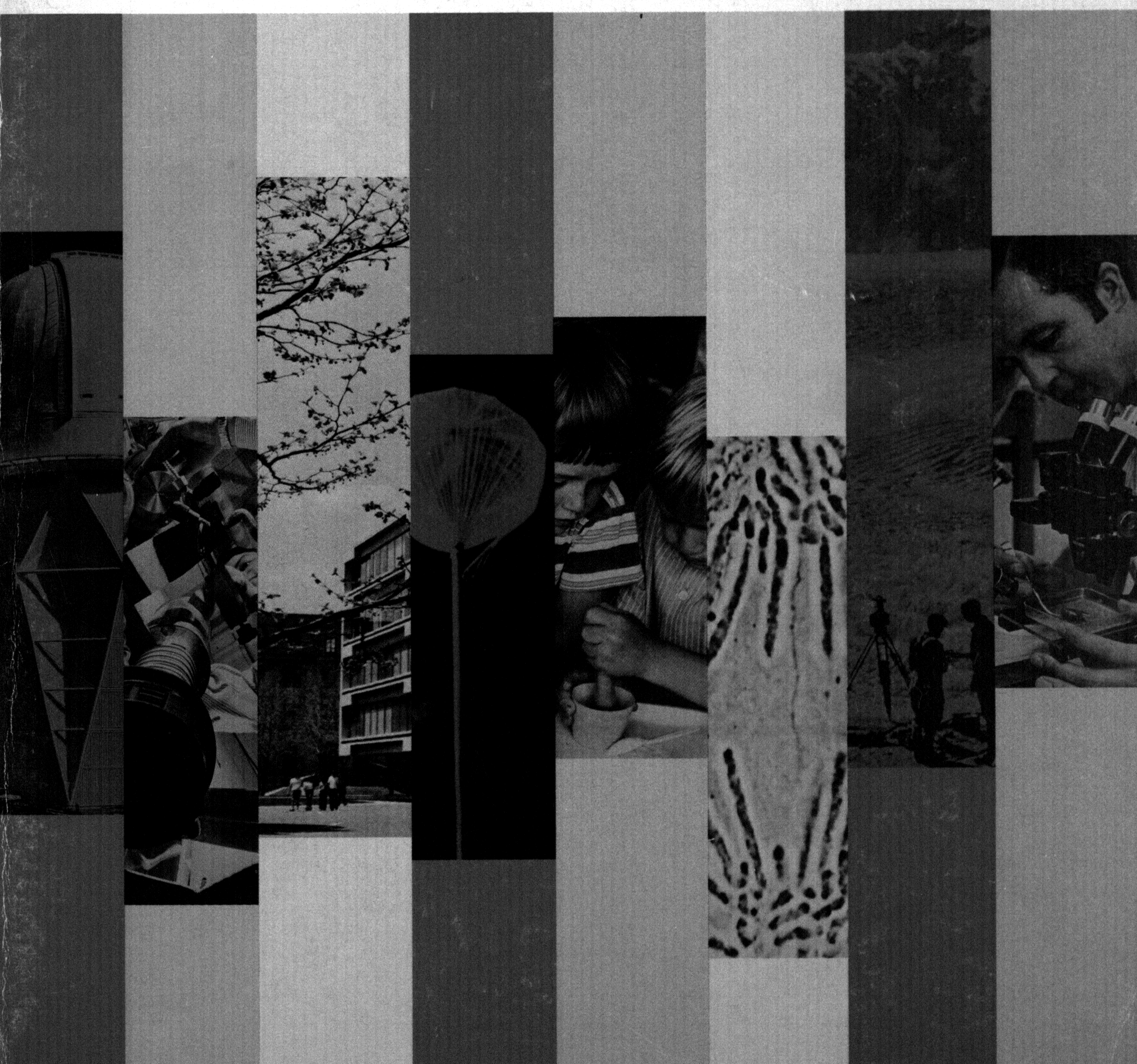
National Science Foundation Annual Report 1970

NSF 71-1



National Science Foundation

Twentieth Annual Report for the Fiscal Year Ended June 30, 1970

Letter of Transmittal

Washington, D.C.

DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1970 of the National Science Foundation for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

W. D. McELROY
Director, National Science Foundation.

The Honorable
The President of the United States.

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1971

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Director's Statement

The Transitional Decade

In the opening year of this new decade, one fact stands out. American society and our Nation as a whole are moving in new directions. Concurrently, science, science education, and the National Science Foundation are entering a significant and distinct period of transition.

This 20th Annual Report—my first as Director of this unique Federal agency—not only highlights the Foundation's activities for fiscal year 1970, but more important, it identifies the benchmarks for future developments.

What will evolve by the end of the decade I cannot say, but I do know the rate of change—and its potential for good and ill—will accelerate at a rapid pace. How we can plan and guide that change to enrich human life is the central question of our era. This question is a special challenge both to scientists, who by the very nature of their training have a responsibility to be both sensitive and responsive to the wants of their fellowman, and also to those institutions like the National Science Foundation whose calling is to support science as it serves society.

I believe it is particularly timely as we begin the new decade to examine the convictions I share with my colleagues at the Foundation underlying new policies and new programs for the 1970's.

