisory Panel for Chemistry

JEROME A. BERSON, Department of Chemistry, University of Wisconsin, Madison, Wis.

CLARK E. BRICKER, Department of Chemistry, University of Kansas, Lawrence, Kans.

DARYLE H. BUSCH, Department of Chemistry, Ohio State University, Columbus, Ohio

JACK HALPERN, Department of Chemistry, University of Chicago, Chicago, Ill.

JOHN A. POPLE, Department of Chemistry, Carnegie-Mellon University, Pittsburgh, Pa.

DAVID P. STEVENSON, Shell Development Company, Emeryville, Calif.

WALTER H. STOCKMAYER, Department of Chemistry, Dartmouth College, Hanover, N.H.

RICHARD B. TURNER, Department of Chemistry, The William Marsh Rice University, Houston, Tex.

K. KEITH INNES, Department of Chemistry, Vanderbilt University, Nashville, Tenn.

H. A. LAITINEN, Department of Chemistry, University of Illinois, Urbana, Ill.

WILLIAM F. MCEWEN, Department of Chemistry, University of Massachusetts, Amherst, Mass.

JOHN S. WAUGH, Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Mass.

KENNETH B. WIBERG (Chairman), Department of Chemistry, Yale University, New Haven, Conn.

Advisory Panel for Developmental Biology

WINSLOW R. BRIGGS, The Biological Laboratories, Harvard University, Cambridge, Mass.

PHILIP GRANT, Department of Biology, University of Oregon, Eugene, Oreg.

JAMES W. LASH, Department of Anatomy, School of Medicine, University of Pennsylvania, Philadelphia, Pa.

PETER M. RAY, Department of Biological Sciences, Stanford University, Palo Alto, Calif.

LIONEL I. REBHUN, Department of Biology, Princeton University, Princeton, N.J.

RICHARD A. RIFKIND, Department of Medicine, College of Physicians and Suregons of Columbia University, New York, N.Y.

ROBERT H. ROWND, Laboratory of Molecular Biology, University of Wisconsin, Wis.

JEROME A. SCHIFF, Department of Biology, Brandeis University, Waltham, Mass.

FRED H. WILT, Department of Zoology, University of California, Berkeley, Calif.

Advisory Panel for Earth Sciences

.CLARENCE R. ALLEN (Chairman), Seismological Laboratory, California Institute of Technology, Pasadena, Calif.

RICHARD R. DOELL, U.S. Geological Survey, Menlo Park, Calif.

ROBERT M. GARRELS, Department of Geology, Northwestern University, Evanston, Ill.

DONALD L. GRAF, Department of Geology and Geophysics, University of Minnesota, Minneapolis, Minn.

ANTON L. HALES, Geosciences Division, Southwest Center for Advanced Studies, Dallas, Tex.

HAROLD L. JAMES, Chief Geologist, U.S. Geological Survey, Washington, D.C.

JOHN S. STEINHART, Carnegie Institution of Washington, Washington, D.C.

FRANCIS G. STEHLI, Department of Geology, Case-Western Reserve University, Cleveland, Ohio.

GEORGE R. TILTON, Department of Geology, University of California, Santa Barbara, Calif.

Advisory Panel for Economics

GEORGE H. BORTS, 6909 Maple Avenue, Chevy Chase, Md.

JOHN S. CHIPMAN, Department of Economics, University of Minnesota, Minneapolis, Minn.

CARL F. CHRIST, Department of Politcal Economy, Johns Hopkins University, Baltimore, Md.

EVSEY D. DOMAR, Department of Economics, Massachusetts Institute of Technology, Cambridge, Mass.

RENDIGS T. FELS, Department of Economics, Vanderbilt University, Nashville, Tenn.

FRANZ GEHRELS, Department of Economics, Indiana University, Bloomington, Ind.

Advisory Panel for Economic and Manpower Studies*

ALLAN CARTTER, Chancellor, New York University, New York, N.Y.

C. A. CHURCH, Manager, Recruiting Information Operation, General Electric Co., New York, N.Y.

GERHARD COLM, Chief Economist, National Planning Association, Washington, D.C.

RICHARD A. HARVILL, President, University of Arizona, Tucson, Ariz.

JOHN W. KENDRICK, Department of Economics, The George Washington University, Washington, D.C.

W. E. KUHN, Professional Engineer, 1840 N.W. Ramsey Drive, Portland, Oreg.

JOHN W. MCCONNELL, President, University of New Hampshire, Durham, N.H.

EMMANUEL G. MESTHENE, Program on Technology and Society, Harvard University, Cambridge, Mass.

ALBERT H. RUBENSTEIN, Department of Industrial Engineering and Management Sciences, The Technological Institute, Northwestern University, Evanston, Ill.

*Panel discontinued April 1968.

Advisory Panel for Environmental Biology

WILLIAM R. DAWSON, Department of Zoology, University of Michigan, Ann Arbor, Mich.

PAUL DEBACH, Department of Biological Control, University of California, Riverside, Calif.

SHELBY GERKING, Department of Zoology, Arizona State University, Tempe, Ariz.

ROBERT F. INGER, Division of Amphibians and Reptiles, Field Museum of Natural History, Chicago, Ill.

MONTE LLOYD, Department of Zoology, University of Chicago, Chicago, Ill.

HENRY J. OOSTING, Department of Botany, Duke University, Durham, N.C.

LAWRENCE R. POMEROY, Department of Zoology, University of Georgia, Athens, Ga.

HOWARD SANDERS, Woods Hole Oceanographic Institution, Woods Hole, Mass.

Advisory Panel for Genetic Biology

ROWLAND H. DAVIS, Department of Botany, University of Michigan, Ann Arbor, Mich.

D. U. GERSTEL, Department of Field Crops, North Carolina State University, Raleigh, N.C.

MELVIN M. GREEN, Department of Genetics, University of California, Davis, Calif.

KEN-ICHI KOJIMA, Department of Zoology, University of Texas, Austin, Tex.

KARL G. LARK, Division of Biology, Kansas State University, Manhattan, Kans.

DREW SCHWARTZ, Department of Botany, Indiana University, Bloomington, Ind.

GUNTHER S. STENT, Molecular Biology, University of California, Berkeley, Calif.

CHARLES YANOFSKY, Department of Biological Sciences, Stanford University, Stanford, Calif.

Advisory Panel for History and Philosophy of Science

DONALD DAVIDSON, Department of Philosophy, Princeton University, Princeton, N.J.

EDWARD GRANT, Department of History and Philosophy of Science, Indiana University, Bloomington, Ind.

JOHN C. GREENE, Department of History, The University of Connecticut, Storrs, Conn.

RICHARD C. JEFFREY, Department of Philosophy, University of Pennsylvania, Philadelphia, Pa.

MARTIN J. KLEIN, Department of History of Science and Medicine, Yale University, New Haven, Conn.

WILFRID S. SELLARS, Department of Philosophy, University of Pittsburgh, Pittsburgh, Pa.

Advisory Panel for Manpower and Education Studies Programs

THOMAS J. MILLS (Chairman), Head, Sponsored Surveys and Studies Section, Office of Economic and Manpower Studies, National Science Foundation, Washington, D.C.

ALEXANDER MOOD, Assistant Commissioner for Educational Statistics, U.S. Office of Education, Washington, D.C.

JOSEPH S. MURTAUGH, Chief, Office of Program Planning, National Institutes of Health, Department of Health, Education, and Welfare, Bethesda, Md.

ELLIOTT S. PIERCE, Deputy Director, Division of Nuclear Education and Training, Atomic Energy Commission, Washington, D.C.

ALBERT KAY, Director of Manpower Resources, Office of Assistant Secretary of Defense (Manpower), The Pentagon, Washington, D.C.

WALTER W. HAASE, Director, Management Information Systems Division, NASA Headquarters, Washington, D.C.

CONRAD TAEUBER, Assistant Director, Bureau of the Census, Department of Commerce, Washington, D.C.

O. GLENN STAHL, Director, Bureau of Programs and Standards, Civil Service Commission, Washington, D.C.

ROBERT H. RANKIN, USMC, Chief Planning Officer, Selective Service Commission, Washington, D.C.

E. C. ELTING, Associate Director, Research Program Development and Evaluation Staff, Department of Agriculture, Washington, D.C.

MARGARET WEST, Director, Office of Program Planning and Evaluation, Bureau of Health Manpower, Public Health Service, Arlington, Va.

HAROLD GOLDSTEIN, Assistant Commissioner, Office of Manpower and Employment Statistics, Bureau of Labor Statistics, U.S. Department of Labor, Washington, D.C.

Advisory Panel for Mathematical Sciences

RICHARD D. ANDERSON, Department of Mathematics, Louisiana State University, Baton Rouge, La.

JULIUS R. BLUM, Department of Mathematics, University of New Mexico, Albuquerque, N. Mex.

R. CREIGHTON BUCK, Department of Mathematics, University of Wisconsin, Madison, Wis.

ISRAEL N. HERSTEIN, Department of Mathematics, University of Chicago, Chicago, Ill.