- PROGRESS IN SCIENCE CANNOT CONTINUE if its foundations—fundamental research—are weakened. This fact must continue to lie at the heart of the Foundation's programs. To tamper or to compromise with a continuing national investment in knowledge would be to

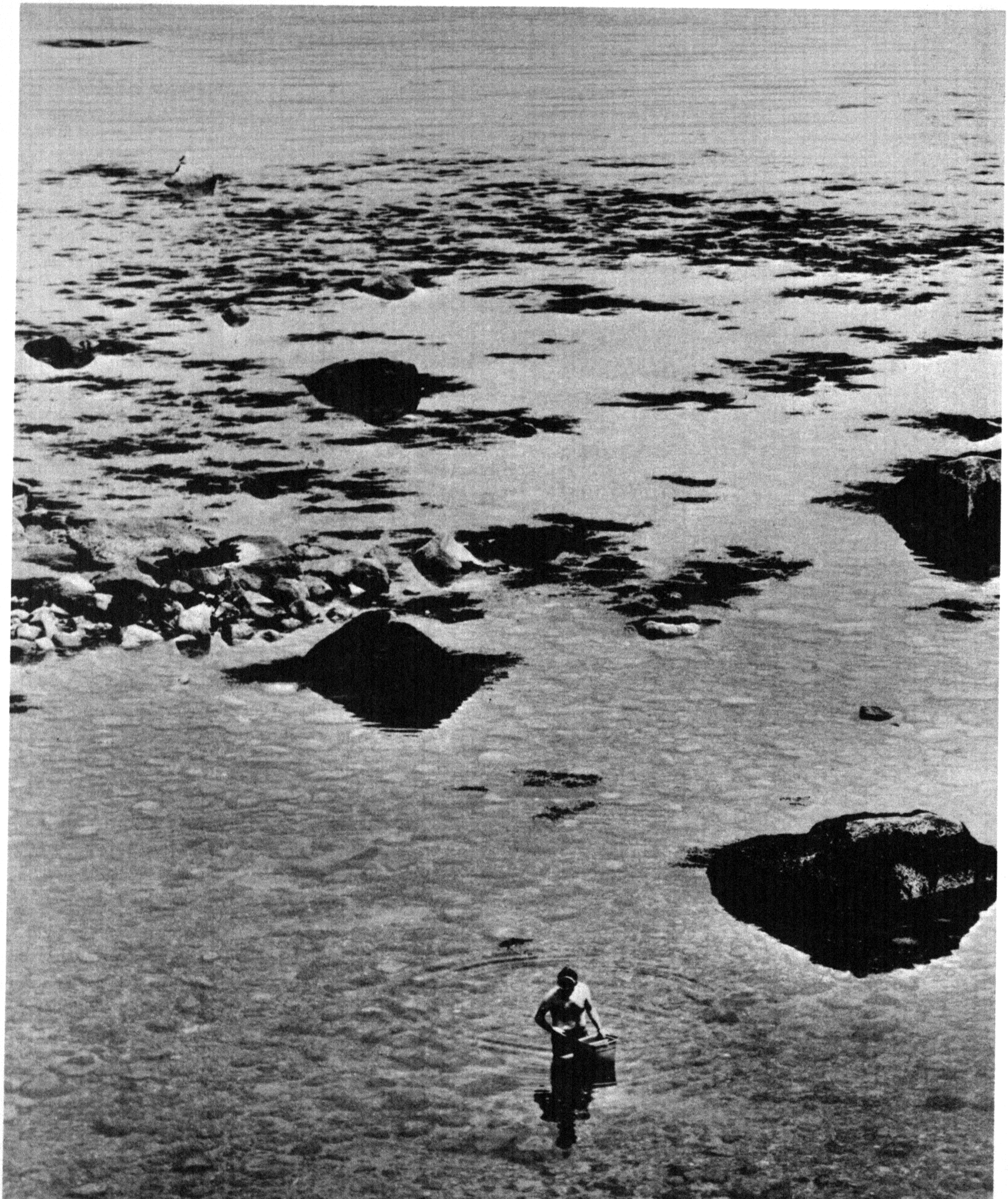
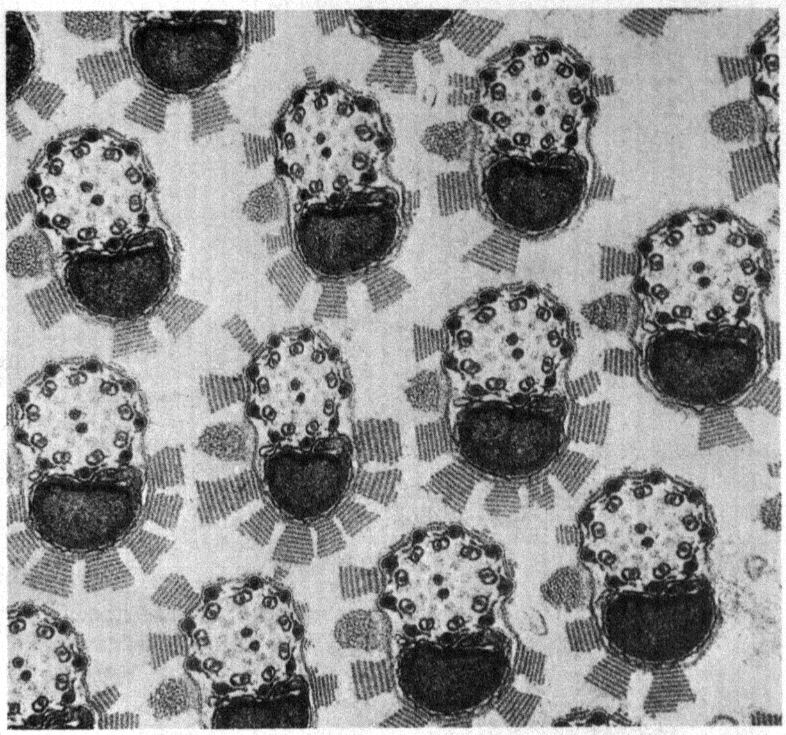


Photo by Herb Weitman/Washington University.