MAGNUS R. HESTENES, Department of Mathematics, University of California, Los Angeles, Calif.

VICTOR L. KLEE, Jr., Department of Mathematics, University of Washington, Seattle, Wash.

ELIAS M. STEIN, Department of Mathematics, Princeton University, Princeton, N.J.

Advisory Panel for Metabolic Biology

EDMOND H. FISCHER, Department of Biochemistry, University of Washington, School of Medicine, Seattle, Wash.

DAVID E. GREEN, Enzyme Institute, University of Wisconsin, Madison, Wis.

JOHN B. HANSON, Department of Agronomy, University of Illinois, Urbana, Ill.

HARRY D. PECK, Division of Biochemistry, University of Georgia, Athens, Ga.

HARRY RUDNEY, Department of Biological Chemistry, University of Cincinnati, Cincinnati, Ohio

HUTTON D. SLADE, Department of Microbiology, Northwestern University Medical School, Chicago, Ill.

ROBERT LANGDON, Department of Biochemistry, University of Florida, School of Medicine, Gainesville, Fla.

WILLIAM R. NES, Department of Biological Sciences, Drexel Institute of Technology, Philadelphia, Pa.

PAUL K. STUMPF, Department of Biochemistry and Biophysics, University of California, Davis, Calif.

Advisory Panel for Molecular Biology

WARREN L. BUTLER, Department of Biology, University of California, La Jolla, Calif.

JOHN R. CANN, Department of Biophysics, University of Colorado Medical Center, Denver, Colo.

JOSEPH F. HOFFMAN, Department of Physiology, Yale University School of Medicine, New Haven, Conn.

DAVID W. KROGMANN, Department of Biochemistry, Purdue University, Lafayette, Ind.

LEONARD LERMAN, Department of Molecular Biology, Vanderbilt University, Nashville, Tenn.

LEON LEVINTOW, Department of Microbiology, University of California School of Medicine, San Francisco, Calif.

ROBERT PERRY, Institute for Cancer Research, Philadelphia, Pa.

JOHN WESTLEY, Department of Biochemistry, University of Chicago, Chicago, Ill.

ROBERT STEINER, Division of Biochemistry, Naval Medical Research Institute, Bethesda, Md.

Advisory Panel for Oceanography

BRUCE B. BENSON, Department of Physics, Amherst College, Amherst, Mass.

CHARLES L. DRAKE, Lamont Geographical Observatory, Columbia University, Palisades, N.Y.

DONALD W. HOOD, Institute of Marine Science, University of Alaska, College, Alaska

MAURICE RATTRAY, Jr., Department of Oceanography, University of Washington, Seattle, Wash.

WILLIAM S. RICHARDSON, Department of Oceanography, Nova University, Fort Lauderdale, Fla.

GENE A. RUSNAK, U.S. Geological Survey, Marine Geology and Hydrology, Pacific, Menlo Park, Calif.

Advisory Panel for Oceanographic Facilities and Ship Operations

EUGENIE CLARK, Cape Haze Marine Laboratory, Sarasota, Fla.

PARKE A. DICKEY, Department of Geology, University of Tulsa, Tulsa, Okla.

JOHN LYMAN, Bureau of Commercial Fisheries, Department of Interior, Washington, D.C.

WARREN C. THOMPSON, Department of Meteorology and Oceanography, U.S. Naval Postgraduate School, Monterey, Calif.

WILLIAM WALTON, Pan American Petroleum Corp., Tulsa, Okla.

MAX SILVERMAN, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, Calif.

ROBERT G. PAQUETTE, AC Electronics, Defense Research Laboratories, Goleta, Calif.

Advisory Panel for Physics

HERBERT B. CALLEN, Department of Physics, University of Pennsylvania, Philadelphia, Pa.

JAMES H. CRAWFORD, Jr., Department of Physics, University of North Carolina, Chapel Hill, N.C.

HSU Y. FAN, Department of Physics, Purdue University, Lafayette, Ind.

WADE L. FITE, Department of Physics, University of Pittsburgh, Pittsburgh, Pa.

NORTON M. HINTZ, School of Physics, University of Minnesota, Minneapolis, Minn.

HUGH MCMANUS, Department of Physics and Astronomy, Michigan State University, East Lansing, Mich.

WILLIAM C. PARKINSON, Cyclotron Lab—North Campus, University of Michigan, Ann Arbor, Mich.

ARTHUR L. SCHAWLOW, Department of Physics, Stanford University, Stanford, Calif.

BERNARD WALDMAN (Chairman), College of Science, University of Notre Dame, Notre Dame, Ind.

RICHARD WILSON, Department of Physics, Harvard University, Cambridge, Mass.

Advisory Panel for Political Science

RICHARD L. PARK, Department of Political Science, University of Michigan, Ann Arbor, Mich.

WILLIAM H. RIKER, Department of Political Science, University of Rochester, Rochester, N.Y.

JAMES A. ROBINSON, Mershon Center for Education in National Security, Ohio State University, Columbus, Ohio.

ALLAN P. SINDLER, Department of Government, Cornell University, Ithaca, N.Y.

KENNETH N. WALTZ, Department of Political Science, Brandeis University, Waltham, Mass.

Advisory Panel for Psychobiology

GEORGE BARLOW, Department of Zoology, University of California, Berkeley, Calif.

MICHAEL R. D'AMATO, Department of Psychology, Rutgers, The State University, New Brunswick, N.J.

JOHN F. HALL, Department of Psychology, Pennsylvania State University, University Park, Pa.

FRANK MCKINNEY, James Ford Bell Museum of Natural History, University of Minnesota, Minneapolis, Minn.

DONALD R. MEYER, Ohio State University Research Center, Columbus, Ohio.

IRWIN POLLACK, Mental Health Research Institute, University of Michigan, Ann Arbor, Mich.

RICHARD THOMPSON, Department of Psychology, University of California, Irvine, Calif.

WARREN S. TORGERSON, Department of Psychology, Johns Hopkins University, Baltimore, Md.

Ad Hoc Review Committee for Radio Astronomy Facilities

ROBERT H. DICKE (Chairman), Department of Physics, Princeton University, Princeton, N.J.

BART J. BOK, Steward Observatory, University of Arizona, Tucson, Ariz.

WILLIAM W. MORGAN, Yerke Observatory, Williams Bay, Wis.

EUGENE N. PARKER, Enrico Fermi Institute for Nuclear Studies, University of Chicago, Chicago, Ill.

STIRLING A. COLGATE, New Mexico Institute of Mining and Technology, Socorro, N. Mex.

RUDOLPH KOMPFNER, Electronics and Radio Research, Bell Telephone Laboratories, Inc., Hoemdel, N.J.

MERLE A. TUVE, Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D.C.

GART WESTERHOUT, Astronomy Program, University of Maryland, College Park, Md.

Advisory Panel for Regulatory Biology

SAMUEL ARONOFF, Department of Biochemistry and Biophysics, Iowa State University, Ames, Iowa.

SAM L. CLARK, Jr., Department of Anatomy, Washington University, St. Louis, Mo.

MILTON FINGERMAN, Department of Biology, Tulane University, New Orleans, La.

TERU HAYASHI, Department of Biology, Illinois Institute of Technology, Chicago, Ill.

RILEY HOUSEWRIGHT, Technical Director, Fort Detrick, Frederick, Md.

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

MANFRED M. MAYER, Department of Microbiology, Johns Hopkins University School of Medicine, Baltimore, Md.

SIDNEY OCHS, Department of Physiology, University of Indiana, Indianapolis, Ind.

ELIJAH B. ROMANOFF, Worcester Foundation for Experimental Biology, Shrewsbury, Mass.

R. P. SCHEFFER, Department of Botany, Michigan State University, East Lansing, Mich.

SIDNEY SOLOMON, University of New Mexico, School of Medicine, Albuquerque, N. Mex.

J. W. UHR, Department of Medicine, New York University, New York, N.Y.

Advisory Panel for Science Development

CARL W. BORGMANN, Advisor on Science and Technology, The Ford Foundation, New York, N.Y.

ROBERT B. BRODE, Professor of Physics, University of California, Berkeley, Calif.

DALE R. CORSON, Provost, Cornell University, Ithaca, N.Y.

JAMES D. EBERT, Director, Department of Embryology, Carnegie Institution of Washington, Baltimore, Md.

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.

O. MEREDITH WILSON, Director, Center for Advanced Study in the Behavioral Sciences, Stanford, Calif.

Advisory Panel for Sea Grant Institutional Support

SANFORD S. ATWOOD, Emory University, Atlanta, Ga.

BERNARD BERMAN, The Bissett-Berman Corp., Santa Monica, Calif.

DOUGLAS BROOKS, Travelers Research Center, Hartford, Conn.

JOHN C. CALHOUN, JR., Texas A. & M. University, College Station, Tex.

JOSEPH E. HENDERSON, Applied Physics Laboratory, University of Washington, Seattle, Wash.

CHALMER G. KIRKBRIDE, Sun Oil Co., Philadelphia, Pa.

DAVID POTTER, Defense Research Laboratory, General Motors Corp., Goleta, Calif.