Photo by University of Alaska.



Microphotograph by David Phillips/Washington University.

cripple future generations by denying them the fruits of today's research.

- SCIENCE, ENGINEERING AND TECHNOLOGY must be reexamined as basic tools of service to society. The traditional objectives of science can be—and must be—supplemented by research and education responsive to social needs.
- WHAT SCIENCE IMPLIES, NOW AND IN THE FUTURE, is rightfully a matter of growing concern to all Americans. Public participation in the making of policy for science must be encouraged.
- THE FOUNDATION IS AN APPROPRIATE INSTRUMENT OF LEADERSHIP for a large segment of American science, and we are prepared to accept that leadership.

Since the decisions we make today will set the new directions for the future, I am keenly aware of the critical role the Foundation should and must play in the immediate years ahead. That role will not be a passive one as long as I am Director.

I believe it important to acknowledge as the hallmarks of the Foundation's orientation towards the future, certain new emphases we have or are in the process of refining. Broad as they are, these emphases may best be viewed from the perspective of how NSF invests in people, in knowledge, and in the institutions which bring the two together.

Investing in People

Over the years, the Foundation has invested in people primarily through the education of scientists and prospective scientists, and to a modest extent, nonscientists. This is still the case, although numerous adaptations to meet our nation's changing needs are taking place. Among the anticipated program modifications we will stress are:

—Alternative doctoral degrees, specialized master degrees, and continuing education programs which will provide training more attuned to the contemporary needs of colleges and industry.

—Curricula for students not intending to make science a career.

—Institutes for teachers which will better enable science teachers and their local school administrators to develop and adapt new courses, materials, and methods within their own school systems.

—Public participation in science policy issues through greater involvement by State and local governments, industrial interests, and private citizens in applying science to their particular problems.

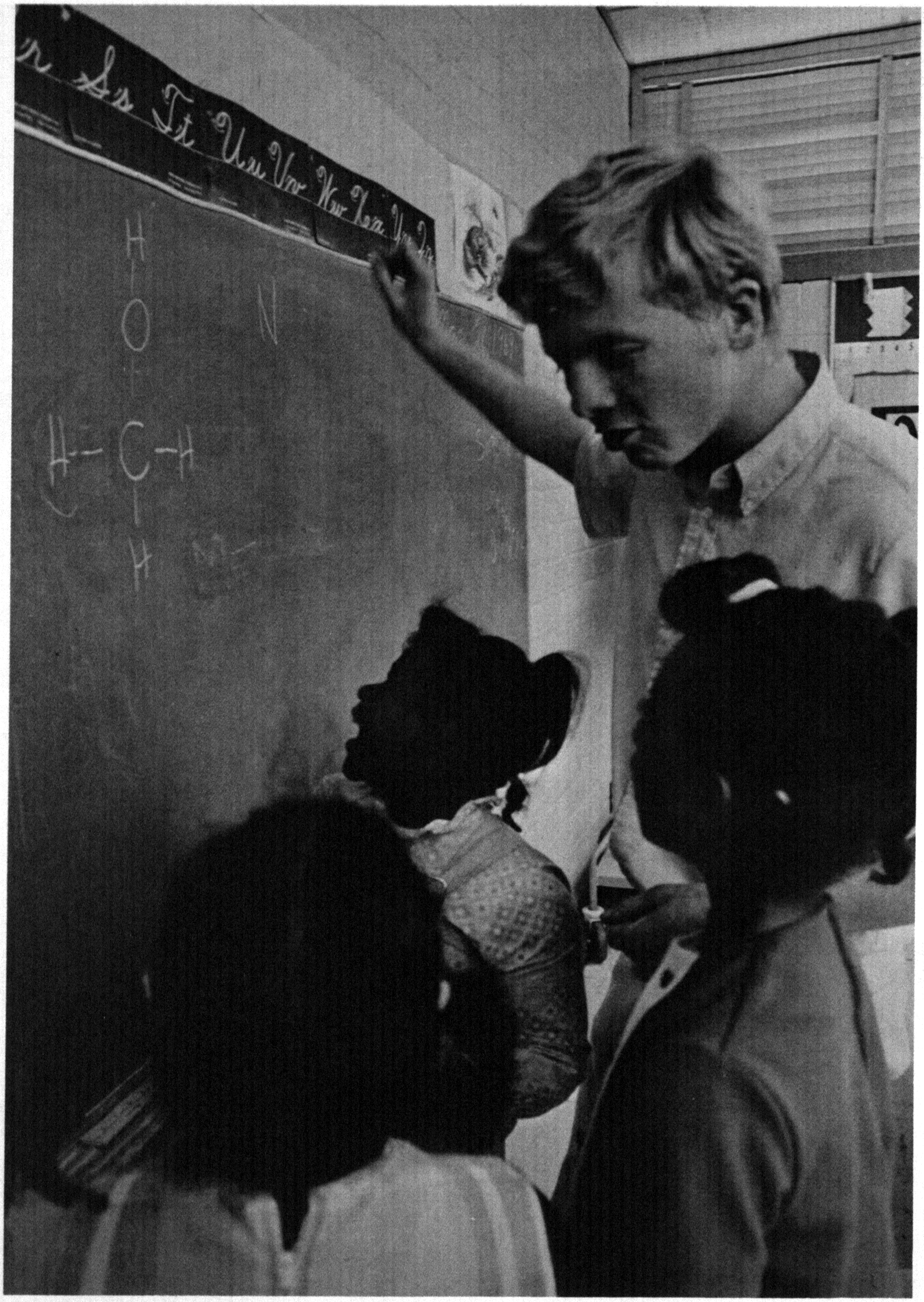


Photo by Floyd Clark/Caltech.

Photo by Robert Bradfield/Cornell Alumni News.

Investing in Knowledge

The core mission of NSF is, and will remain, to advance the progress of science. One specific and central function is, of course, the support of scientific research; in fact, NSF is the only agency charged with this primary responsibility.

To build on our past scientific accomplishments, research support for the various scientific disciplines should be reasonably adequate. But how is adequacy to be decided? What are the criteria to be used? With the funds available to NSF, in a time of limited funding, we must first allocate our resources to achieve proper balance among the various scientific fields. We then must focus more sharply by considering such factors as the scientific opportunities made possible by the development of new scientific knowledge, instruments, and techniques, the impact of the research proposed on other fields, the applicability of the proposed investigations to societal or environmental problems, and its relationship to other NSF and Federal agency research programs.

I would be less than candid if I implied that these considerations result in any clearcut answer as to the best program balance for NSF research in the future. But I anticipate increased emphasis in the following areas:

Disciplinary Research Support . . . predictable funding stability at a satisfactory level for disciplinary research support is one of our most important goals; our best scientists must be assured adequate support and we cannot afford to ignore younger scientists of promise.

Interdisciplinary Research . . . expanding problem-oriented research and related training activities is an important step in responding to the Nation's pressing social needs; the program of Interdisciplinary Research Relevant to the Problems of Our Society (IRRPOS) is the Foundation's catalyst effort in this.

Specialized Research Facilities and Equipment . . . increasing capital commitments in specialized research facilities is a must when the economy becomes more stabilized; the frontiers of science can only advance when adequate tools are available.