ROBERT H. ROY, Johns Hopkins University, Baltimore, Md.

H. B. STEINBACH, Woods Hole Oceanographic Institution, Woods Hole, Mass.

ORD ALEXANDER, Alexander Real Estate, Washington, D.C.

WILLIAM T. BURKE, University of Washington, Seattle, Wash.

PAUL R. BURKHOLDER, Lamont Geological Observatory, Palisades, N.Y.

JOHN H. BUSSER, American Institute of Biological Sciences, Washington, D.C.

FRED R. CAGLE, Tulane University, New Orleans, La.

JOSEPH M. CALDWELL, Coastal Engineering Research Center, U.S. Army Corps of Engineers, Washington, D.C.

WILBERT M. CHAPMAN, Van Camp Seafood Co., San Diego, Calif.

LEIGHTON COLLINS, American Society for Engineering Education, Washington, D.C.

THOMAS CRAWFORD, University of Rhode Island, Kingston, R.I.

EUGENE L. CRONIN, University of Maryland, College Park, Md.

JAMES A. CRUTCHFIELD, University of Washington, Seattle, Wash.

SYLVIA EARLE, Harvard University, Cambridge, Mass.

HAVEN EMERSON, Ocean General, Washington, D.C.

LEWIS R. FIBEL, American Association of Junior Colleges, Washington, D.C.

ROGER FULLING, E. I. duPont de Nemours & Co., Wilmington, Del.

ROY D. GAUL, Westinghouse Research Laboratory, San Diego, Calif.

C. PHILIP GILMORE, General Dynamics Corp., Quincy, Mass.

DONALD HOOD, University of Alaska, College, Alaska

JOHN D. ISAACS, Scripps Institution of Oceanography, La Jolla, Calif.

PAUL M. JACOBS, The Gorton Corp., Gloucester, Mass.

MILTON G. JOHNSON, Environmental Science Services Administration, Rockville, Md.

WILLIAM KEILHORN, 1651 Paseo Vonita, La Jolla, Calif.

GEORGE R. LUNZ, Bears Bluff Laboratories, Wadmalaw Island, S.C.

CHRISTIAN LAMBERTSON, University of Pennsylvania, Philadelphia, Pa.

JOHN LYMAN, University of North Carolina, Chapel Hill, N.C.

ARTHUR MAXWELL, Woods Hole Oceanographic Institution, Woods Hole, Mass.

H. CRANE MILLER, Smithsonian Institution, Washington, D.C.

JOHNES K. MOORE, Salem State College, Salem, Mass.

FRANK A. NEMEC, Lykes Bros. Shipping Lines, New Orleans, La.

MICHAEL NEUSHUL, Jr., University of California, Santa Barbara, Calif.

ARTHUR NOVAK, Louisiana State University, Baton Rouge, La.

JOHN W. PADAN, Bureau of Mines, Department of the Interior, Tiburon, Calif.

GERARD R. POMERAT, Rockefeller Foundation, New York, N.Y.

LAWRENCE POMEROY, University of Georgia, Athens, Ga.

ADRIAN RICHARDS, University of Illinois, Urbana, Ill.

RUSSELL SINHUBER, Oregon State University, Corvallis, Oreg.

JAMES SNODGRASS, Scripps Institution of Oceanography, La Jolla, Calif.

MILLER B. SPANGLER, National Planning Association, Washington, D.C.

EDWARD STEPHAN, Ocean Systems, Inc., Arlington, Va.

WILLIAM G. TORPEY, Office of Emergency Planning, Washington, D.C.

RICHARD C. VETTER, Committee on Oceanography, National Academy of Sciences, Washington, D.C.

WILLIAM S. VON ARX, Woods Hole Oceanographic Institution, Woods Hole, Mass.

ELIZABETH WALLACE, Oyster Institute of North America, Sayville, Long Island, N.Y.

322-215 O—68——18

Advisory Panel for Sociology and Social Psychology

THEODORE R. ANDERSON, Department of Sociology, University of Oregon, Eugene, Oreg.

DONALD T. CAMPBELL, Department of Psychology, Northwestern University, Evanston, Ill.

ERNEST Q. CAMPBELL, Department of Sociology and Anthropology, Vanderbilt University, Nashville, Tenn.

RICHARD J. HILL, Department of Sociology, Purdue University, Lafayette, Ind.

HERBERT H. HYMAN, Department of Sociology, Columbia University, New York, N.Y.

MILTON ROKEACH, Department of Psychology, Michigan State University, East Lansing, Mich.

MILTON J. ROSENBERG, Department of Psychology, University of Chicago, Chicago, Ill.

PERCY H. TANNENBAUM, Annenberg School of Communications, University of Pennsylvania, Philadelphia, Pa.

Advisory Panel for Systematic Biology

HENRY N. ANDREWS, Jr., Department of Botany, University of Connecticut, Storrs, Conn.

JOHN O. CORLISS, Department of Biological Sciences, University of Illinois at Chicago Circle, Chicago, Ill.

ROBERT K. GODFREY, Department of Botany, Florida State University, Tallahassee, Fla.

EUGENE N. KOZLOFF, Friday Harbor Laboratories, University of Washington, Friday Harbor, Wash.

E. GORTON LINSLEY, Dean, College of Agriculture, University of California, Berkeley, Calif.

MALCOLM C. MCKENNA, Department of Geology and Paleontology, American Museum of Natural History, New York, N.Y.

C. RICHARD ROBINS, Institute of Marine Sciences, University of Miami, Miami, Fla.

ALEXANDER H. SMITH, Department of Botany, University of Michigan, Ann Arbor, Mich.

Advisory Panel for Instiutional Computing Services Section

SAMUEL D. CONTE, Director, Computation Center, Purdue University, Lafayette, Ind.

EARLE C. FOWLER, Department of Physics, Duke University, Durham, N.C.

JAY M. GOLDBERG, Department of Physiology, University of Chicago, Chicago, Ill.

HARRY D. HUSKEY, Computer Center, University of California, Santa Cruz, Calif.

DAVID E. LAMB, Department of Statistics and Computer Science, University of Delaware, Newark, Del.

MAX VERNON MATHEWS, Bell Telephone Laboratory, Inc., Murray Hill, N.J.

FREDERICK A. MATSEN, Department of Chemistry, University of Texas, Austin, Tex.

GILBERT D. MCCANN, Willis H. Booth Computing Center, California Institute of Technology, Pasadena, Calif.

ERNEST P. MILES, Jr., Computing Center and Department of Mathematics, Florida State University, Tallahassee, Fla.

ITHIEL DE SOLA POOL, Department of Political Science, Massachusetts Institute of Technology, Cambridge, Mass.

OTIS W. RECHARD, Director, Computer Center, Washington State University, Pullman, Wash.

AKSEL C. WIIN-NIELSEN, Department of Meteorology and Oceanography, University of Michigan, Ann Arbor, Mich.

Advisory Panel for Weather Modification

ROSCOE H. BRAHAM, Jr., Department of the Geophysical Sciences, University of Chicago, Chicago, Ill.

HORACE R. BYERS (Chairman), Dean, College of Geosciences, Texas A. & M. University, College Station, Tex.

CHARLES L. HOSLER, Dean of Mineral Industries, Pennsylvania State University, University Park, Pa.

ARCHIE M. KAHAN, Bureau of Reclamation, Department of the Interior, Denver, Colo.

JAMES E. MCDONALD, Institute of Atmospheric Physics, University of Arizona, Tucson, Ariz.

W. R. DERRICK SEWELL, Department of Geography, University of Victoria, Victoria, British Columbia.

Consultants for Facilities and Special Programs

SANFORD S. ATWOOD, President, Emory University, Atlanta, Ga.

RICHARD H. BACHUS, Woods Hole Oceanographic Institution, Woods Hole, Mass.

LESLIE A. CHAMBERS, Director, Hancock Foundation, University of Southern California, Los Angeles, Calif.

VERNON I. CHEADLE, Chancellor, University of California, Santa Barbara, Calif.

GEORGE F. EDMUNDS, Jr., University of Utah, Salt Lake City, Utah.

ROBERT L. FERNALD, Director, Friday Harbor Laboratories, University of Washington, Seattle, Wash.

JEFFERY D. FRAUTSCHY, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, Calif.

SHELBY GERKING, Head, Department of Zoology, Arizona State University, Tempe, Ariz.

CADET H. HAND, Jr., Department of Zoology, University of California, Berkeley, Calif.

ARTHUR D. HASLER, Laboratory of Limnology, University of Wisconsin, Madison, Wis.

ROBERT HIATT, Vice President for Academic Affairs, University of Hawaii, Honolulu, Hawaii.

GEORGE H. LAUFF, Kellogg Biological Station, Michigan State University, Hickory Corners, Mich.

JONATHAN LEIBY, Woods Hole Oceanographic Institution, Woods Hole, Mass.

F. HARLAN LEWIS, Dean of Life Sciences, University of California, Los Angeles, Calif.

EDWARD CHIN, Department of Biology, Texas A. & M. University, Marine Laboratory, Galveston, Tex.