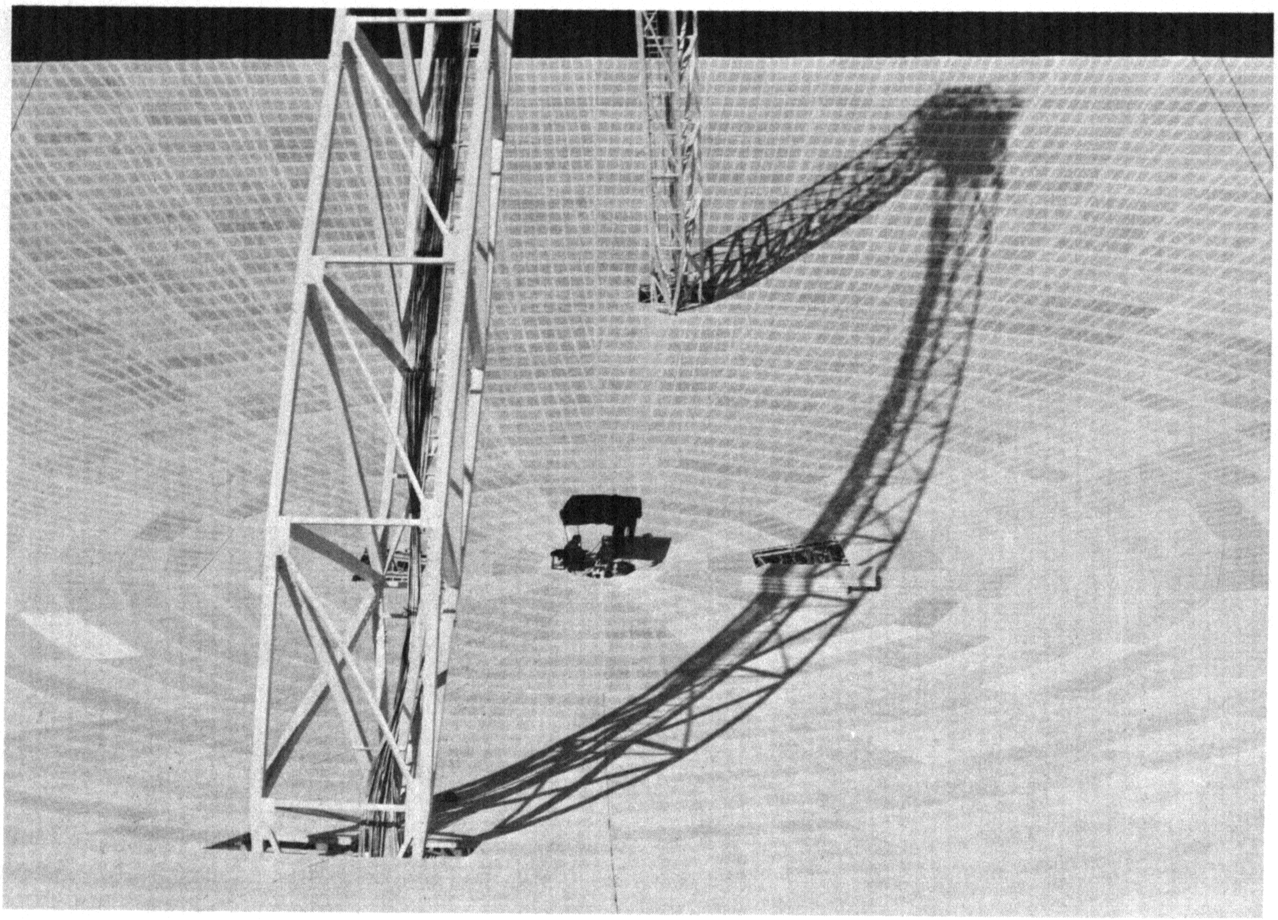


Photo by National Radio Astronomy Observatory.

Investing in Academic Institutions

Given the complex difficulties facing the Nation's colleges and universities, I cannot offer a short answer to the hard problems of maintaining and improving institutional effectiveness. The Foundation and our institutions of higher education are inextricably bound together but, as every college president knows, NSF is not a major benefactor of the institution's general health.

We do help in small ways through the provision of annual formula funds for science to be used at the discretion of colleges and universities, and increasingly through flexibility given institutional officials in administering research and education programs. Most significantly, NSF has strengthened science on a broad front in more than 30 universities and in individual areas of science at 54 other universities through large-scale development grants. Successful as these programs have been, we believe future emphases should be along somewhat different lines, for example:

—Fostering of new multidisciplinary departments

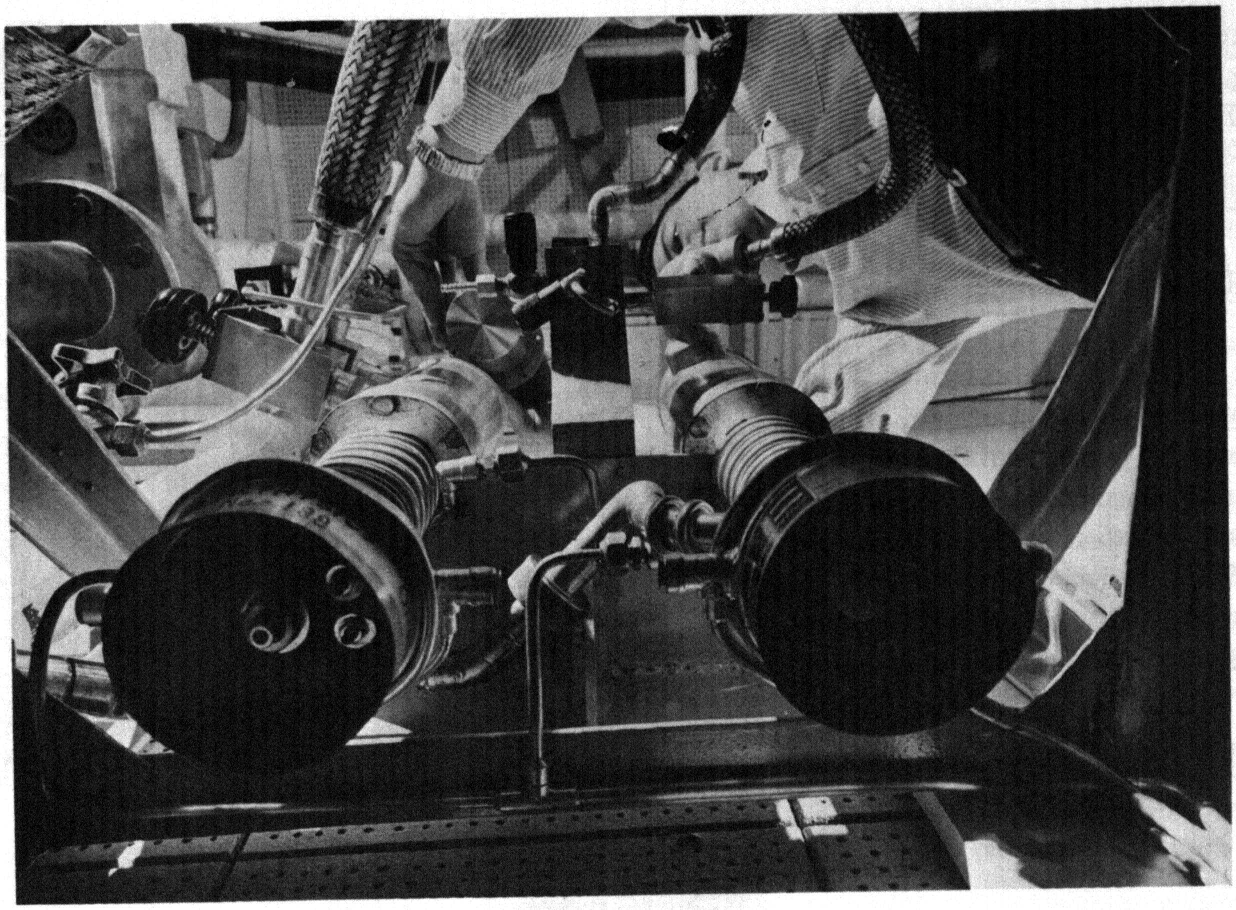


Photo by Herb Weitman/Washington University.

and centers with efforts directed toward specific societal problems. A number of problems believed amenable to this approach have already been identified.