EDWARD E. CLEBSCH, Department of Botany, University of Tennessee, Knoxville, Tenn.

LINCOLN CONSTANCE, Department of Botany, University of California, Berkeley, Calif.

WILLIAM H. MARSHALL, Director of Field Biology Program, College of Biological Sciences, University of Minnesota, St. Paul, Minn.

ROBERT B. PLATT, Department of Biology, Emory University, Atlanta, Ga.

J. ROGER PORTER, Department of Microbiology, State University of Iowa, Iowa City, Iowa.

EDWARD C. RANEY, Division of Biological Sciences, Cornell University, Ithaca, N.Y.

JOHN F. REED, President, Fort Lewis College, Durango, Colo.

CARL D. RIGGS, Director and Dean, Graduate College, University of Oklahoma, Norman, Okla.

JOHN H. RYTHER, Woods Hole Oceanographic Institution, Woods Hole, Mass.

THOMAS T. SANDEL, Computer Research Laboratory, Washington University, St. Louis, Mo.

BOBB SCHAEFFER, American Museum of Natural History, New York, N.Y.

KNUT SCHMIDT-NIELSEN, Department of Zoology, Duke University, Durham, N.C.

CHARLES G. SIBLEY, Department of Biology, Yale University, New Haven, Conn.

ALBERT C. SMITH, Department of Botany, University of Hawaii, Honolulu, Hawaii

DONALD W. TINKLE, Department of Zoology, University of Michigan, Ann Arbor, Mich.

STANLEY WATSON, Woods Hole Oceanographic Institution, Woods Hole, Mass.

FRITS W. WENT, University of Nevada, Desert Research Institute, Reno, Nev.

RAINER ZANGERL, Chicago Field Museum of Natural History, Chicago, Ill.

APPENDIX B

Financial Report for Fiscal Year 1968

SALARIES AND EXPENSES APPROPRIATION

RECEIPTS

Appropriated for fiscal year 1968	$495,000,000	
Unobligated balance from fiscal year 1967	36,657,344	
Recovery of prior year obligation	21,000,000	
Reimbursement from non-Federal source	237,352	
Less: Bureau of Budget reserve established under Public Law 90–218	−46,500,000	
Total available for obligation		$506,394,696

OBLIGATIONS

Support of Scientific Research:	
Scientific Research Project Support:	
Biological and medical sciences	50,323,281
Mathematical and physical sciences	62,561,041
Social sciences	14,665,324
Environmental sciences	23,667,295
Engineering	19,397,471
Subtotal	170,614,412
Specialized Research Facilities and Equipment:	
Biological sciences research facilities:	
Specialized biological facilities	1,709,201
Oceanographic research vessels and facilities	2,954,000
Environmental sciences research facilities:	
Oceanographic research facilities	1,757,462
University atmospheric research facilities	787,881
Physical sciences research facilities:	
Chemistry research instruments	4,296,188
University astronomy research facilities	661,700
University physics research facilities	4,697,214
Engineering research facilities	1,072,556
Specialized social science research facilities	1,006,100
Subtotal	18,942,302

Support of Scientific Research—Continued		
Specialized Research Facilities and Equipment—Continued		
National Research Programs:		
Antarctic research program	$7, 643, 926	
Global atmospheric research program	200, 000	
International biological program	700, 000	
Ocean sediment coring program	4, 167, 500	
Weather modification program	2, 771, 894	
Subtotal	15, 483, 326	
National Research Centers:		
National Radio Astronomy Observatory	4, 864, 000	
Kitt Peak National Observatory	12, 475, 368	
Cerro Tololo Inter-American Observatory	2, 325, 000	
National Center for Atmospheric Research	11, 799, 712	
Subtotal	31, 464, 080	
Subtotal, support of scientific research		$236, 504, 114
National Sea Grant Program		4, 999, 900
Computing Activities in Education and Research		21, 997, 555
Institutional Support for Science:		
Institutional grants for science	14, 153, 161	
Graduate science facilities	17, 830, 671	
Subtotal	31, 983, 832	
Science development programs:		
University science development	29, 631, 000	
Departmental science development	12, 007, 100	
College science improvement	9, 623, 600	
Subtotal	51, 261, 700	
Subtotal, institutional support for science		83, 245, 532
Science Education Support:		
Pre-college education in science:		
Course content improvement	13, 307, 243	
Cooperative college-school program	3, 386, 732	
Special projects	433, 078	
Institutes	34, 224, 727	
Research participation and science activities for teachers	1, 234, 972	
Science education for students	2, 066, 786	
Subtotal	54, 653, 538	

Science Education Support—Continued		
Undergraduate education in science:		
Course content improvement	$6, 045, 054	
Instructional equipment for undergraduate education	4, 335, 789	
Institutes	4, 103 020	
Research participation and science activities for teachers	1, 612, 687	
Science education for teachers	4, 141, 600	
Special projects	905, 718	
Pre-service teacher education	370, 000	
Subtotal	21, 513, 868	
Graduate education in science:		
Fellowships and traineeships	46, 057, 371	
Advanced science education projects:		
Special projects	1, 138, 127	
Advanced science seminars	1, 469, 663	
Subtotal	48, 665, 161	
Subtotal, science education support		$124, 832, 567
Science Information Activities		14, 396, 057
International Cooperative Scientific Activities		1, 427, 120
Planning and Policy Studies		2, 446, 464
Program Development and Management		15, 378, 360
Total, NSF		505, 227, 669
Unobligated balance carried forward to fiscal year 1969		1, 167, 027
Total		506, 394, 696

TRUST FUND

RECEIPTS

Unobligated balance from fiscal year 1967	6, 689
Donations from private sources	1, 737
Total availability	8, 426

OBLIGATIONS

Total obligations for fiscal year 1968	934
Unobligated balance carried forward to fiscal year 1969	7, 492
Total	8, 426

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 eight patents by the U.S. Patent Office covering inventions arising out of Foundation-supported activities. Seven of these patents derived from the contract with Brown & Root, Inc., for work on Project Mohole, and one resulted from a grant to Washington University. Title to the seven inventions developed under the Brown & Root contract is in the U.S. Government, and the Government has a nonexclusive, irrevocable, nontransferable, royalty-free, worldwide license in the other patent.

Patent No. 3,344,872 entitled "Apparatus for Indicating the Length of Core in a Core Barrel" was issued on October 3, 1967, on an invention made by Reuben A. Bergan during the course of work performed under NSF–C260 with Brown & Root, Inc. This invention relates to apparatus for indicating at the surface the length of core in a core barrel as the core is being cut from a subterranean formation.

Patent No. 3,349,856 entitled "Bumper Sub Position Indicator" was issued on October 31, 1967, on an invention made by Vernon C. H. Richardson during the course of work performed under NSF–C260 with Brown & Root, Inc. This invention relates generally to apparatus for providing a surface indication when the two telescoping sections of a bumper sub located in a string of drill pipe are in a preselected position relative to each other.

Patent No. 3,359,782 entitled "Well Bore Inclinometer Apparatus" was issued on December 26, 1967, on an invention made by Luong Van Bey during the course of work performed under NSF–C260 with Brown & Root, Inc. This invention relates to apparatus for measuring the inclination from the vertical of a well bore.

Patent No. 3,365,081 entitled "Pipe Elevator and Positioning Apparatus Therefor" was issued on January 23, 1968, on an invention made by Archie R. McLerran during the course of work performed under NSF–C260 with Brown & Root, Inc. This invention relates to apparatus which guides and positions a pipe elevator for receiving pipe from either a horizontal pipe rack or a well bore.

Patent No. 3,367,422 entitled "Bumper Sub Position Indicator" was issued on February 6, 1968, on an invention made by Darrell L. Sims during the course of work performed under NSF–C260 with Brown & Root, Inc. This invention relates generally to apparatus for providing a surface indication when the two telescoping sections of a bumper sub located in a string of drill pipe are in a preselected position relative to each other.

Patent No. 3,373,827 entitled "Apparatus for Coring Subterranean Formations Under a Body of Water" was issued on March 19, 1968, on an invention made by Jules N. Biron, Durward B. Jones and Darrell L. Sims during the course of work performed under NSF–C260 with Brown & Root, Inc. This invention relates generally to apparatus for obtaining cores of subterranean formations below a body of water, and, in particular, to such apparatus that is lowered to the bottom on a flexible line or cable.

Patent No. 3,379,867 entitled "Electronic Network Synthesis of Mathematical Matric Equations" was issued on April 23, 1968, on an invention made by Pierre M. Honnell during the course of research supported by a grant to Washington University, University City, Mo. This invention relates to electronic devices for the synthesis of matric calculus equations.

Patent No. 3,383,122 entitled "Angular Breakaway Pipe Joint" was issued on May 14, 1968, on an invention made by Vernon C. H. Richardson during the course of work performed under NSF–C260 with Brown & Root, Inc. This invention relates generally to a joint for connecting together two pipe sections, and in particular to such a joint that will release the connection when the pipe sections are misaligned a predetermined amount.

APPENDIX D

National Science Foundation-Supported Scientific Conferences, Symposia, and Advanced Science Seminars Held During Fiscal Year 1968

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE BIOLOGICAL AND MEDICAL SCIENCES

CONFERENCE ON KINETIC STUDIES OF ENZYME PROCESSES.—Chicago, Ill.; Sept. 13, 1967; Chairman: Frank Westheimer, Harvard University; Sponsor: American Chemical Society.

SYMPOSIUM ON NUCLEIC ACIDS IN IMMUNOLOGY.—Rutgers, the State University, New Brunswick, N.J.; Oct. 16–18, 1967; Chairman: Otto Plescia, Rutgers, the State University; Sponsor: Rutgers, the State University.

REGIONAL CONFERENCES OF THE SOCIETY FOR DEVELOPMENTAL BIOLOGY:

ROCKY MOUNTAIN CONFERENCE.—Teton Village, Wyo.; Oct. 13–15, 1967; Chairman: R. A. Jenkins, University of Wyoming; Sponsor: Society for Developmental Biology and the National Science Foundation.

WEST COAST CONFERENCE.—Asilomar, Calif.; Nov. 24–26, 1967; Chairman: David Epel, Stanford University; Sponsor: Society for Developmental Biology and the National Science Foundation.

SOUTHEASTERN CONFERENCE.—Wakulla Springs, Fla.; Mar. 22–23, 1968; Chairman: Michael J. Greenberg, Florida State University; Sponsor: Society for Developmental Biology and the National Science Foundation.

MIDWEST CONFERENCE.—Miami University, Oxford, Ohio; May 8–11, 1968; Chairman: Allan L. Allenspach, Miami University at Oxford; Sponsor: Society for Developmental Biology and the National Science Foundation.

CONFERENCE ON EXPERIMENTAL APPROACHES TO THE STUDY OF EMOTIONAL BEHAVIOR.—New York City; Nov. 16–18, 1967; Chairman: Ethel Tobach, American Museum of Natural History; Sponsors: New York Academy of Sciences and the National Science Foundation.

SYMPOSIUM ON PRIMARY PRODUCTIVITY AND MINERAL CYCLING IN NATURAL ECOSYSTEMS.—New York City; Dec. 27, 1967; Chairman: Harold E. Young, University of Maine; Sponsor: American Association for the Advancement of Science.

THIRTY-THIRD COLD SPRING HARBOR SYMPOSIUM ON QUANTITATIVE BIOLOGY.—Cold Spring Harbor, N.Y.; June 5–12, 1968; Chairman: James D. Watson, Harvard University; Sponsors: National Science Foundation, U.S. Air Force, National Institutes of Health and Atomic Energy Commission.

TWENTY-SEVENTH SYMPOSIUM OF THE SOCIETY FOR DEVELOPMENTAL BIOLOGY.—Ithaca College, Ithaca, N.Y.; June 19–21, 1968; Chairman: John Saunders, SUNY at Albany; Sponsor: Society for Developmental Biology and the National Science Foundation.

GORDON RESEARCH CONFERENCES:

CELL STRUCTURE AND METABOLISM.—Meriden, N.H.; June 24-28, 1968; Chairman: George A. Palade, Rockefeller University; Sponsor: Gordon Research Conference.

NUCLEIC ACIDS.—New Hampton, N.H.; June 17–21, 1968; Chairmen: Gunther Stent, University of California, and Armin D. Kaiser, Stanford University School of Medicines; Sponsors: Gordon Research Conference and the National Science Foundation.

PROTEINS.—New Hampton, N.H.; June 24–28, 1968; Chairmen: Edmund Ficher, University of Washington, and Daniel Koshland, University of California at Berkeley; Sponsor: Gordon Research Conference.

BIOLOGICAL LAMELLAE AND RELATED PHYSICAL LAMELLAR SYSTEMS.—Tilton, N.H.; June 17–21, 1968; Chairman: Alexander Mauro, Rockefeller University; Sponsor: Gordon Research Conference.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN COMPUTER SCIENCE

WORKING CONFERENCE ON COMPUTER-BASED INSTRUCTIONS.—Snowmass-at-Aspen, Colo.; June 17–18, 1968; Chairmen: Daniel Alpert, University of Illinois, Urbana, and Patrick Suppes, Stanford University; Sponsors: University of Illinois and Stanford University.

CONFERENCE IN COMPUTER GRAPHICS.—Urbana, Ill.; Nov. 6–8, 1967; Chairman: C. W. Gear, University of Illinois, Urbana; Sponsor: University of Illinois.

EXPLORATORY CONFERENCE ON USES OF COMPUTERS IN STATISTICS, MATHEMATICS, PHYSICS, AND CHEMISTRY.—College Park, Md.; Dec. 8-9, 1967; Chairman: J. David Lockard, University of Maryland; Sponsor: University of Maryland.

INTENSIVE SUMMER COURSE ON DIGITAL COMPUTERS IN CHEMICAL INSTRUMENTATION.—Lafayette, Ind.; June 9–28, 1968; Chairman: Sam P. Perone, Purdue University; Sponsor: Purdue University.

COMPUTER GRAPHICS AND ARCHITECTURE CONFERENCE.—New Haven, Conn.; Apr. 18–20, 1968; Chairman: Howard S. Weaver, Yale University; Sponsor: Yale University.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE ENGINEERING SCIENCES

TENTH MIDWESTERN MECHANICS CONFERENCE.—Fort Collins, Colo.; Aug. 21–23, 1967; Chairman: J. E. Cermak, Colorado State University; Sponsor: Colorado State University.

INTERNATIONAL SYMPOSIUM ON WAVE PROPAGATION AND DYNAMIC PROPERTIES OF EARTH MATERIALS.—Albuquerque, N. Mex.; Aug. 23–25, 1967; Chairman: George E. Triandafilidis; Cosponsors: The University of New Mexico and American Society of Civil Engineers.

THE CONFERENCE ON THE MATRIX OF CONCRETE.—Urbana, Ill.; Sept. 5–6, 1967; Chairman: Clyde E. Kessler, University of Illinois; Sponsor: University of Illinois.

TWELFTH CONGRESS OF THE INTERNATIONAL ASSOCIATION FOR HYDRAULIC RESEARCH AND INTERNATIONAL HYDROLOGY SYMPOSIUM.—Fort Collins, Colo.; Sept. 6–14, 1967; Chairman: Daryl B. Simons, Colorado State University; Sponsor: Colorado State University.

CONFERENCE ON EFFECTS OF DIFUSE ELECTRICAL CURRENTS ON PHYSIOLOGICAL MECHANISMS WITH APPLICATION TO ELECTROANESTHESIA AND ELECTROSLEEP.—Milwaukee, Wis.; Oct. 25–28, 1967; Chairman: Anthony Sances, Jr. Marquette University; Sponsor: Marquette University.

SECOND CONFERENCE OF THE CHARACTERIZATION OF MATERIALS.—Rochester, N.Y.; Nov. 8–10, 1967; Chairman: Kenneth J. Teegarden, University of Rochester; Sponsor: University of Rochester.

INTERNATIONAL CONFERENCE ON MASONRY STRUCTURAL SYSTEMS.—Austin, Tex.; Nov. 30–Dec. 2, 1967; Chairmen: J. Neils Thompson and Franklin B. Johnson, University of Texas; Cosponsors: Clay Products Association of the Southwest, Structural Clay Products Institute.

HAWAII INTERNATIONAL CONFERENCE ON SYSTEM SCIENCES.—Honolulu, Hawaii; Jan. 29–31, 1968; Chairman: Franklin F. Kuo, University of Hawaii; Sponsor: University of Hawaii.

FUNDAMENTAL CORROSION RESEARCH IN PROGRESS.—Cleveland, Ohio; Mar. 18–22, 1968; Chairman: R. W. Staehle, The Ohio State University; Sponsor: National Association of Corrosion Engineers.

INTERNATIONAL CONFERENCE ON POWDER TECHNOLOGY.—Chicago, Ill., May 20–23, 1968; Chairman: Morton J. Klein, IIT Research Institute; Cosponsors: IIT Research Institute and the American Society for Testing Materials.

CONFERENCE ON STABILITY OF METAL STRUCTURES.—San Francisco, Calif.; May 23–24, 1968; Chairman: Lynn S. Beedle, Lehigh University; Cosponsors: Lehigh University and The Column Research Council.

SECOND INTERNATIONAL SYMPOSIUM ON GAS LUBRICATION, DESIGN, APPLICATION, AND EXHIBIT.—Las Vegas, Nev., June 17–20, 1968; Chairmen: C. M. Allen, Battelle Memorial Institute and S. W. Doroff, Office of Naval Research; Sponsor: American Society of Mechanical Engineers.

CONFERENCE ON PRECISION ELECTROMAGNETIC MEASUREMENTS.—Boulder, Colo.; June 25–28, 1968; Chairman: Chester H. Page, National Bureau of Standards; Cosponsors: National Bureau of Standards, Institute of Electrical and Electronics Engineers, International Scientific Radio Union.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE ENVIRONMENTAL SCIENCES

CONFEENCE ON COMPARISONS BETWEEN NEWFOUNDLAND AND BRITAIN RELATING TO CONTINENTAL DRIFT.—St. John's, Newfoundland, Aug. 17–Sept. 5, 1967; Chairman: Marshall Kay, Department of Geology; Co-sponsor: Columbia University.