—Strengthening of investments in institutions planning to improve and expand their social sciences. The national demand for social scientists is expected to exceed the foreseeable supply, especially as to the multidisciplinary specialist with abilities to teach and investigate through a wide spectrum of the social sciences.

—Broadening of support to institutions possessing interdisciplinary strengths in scientific research and education with special attention directed toward the improvement of university programs in the computer sciences.

As the new decade unfolds, the Foundation will require a great measure of cooperation and support from the scientific community in handling many of our "new thrust" programs, especially those which relate to the development of problem-oriented institutional capabilities. In addition to support for traditional disciplinary research, NSF will also concentrate other resources upon the solution of acute national difficulties by identifying areas of research, by actively seeking proposals, and by helping to work out new institutional arrangements. The Foundation's additional lead agency responsibilities in national and international research programs, such as Earthquake Engineering, Arctic Research, and the International Decade of Ocean Exploration, will assume a broader role as the decade progresses.

I firmly believe the Foundation is entering "The Transitional Decade" with vigor, imagination, and a new sense of responsiveness. The more subtle events of fiscal year 1970, indicating the probable directions for the future, underscore my belief. In short, I view the years ahead with confidence and optimism—thanks to an immeasurable degree to the leadership and wisdom of my two distinguished predecessors, Alan Waterman and Leland Haworth, and a deeply committed National Science Board, and staff.

W. D. McElroy
Director

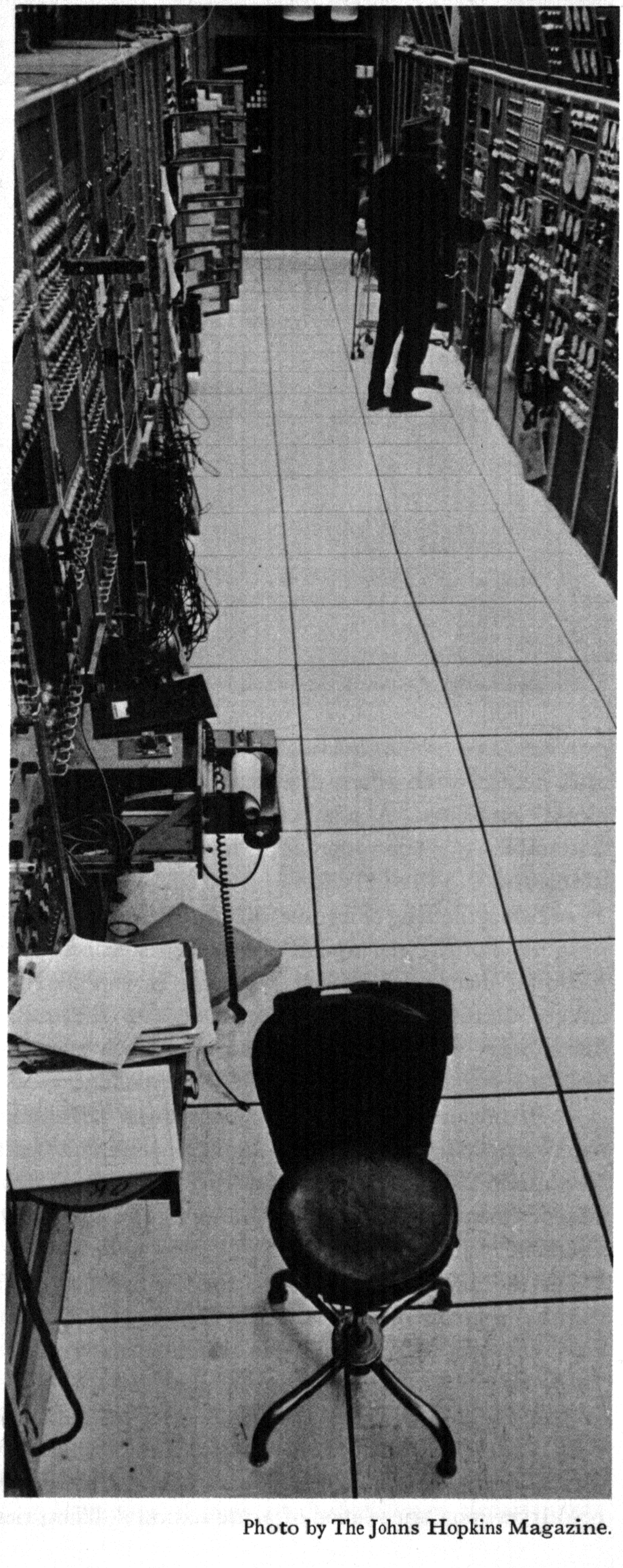


Photo by The Johns Hopkins Magazine.