1967 NATIONAL CLAY MINERALS CONFERENCE.—Golden, Colo., Aug. 28–31, 1967; Chairman: Robert Carpenter, CSM; Co-sponsors: the Clay Minerals Society, and the Colorado School of Mines in collaboration with the U.S. Geological Survey, Denver.

CONFERENCE OF THE LEGAL IMPLICATIONS OF WEATHER MODIFICATION ACTIVITIES.—Dallas, Tex., Dec. 6–7, 1967; Chairman: Howard J. Taubenfeld, Southern Methodist University School of Law; Co-sponsor: Southern Methodist University.

SYMPOSIUM ON REMOTE SENSING IN THE POLAR REGIONS.—Easton, Md., Mar. 6–8, 1968; Chairman: John C. Reed, AINA; Co-sponsors: U.S. Geological Survey, Army Research Office (Durham), Office of Naval Research, Arctic Institute of North America.

CONFERENCE OF THE ENVIRONMENT OF THE PRIMITIVE EARTH.—Cambridge, Mass., Mar. 10–13, 1968; Chairman: Raymond Siever, Department of Geological Sciences; Co-sponsor: Geochemical Society (Boulder, Colo.) in cooperation with the Department of Geological Sciences, Harvard University.

NATIONAL CONFERENCE ON WEATHER MODIFICATION.—Albany, N.Y., Apr. 28–May 1, 1968; Chairman: Earl G. Droessler, State University of New York at Albany; Co-sponsor: American Meteorological Society (Boston, Mass.)

FOURTH INTERNATIONAL CONFERENCE ON THE UNIVERSAL ASPECTS OF ATMOSPHERIC ELECTRICITY.—Tokyo, Japan, May 12–18, 1968; Chairman: Samuel C. Coroniti, Space Sciences Division, AVCO (Lowell, Mass.); Co-sponsors: the Joint Committee of the International Association of Geomagnetism and Aeronomy and the International Association of Meteorology and Atmospheric Physics (IAGA/IAMAP) and the Science Council of Japan, Air Force Office of Scientific Research, and the Office of Naval Research.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE MATHEMATICAL AND PHYSICAL SCIENCES

1967 GORDON CONFERENCE ON NUCLEAR STRUCTURE.—Tilton, N.H., July 31–Aug. 4, 1967; Chairman: J. P. Schiffer, Argonne National Laboratory; Vice Chairman: J. Weneser, Brookhaven National Laboratory; Co-sponsor: The Gordon Research Conferences, Inc. (Director, Dr. W. George Parks, University of Rhode Island, Kingston, R.I.)

1967 GORDON RESEARCH CONFERENCE ON PHOTONUCLEAR REACTIONS.—Tilton, N.H., Aug. 14–18, 1967; Chairman: Paul F. Yergin, Rensselaer Polytechnic Institute; Vice Chairman: Stavros Fallieros, Bartol Research Foundation; Co-sponsor: The Gordon Research Conferences, Inc.

SECOND HAWAII TOPICAL CONFERENCE ON STRONG AND WEAK INTERACTIONS IN PARTICLE PHYSICS.—Honolulu, Hawaii, Aug. 14–25, 1967; Chairman: San Fu Tuan, Department of Physics; Co-sponsor: University of Hawaii.

INTERNATIONAL CONFERENCE ON HYPERFINE INTERACTIONS DETECTED BY NUCLEAR RADIATION.—Asilomar, Calif., Aug. 25–30, 1967; Chairman: John O. Rasmussen, Department of Chemistry; Vice Chairman: C. D. Jeffries, Department of Physics; Co-sponsors: The Atomic Energy Commission, the American Physical Society, and the University of California, Berkeley.

INTERNATIONAL OXIDATION SYMPOSIUM—REACTIONS OF ORGANIC COMPOUNDS WITH OXYGEN.—San Francisco, Calif., Aug. 28–Sept. 1, 1967; Chairman: Frank R. Mayo, SRI; Co-sponsors: Army Research Office (Durham) and Stanford Research Institute.

INTERNATIONAL THEORETICAL PHYSICS CONFERENCE ON PARTICLES AND FIELDS.—Rochester, N.Y., Aug. 28–Sept. 1, 1967; Chairman: R. E. Marshak, Department of Physics and Astronomy; Co-sponsors: Atomic Energy Commission, Air Force Office of Scientific Research, National Academy of Sciences, International Union of Pure and Applied Physics, and the University of Rochester.

1967 INTERNATIONAL CONGRESS ON MAGNETISM.—Cambridge, Mass., Sept. 11–16, 1967; Chairman: J. H. Van Vleck, Harvard University; Co-sponsors: Atomic Energy Commission, Office of Naval Research, Air Force Cambridge Research Laboratories, International Union of Pure and Applied Physics, American Institute of Physics.

ATOMIC SPECTROSCOPY SYMPOSIUM.—National Bureau of Standards, Gaithersburg, Md., Sept. 11–14, 1967; Chairman: Hugh Odishaw, National Academy of Sciences-National Research Council; Co-sponsors: National Bureau of Standards and the U.S. Research Council Committee on Line Spectra of the Elements.

THIRD INTERNATIONAL SYMPOSIUM ON HIGH TEMPERATURE TECHNOLOGY.—Asilomar, Calif., Sept. 17–20, 1967; Chairman: Nevin K. Hiester, Stanford Research Institute; Vice Chairman: Raymond Walker, Picatinny Arsenal; Co-sponsors: Atomic Energy Commission, National Aeronautics and Space Administration, Advanced Research Projects Agency, Air Force Materials Laboratory, Stanford Research Institute, and private industry.

CONFERENCE ON LOCALIZED EXCITATIONS IN SOLIDS.—Irvine, Calif., Sept. 18–22, 1967; Chairman: E. W. Montroll, University of Rochester; Co-sponsors: Office of

Naval Research, Army Research Office (Durham), International Union of Pure and Applied Physics, University of Southern California, and University of California, Irvine.

TWENTY-SECOND ANNUAL SYMPOSIUM ON MOLECULAR STRUCTURE AND SPECTROSCOPY.—Columbus, Ohio, Sept. 5–9, 1967; Co-chairmen: K. Narahari Rao and H. H. Nielsen; Co-sponsor: Ohio State University and the Office of Naval Research.

SIXTH EASTERN THEORETICAL PHYSICS CONFERENCE.—Nashville, Tenn., Dec. 1–2, 1967; Chairman: Ingram Bloch, Department of Physics and Astronomy; Co-sponsor: Vanderbilt University.

SYMPOSIUM ON HII REGIONS.—Charlottesville, Va., Dec. 8–11, 1967; Chairman: William E. Howard, III, NRAO; Co-sponsors: the National Radio Astronomy Observatory and the Arecibo Ionospheric Observatory.

NEW MEXICO STATE UNIVERSITY MATHEMATICS SYMPOSIA.—Las Cruces, N. Mex., Dec. 27–30, 1967; Chairman: Paul J. Cohen, Stanford University; Co-sponsor: New Mexico State University.

CONFERENCE ON SEYFERT GALAXIES AND RELATED OBJECTS.—Tucson, Ariz., Feb. 14–16, 1968; Co-chairmen: A. G. Pacholczyk and Ray J. Weymann, Department of Astronomy; Co-sponsor: University of Arizona.

SECOND AUSTIN SYMPOSIUM ON GAS PHASE MOLECULAR STRUCTURE.—Austin, Tex., Feb. 26–27, 1968; Co-chairmen: James E. Boggs, Department of Chemistry and Harold P. Hanson, Department of Physics; Co-sponsor: University of Texas.

NINTH EXPERIMENTAL NUCLEAR MAGNETIC RESONANCE CONFERENCE.—Pittsburgh, Pa., Feb. 29–Mar. 2, 1968; Chairman: Paul R. Shafer, Dartmouth College; Co-sponsor: Carnegie-Mellon University.

INTERNATIONAL CONFERENCE ON THE METAL—NONMETAL TRANSITION.—San Francisco, Calif., Mar. 14–15, 1968; Chairman: James C. Thompson, Department of Physics; Co-sponsors: Advanced Research Projects Agency, American Physical Society, International Union of Pure and Applied Physics, and the University of Texas.

CONFERENCE ON THE EXPERIMENTAL VERIFICATION OF THE REGGE POLE HYPOTHESIS IN HIGH ENERGY PHYSICS.—Eugene, Oreg., Mar. 14–16, 1968; Chairman: Michael J. Moravcsik, Department of Physics; Co-sponsors: Willamette Valley Research Council, Atomic Energy Commission, and the University of Oregon.

SYMPOSIUM IN PURE MATHEMATICS ON COMBINATORICS.—Los Angeles, Calif., Mar. 21–23, 1968; Chairman: Theodore S. Motzkin, Department of Mathematics (UCLA); Co-sponsor: American Mathematical Society (Gordon L. Walker, Executive Director)

SECOND INTERNATIONAL CONFERENCE ON VACUUM ULTRAVIOLET AND X-RAY SPECTROSCOPY OF LABORATORY AND ASTROPHYSICAL PLASMAS.—College Park, Md., Mar. 25–27, 1968; Chairman: Hans R. Griem, Department of Physics and Astronomy; Co-sponsors: National Aeronautics and Space Administration and the University of Maryland.

SECOND CONFERENCE ON LINEAR FREE ENERGY RELATIONSHIPS.—Irvine, Calif., Mar. 27–29, 1968; Chairman: Robert W. Taft, Department of Chemistry; Co-sponsor: University of California, Irvine.

A SYMPOSIUM ON LOW LUMINOSITY STARS.—Charlottesville, Va., Mar. 28–30, 1968; Co-chairmen: Laurence W. Frederick and Shiv S. Kumar, Leander McCormick Observatory; Co-sponsors: the American Astronomical Society and the University or Virginia.

MIDWEST CONFERENCE ON THEORETICAL PHYSICS.—Ann Arbor, Mich., Mar. 29–30, 1968; Chairman: Gordon L. Kane, Department of Physics; Co-sponsor: University of Michigan.

A SYMPOSIUM ON NONLINEAR FUNCTIONAL ANALYSIS.—Chicago, Ill., Apr. 16–19, 1968; Chairman: Felix E. Browder, Department of Mathematics; Co-sponsor: American Mathematical Society and the University of Chicago.

International Conference on Atomic Physics.—New York, N.Y., June 3–7, 1968; Chairman: Vernon W. Hughes, Department of Physics, Yale University; Co-sponsors: Air Force Office of Scientific Research, Office of Naval Research, Army Research Office (Durham), International Union of Pure and Applied Physics, and Yale University.

Symposium on Wolf-Rayet Stars.—Boulder, Colo., June 10–15, 1968; Chairman: Richard N. Thomas, JILA; Co-sponsors: Joint Institute for Laboratory Astrophysics (National Bureau of Standards-University of Colorado), Harvard College Observaory, and Smithsonian Astrophysical Observatory.

Conference on Algebraic Topology.—Chicago, Ill., June 19–30, 1968; Chairman: Victor K. A. M. Gugenheim, Department of Mathematics; Co-sponsor; University of Illinois at Chicago Circle.

SCIENTIFIC CONFERENCES AND SYMPOSIA IN THE SOCIAL SCIENCES

Research Conference on Political Elites.—Ann Arbor, Mich.; July-August 1967; Chairman: Warren E. Miller; Sponsor: Inter-University Consortium for Political Research and University of Michigan.

Research Conference on the Study of Political Socialization.—Ann Arbor, Mich.; Aug. 7–18, 1967; Chairman: Warren E. Miller; Sponsor: Inter-University Consortium for Political Research and University of Michigan.

Conference on International Agrarian Problems.—Seattle, Wash.; Aug. 23–26, 1967; Chairman: W. A. Douglas Jackson; Sponsor: University of Washington.

National Conferences on Content Analysis.—Philadelphia, Pa.; Nov. 16–18, 1967; Chairman: George Gerbner; Sponsor: Annenberg School of Communications.

Conference on the Role of Agriculture in Economic Development.—Princeton, N. J.; Dec. 1–2, 1967; Chairman: Erik Thorbecke, Iowa State University; Sponsor: Universities, National Bureau Committee for Economic Research.

Research Conference on Measurement of the Religious Variable.—Dallas, Tex.; Apr. 4–6, 1968; Chairman: Morton B. King; Sponsor: Southern Methodist University.

Conference on Economics of Public Output.—Princeton, N.J.; Apr. 26–27, 1968; Chairman: Julius Margolis, Stanford University; Sponsor: Universities, National Bureau Committee for Economic Research.

Conference on the National Archives and Statistical Research.—Washington, D.C.; May 27–28, 1968; Chairman: James B. Rhoads; Sponsor: National Archives and Records Center and National Academy of Sciences.

Conference on Econometrics.—Columbus, Ohio; May 27–28, 1968; Chairman: Karl Brunner; Sponsor: Ohio State University

Conference on Explanation in Biology.—Monterey, Calif.; June 7–11, 1968; Chairman: Everett Mendelsohn, Harvard University; Dudley Shapere, University of Chicago; Garland Allen, Washington University; Sponsor: Commission on Undergraduate Education in the Biological Sciences.

Conference on Money and Economic Growth.—Providence, R. I.; June 16–19. 1968; Chairman: Jerome L. Stein; Sponsor: Brown University.

ADVANCED SCIENCE SEMINARS

Advanced Science Seminar in Linguistics.—Urbana, Ill.; June 17–Aug. 10, 1968; Director: R. B. Lees, The University of Illinois; Grantee: American Council of Learned Societies.

INTERNATIONAL FIELD INSTITUTE.—Japan; July 1–Aug. 15, 1967; Director: D. F. Merriam, State Geological Survey of Kansas; Grantee: American Geological Institute.

MATHEMATICS OF THE DECISION SCIENCES.—Stanford, Calif.; July 10–Aug. 11, 1967; Director: G. L. Walker, The American Mathematical Society; Grantee: American Mathematical Society.

INSTITUTE IN SYSTEMATICS FOR BOTANISTS.—Washington, D.C.; June 24–Aug. 12, 1968; Director: A. Cronquist, New York Botanical Garden; Grantee: American Society of Plant Taxonomists.

REGIONAL CONFERENCES IN COMPARATIVE ENDOCRINOLOGY.—Ann Arbor, Mich.; Boston, Mass.; Dallas, Tex.; and Burnaby 2, British Columbia, Canada; July 1, 1967 to Aug. 30, 1968; Director: W. Chavin, Wayne State University; Grantee: American Society of Zoologists.

SEMINAR ON ENERGY FLOW AND ECOLOGICAL SYSTEMS.—College Station, Tex.; Aug. 25, 1967; Director: F. B. Turner, University of California at Los Angeles; Grantee: American Society of Zoologists.

SUMMER SEMINAR IN THEORETICAL PHYSICS.—Waltham, Mass.; June 17–July 26, 1968; Director: J. S. Goldstein, Brandeis University; Grantee: Brandeis University.

SIXTH SUMMER SEMINAR ON HIGHER MATHEMATICS.—Montreal, Canada; June 26–July 28, 1967; Director: J. J. McNamee, Canadian Mathematical Congress; Grantee: Canadian Mathematical Congress.

CONFERENCE ON MARINE INVERTEBRATE LARVAE.—Beaufort, N.C.; Sept. 2–Oct. 1967; Director: C. G. Bookhout, Duke Marine Laboratory; Grantee: Duke University.

TRAINING PROGRAM IN COMPARATIVE SOCIOLOGY.—Bloomington, Ind.; June 17–Aug. 9, 1968; Director: F. B. Waisanen, Michigan State University; Grantee: Indiana University.

INSTITUTE IN DYNAMICAL ASTRONOMY.—Cambridge, Mass.; June 17–July 13, 1968; Director: V. Szebehely, Yale University; Grantee: Massachusetts Institute of Technology.

INSTITUTE OF GLACIOLOGICAL AND ARCTIC SCIENCES.—Juneau Icefield, Alaska; July 17–Sept. 3, 1967; Director: N. M. Miller, Michigan State University; Grantee: Michigan State University.

SEMINAR IN SOCIOLINGUISTICS.—Berkeley, Calif.; June 19–Sept. 7, 1968; Director: E. Sibley, Social Science Research Council; Grantee: Social Science Research Council.

FIELD TRAINING IN CULTURAL ANTHROPOLOGY.—Oaxaca, Mexico; June 23–Aug. 31, 1968; Director: B. D. Paul, Stanford University; Grantee: Stanford University.

TRAINING COURSES IN OCEANOGRAPHY IN SOUTHEAST ALASKA.—Douglas, Alaska; June 17–Aug. 23, 1968; Director: D. W. Hood, University of Alaska; Grantee: University of Alaska.

ADVANCED FIELD TRAINING IN ARCHAEOLOGY.—Grasshopper, Ariz.; June 7–Aug. 2, 1968; Director: R. H. Thompson, University of Arizona; Grantee: University of Arizona.

SYMPOSIUM ON NONWETTABLE SOILS.—Riverside, Calif.; May 6–10, 1968; Director: W. A. Hall, University of California, Riverside; Grantee: University of California, Riverside.

SEMINAR IN THEORETICAL PHYSICS.—La Jolla, Calif.; Aug. 1–Sept. 1, 1967; Director: K. A. Brueckner, University of California, San Diego; Grantee: University of California, San Diego.

TRAINING PROGRAM IN POPULATION GENETICS AND DEMOGRAPHY.—Chicago, Ill.; Sept. 1, 1967–Aug. 31, 1968; Director: R. C. Lewontin, University of Chicago; Grantee: University of Chicago.

322-215 O—68——19

Ninth Latin American School of Physics.—Santiago, Chile; July 3–28, 1967; Director: I. Saavedra, Universidad de Chile; Grantee: Universidad de Chile.