Research Support Activities

The National Science Foundation supports scientific research primarily through grants to colleges and universities for projects proposed by the scientists who will conduct the research. Activities covered in this chapter are divided into four[1] major categories:

- Research grants to institutions for scientific investigations by individual scientists or groups of scientists.
- Grants to academic institutions for acquisition of specialized research equipment and facilities.
- Support of cooperative National (and International) Research Programs.
- Support of National Research Centers funded by the Foundation and operated under university management.

Scientific Research Support

In fiscal year 1970, the Foundation awarded 3,817 grants for research projects amounting to a total of $161.7 million. Comparable figures for fiscal 1969 were 4,053 grants for a total of $176.0 million. Table 1 gives the distribution, number, and amount of grants according to fields of science for fiscal years 1968, 1969, and 1970. Of all the actions taken by the Foundation on research project proposals in fiscal year 1970, 47 percent were awards as compared to 51 percent in 1969. Grants were awarded to 410 institutions, including 310 colleges and universities, in all 50 States, the District of Columbia and Puerto Rico. Ninety-five percent of the funds went to academic institutions. Of these, 211 received two or more research grants and 117 received at least $200,000.

[1] Research undertaken in connection with the National Sea Grant Program and computing activities in research are discussed in separate chapters.

Specialized Research Facilities and Equipment

The purpose of the Specialized Research Facilities and Equipment Program is to help institutions obtain the scientific equipment and facilities required for the conduct of very advanced research projects. These range from facilities such as nuclear accelerators and oceanographic ships to equipment of a specialized nature, such as electron microscopes, mass spectrometers and cryogenic equipment, required for common use by several investigators at an institution. The availability of these facilities and equipment enables research scientists to be more productive as well as to make possible the conduct of some scientific investigations which would not be possible otherwise.

National and Special Research Programs

National Research Programs are specifically identified as major research efforts undertaken to accomplish a designated objective related to one or more fields of science. Some of these programs include aspects of applied science, and some may be interdisciplinary in nature. In some cases, the work may be performed in a specific geographical area, and some activities involve international cooperation and coordination. In some instances the Foundation has been assigned responsibility for these programs by the President, or by the Congress, or by agreement within the Executive Branch of Government.

Table 3 which summarizes grants and contracts for National Research Programs over the past 3 years, includes the first awards for Interdisciplinary Research Relevant to Problems of Our Society (IRRPOS), a new program initiated by the Foundation in fiscal year 1970.

Table 1
Scientific Research Projects
Fiscal Years 1968, 1969, and 1970

[Dollars in millions]

	Fiscal year 1968		Fiscal year 1969		Fiscal year 1970	
	Number	Amount	Number	Amount	Number	Amount
Astronomy:						
Optical	....	$4.06	....	$3.85	....	$3.71
Radio	....	2.14	....	2.96	....	2.09
Subtotal	119	6.19	125	6.82	108	5.80
Atmospheric Sciences:						
Aeronomy	....	1.89	....	1.65	....	1.69
Meteorology	....	3.94	....	4.32	....	3.95
Solar-Terrestrial	....	1.74	....	2.25	....	2.28
Subtotal	103	7.57	116	8.21	118	7.92
Biology:						
Cellular Biology	....	10.02	....	9.28	....	8.68
Ecology and Systematic Biology	....	8.65	....	7.96	....	8.60
Molecular Biology	....	10.34	....	9.88	....	9.76
Physiological Processes	....	11.18	....	10.04	....	9.53
Psychobiology	....	4.27	....	4.02	....	4.30
Subtotal	1,130	44.46	1,173	41.18	1,072	40.87
Chemistry:						
Chemical Analysis	....	1.07	....	1.48	....	1.71
Chemical Dynamics	....	3.73	....	4.16	....	3.58
Chemical Thermodynamics	....	1.60	....	1.56	....	1.86
Quantum Chemistry	....	3.38	....	3.54	....	3.39
Structural Chemistry	....	3.73	....	3.22	....	2.80
Synthetic Chemistry	....	4.26	....	3.90	....	4.05
Subtotal	454	17.77	484	17.85	449	17.40
Earth Sciences:						
Geology	....	1.56	....	1.31	....	1.42
Geochemistry	....	2.97	....	3.31	....	3.07
Geophysics	....	3.28	....	3.30	....	3.36
Subtotal	214	7.81	200	7.92	196	7.85
Engineering:						
Engineering Chemistry	....	2.84	....	2.73	....	2.82
Engineering Energetics	....	3.11	....	2.94	....	2.86
Engineering Materials	....	3.44	....	3.23	....	3.29
Engineering Mechanics	....	5.93	....	6.39	....	6.55
Engineering Systems	....	3.44	....	3.00	....	[1]
Special Engineering Programs	....	.63	....	.98	....	1.17
Subtotal	506	19.40	491	19.27	463	16.70
Mathematics:						
Algebra and Topology	....	4.44	....	4.39	....	4.49
Analysis, Foundations, and Geometry	....	4.32	....	4.37	....	4.34
Applied Mathematics and Statistics	....	3.94	....	3.94	....	3.83
Subtotal	405	12.70	462	12.70	489	12.66
Oceanography: [2]						
Biological Oceanography	....	2.41	....	3.13	....	3.66
Physical Oceanography	....	1.94	....	2.16	....	2.07
Geological Oceanography	....	2.91	....	2.55	....	3.18
Support, Ship Operations	....	6.88	....	8.64	....	[3]
Subtotal	239	14.14	280	16.48	218	8.91
Physics:						
Atomic, Molecular, and Plasma Physics	....	2.33	....	2.46	....	2.72
Elementary Particle Physics	....	6.48	....	11.53	....	11.24
Nuclear Physics	....	9.07	....	8.01	....	6.45
Solid State and Low Temperature Physics	....	4.40	....	4.61	....	4.42
Theoretical Physics	....	3.63	....	3.73	....	3.34
Subtotal	236	25.90	283	30.35	245	28.18
Social Sciences:						
Anthropology	....	3.50	....	3.42	....	3.48
Economics	....	3.58	....	4.29	....	4.34
Geography	....	.59	....	.19	....	.48
Sociology and Social Psychology	....	3.73	....	3.29	....	3.35
Political Science	....	.76	....	1.28	....	1.19
History and Philosophy of Science	....	.73	....	.87	....	.83
Special Projects	....	1.76	....	1.90	....	1.74
Subtotal	426	14.67	474	15.24	459	15.42
Total	3,832	170.61	4,053	176.02	3,817	161.71