Institute for Theoretical Physics.—Boulder, Colo.; June 17–Aug. 23, 1968; Director: K. Mahanthappa, University of Colorado; Grantee: University of Colorado.

Winter Institute in Quantum Chemistry, Solid-State Physics, and Quantum Biology.—Gainesville, Fla.; Dec. 4, 1967–Jan. 20, 1968; Director: P. O. Löwdin, University of Florida; Grantee: University of Florida.

Computer-Aided Design in Engineering Education.—Houston, Tex.; June 10–Aug. 5, 1968; Director: G. F. Paskusz, University of Houston; Grantee: University of Houston.

Field Methods for Systematic Vertebrate Zoologists and Paleontologists.—Interface of the Prairie and Mountains between New Mexico and Alberta, Canada; June 6–Aug. 1, 1967 and Aug. 1–Sept. 10, 1967; Director: E. R. Hall, University of Kansas; Grantee: University of Kansas.

Great Plains Archaeological Field School.—Locations in the State of Kansas; June 17–Aug. 11, 1968; Director: A. E. Johnson, University of Kansas; Grantee: University of Kansas.

Advanced Science Seminar in Tropical Botany.—Coral Gables, Fla.; June 17–26, 1968; Director: T. Alexander, University of Miami; Grantee: University of Miami.

Advanced Science Seminars on Quantitative Political Science Research.—Ann Arbor, Mich.; June 26–Aug. 16, 1968; Director: W. E. Miller, University of Michigan; Grantee: University of Michigan.

Paleobiological Aspects of Animal Growth and Development.—New Orleans, La.; Nov. 20–22, 1967; Director: D. B. Macurda, Jr., Museum of Paleontology, the University of Michigan; Grantee: The University of Michigan.

Seminars in Higher Mental Processes.—Minneapolis, Minn.; June 17–July 19, 1968; Director: J. J. Jenkins, University of Minnesota; Grantee: University of Minnesota.

Field Training for Anthropologists.—San Francisco, Calif.; June 16–Aug. 24, 1968; Director: W. L. d'Azevedo, University of Nevada; Grantee: University of Nevada.

Seminar on Physiological Systems in Semiarid Environments.—Albuquerque, N. Mex.; Nov. 9–11, 1967; Director: M. L. Riedesel, University of New Mexico; Grantee: University of New Mexico.

Recent Advances in Radiative Heat Transfer.—Norman, Okla.; Apr. 22–26, 1968; Director: T. J. Love, University of Oklahoma; Grantee: University of Oklahoma.

Field Training in Cultural Anthropology.—Tezuitlan, Puebla, Mexico; June 16–Aug. 24, 1968; Director: D. Landy, University of Pittsburgh; Grantee: University of Pittsburgh.

Systems Ecology Seminar Project.—Knoxville, Tenn.; Sept. 1, 1967–Aug. 31, 1968; Director: J. S. Olson, University of Tennessee; Grantee: University of Tennessee.

Summer Training Program in Behavioral Sciences and Law.—Madison, Wis.; June 24–Aug. 16, 1968; Director: Joel B. Grossman, University of Wisconsin; Grantee: University of Wisconsin.

Field School for Training Graduate Students in Anthropology.—Ixmiquilpan, Mexico; June 25–Aug. 27, 1968; Director: H. R. Bernard, Washington State University; Grantee: Washington State University.

Intensive Course in Methods in Human Biology.—Detroit, Mich.; Apr. 15–May 3, 1968; Director: G. Lasker, Wayne State University; Grantee: Wayne State University.

POSTDOCTORAL RESEARCH TRAINING PROGRAM IN BIOLOGICAL OCEANOGRAPHY.—Woods Hole, Mass.; Sept. 1, 1967 to Aug. 31, 1968; Director: J. H. Ryther, Woods Hole Oceanographic Institution; Grantee: Woods Hole Oceanographic Institution.

SUMMER PROGRAM IN GEOPHYSICAL FLUID DYNAMICS.—Woods Hole, Mass.; June 24–Aug. 31, 1968; Director: G. Veronis, Yale University; Grantee: Woods Hole Oceanographic Institution.

APPENDIX E

PUBLICATIONS OF THE NATIONAL SCIENCE FOUNDATION FISCAL YEAR 1968

1. PROCEEDINGS OF A CONFERENCE ON TECHNOLOGY TRANSFER AND INNOVATION (NSF 67–5).
2. DYNAMICS OF ACADEMIC SCIENCE (NSF 67–6).
3. NATIONAL PATTERNS OF RESEARCH AND DEVELOPMENT RESOURCES—1953–68—Funds Manpower in the United States.
4. GEOGRAPHIC DISTRIBUTION OF FEDERAL FUNDS FOR RESEARCH AND DEVELOPMENT, Fiscal Year 1965 (NSF 67–8).
5. LITERATURE RELATED TO PLANNING, DESIGN, AND CONSTRUCTION OF SCIENCE FACILITIES (NSF 67–10).
6. THE PROSPECTIVE MANPOWER SITUATION FOR SCIENCE AND ENGINEERING STAFF IN UNIVERSITIES AND COLLEGES, 1965–75 (NSF 67–11).
7. BASIC RESEARCH, APPLIED RESEARCH, AND DEVELOPMENT IN INDUSTRY, 1965 (NSF 67–12).
8. SCIENTIFIC INFORMATION NOTES, June–July 1967, Vol. 9, No. 3 (NSF 67–13).
9. FEDERAL SUPPORT TO UNIVERSITIES AND COLLEGES, Fiscal Years 1963–66 (NSF 67–14).
10. SYSTEMS FOR MEASURING AND REPORTING THE RESOURCES AND ACTIVITIES OF COLLEGES AND UNIVERSITIES (NSF 67–15).
11. RESEARCH AND DEVELOPMENT ACTIVITIES IN STATE GOVERNMENT AGENCIES, Fiscal Years 1964 and 1965 (NSF 67–16).
12. SCIENTIFIC ACTIVITIES OF NONPROFIT INSTITUTIONS (NSF 67–17).
13. SUGGESTIONS FOR SUBMISSION OF PROPOSALS, THE NATIONAL SEA GRANT PROGRAM (NSF 67–18).
14. FEDERAL FUNDS FOR RESEARCH, DEVELOPMENT, AND OTHER SCIENTIFIC ACTIVITIES, Fiscal Years 1966, 1967, and 1968, Vol. XVI (NSF 67–19).
15. SCIENTIFIC INFORMATION NOTES, August–September 1967, Vol. 9, No. 4 (NSF 67–20).
16. SCIENTIFIC AND TECHNICAL PERSONNEL IN THE FEDERAL GOVERNMENT, 1964 (NSF 67–21).
17. SCIENTIFIC INFORMATION NOTES, October-November 1967, Vol. 9, No. 5 (NSF 67–22).
18. SUGGESTIONS FOR SUBMISSION OF A PROPOSAL FOR UNIVERSITY SCIENCE DEVELOPMENT SUPPLEMENTAL GRANT (NSF 67–23).
19. CAREER OPPORTUNITIES WITH THE NATIONAL SCIENCE FOUNDATION (NSF 67–24).

20. SCIENTIFIC INFORMATION NOTES, December 1967 to January 1968, Vol. 9, No. 6 (NSF 67–26).
21. 17TH ANNUAL REPORT, 1967, National Science Foundation (NSF 68–1).
22. GRANTS AND AWARDS, 1967, National Science Foundation (NSF 68–2).
23. GRANTS FOR EDUCATION IN SCIENCE (NSF 68–3).
24. GRANTS FOR COMPUTING ACTIVITIES (NSF 68–4).
25. REVIEWS OF DATA ON SCIENCE RESOURCES, No. 12, "Reaserch and Development in Industry, 1966" (NSF 68–5).
26. NATIONAL SCIENCE FOUNDATION GUIDE TO PROGRAMS (NSF 68–6).
27. AMERICAN SCIENCE MANPOWER 1966, A Report of the National Register of Scientific and Technical Personnel (NSF 68–7).
28. GRANTS FOR INSTITUTIONAL COMPUTING SERVICES (NSF 68–8).
29. SUMMARY OF AMERICAN SCIENCE MANPOWER 1966 (NSF 68–9).
30. PUBLICATIONS OF THE NATIONAL SCIENCE FOUNDATION, March 1968 (NSF 68–10).
31. ORIENTATION TO THE NATIONAL SCIENCE FOUNDATION (NSF 68–11).
32. SCIENTIFIC INFORMATION NOTES, February–March 1968, Vol. 10, No. 1 (NSF 68–12).
33. REVIEWS OF DATA ON SCIENCE RESOURCES, No. 13, "Scientists, Engineers, and Physicians from Abroad, Fiscal Year 1965" (NSF 68–14).
34. SCIENTIFIC INFORMATION NOTES, April–May 1968, Vol. 10, No. 2 (NSF 68–15).

INDEX

B

C

D

H

I

J

N

W

X

Y

Z

U.S. GOVERNMENT PRINTING OFFICE : 1969—O 322-215