[1] Included in National and Special Research Programs for FY 1970.
[2] Includes marine biology.
[3] Included in National and Special Research Programs for FY 1970.

Table 2
Specialized Research Facilities and Equipment
Fiscal Years 1968, 1969, and 1970

[Dollars in millions]

	Fiscal year 1968		Fiscal year 1969		Fiscal year 1970	
	Number	Amount	Number	Amount	Number	Amount
Astronomy	4	$0.662	5	$0.324	5	$0.190
Atmospheric Sciences	11	.788	8	.298	4	.199
Biological and Medical Sciences	30	1.709	34	.880	11	.918
Chemistry	113	4.296	57	1.700	63	1.697
Earth Sciences	0	0	0	0	3	.103
Engineering	43	1.073	26	.880	28	.600
Oceanography	9	4.711	1	1.397	[1]	[1]
Physics	19	4.697	25	1.300	12	2.499
Social Sciences	3	1.006	2	.438	1	.298
Total	232	18.942	158	7.216	127	6.504

[1] Included in National and Special Research Programs for FY 1970.

Table 3
National and Special Research Programs
Fiscal Years 1968, 1969, and 1970

[Dollars in millions]

	Fiscal year 1968		Fiscal year 1969		Fiscal year 1970	
	Number	Amount	Number	Amount	Number	Amount
Arctic Research program	0	0	0	0	2	$0.13
Ocean Sediment Coring program	4	$4.17	5	$2.43	25	6.56
Global Atmospheric Research program	1	.20	9	.54	19	1.49
Interdisciplinary Research Relevant to Problems of Our Society	0	0	0	0	21	5.98
International Biological program	1	.70	16	1.22	24	4.00
U.S. Antarctic Research program	149	7.64	145	6.88	128	7.28
Weather Modification program	32	2.77	24	2.43	27	2.63
Engineering systems	----	----	----	----	92	3.30
Oceanographic Ship Operations and Facilities	----	----	----	----	31	7.60
Total	187	15.48	199	13.48	369	38.97

Foundation support for National and Special Research Programs more than doubled in fiscal year 1970 over the previous year. Most research supported by these programs is associated with the environment, an area of expanded emphasis in many other Foundation programs as well in fiscal year 1970. In addition to the programs listed, the Foundation in fiscal year 1970 was designated lead agency for the International Decade of Ocean Exploration (IDOE), an international program proposed by the United States and endorsed by the General Assembly of the United Nations. Initial planning for IDOE places emphasis on environmental quality, environmental forecasting, and seabed assessment. It is expected that the first awards for IDOE will be announced early in calendar year 1971.

National Research Centers

The National Science Foundation provides support for the development and operation of National Research Centers established to meet national needs for research in specific areas of science requiring facilities, equipment, staffing, and operational support which are beyond the financial capabilities of private or State institutions and which would not appropriately be provided to a single institution to the exclusion of others. Unlike many federally sponsored research laboratories, the NSF-supported National Research Centers do not perform specific research tasks assigned by or for the direct benefit of the Government. They are established and supported for the purpose of making available, to all qualified scientists, the facilities, equipment, skilled personnel support, and other resources required for the performance of independent research of their own choosing, in the applicable areas of science.

In recent years, the Foundation has supported three astronomy centers (Cerro Tololo Inter-American Observatory, Kitt Peak National Observatory, and National Radio Astronomy Observatory) and one atmospheric research center (National Center for Atmospheric Research). In fiscal year 1970, the Foundation assumed principal funding responsibility for the Arecibo Observatory in Puerto Rico, and established it as a fifth NSF-sponsored National Research Center. This observatory was built with funds provided by the Department of Defense and, prior to fiscal year 1970, principal funding support was furnished by the Department of Defense.

Funding levels for the National Research Centers during fiscal years 1968, 1969, and 1970 are given in the table below.

Table 4
National Research Centers
Fiscal Years 1968, 1969, and 1970

	Fiscal year 1968			Fiscal year 1969			Fiscal year 1970		
	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	$1,502,000	$823,000	$2,325,000	$3,449,000	$1,101,000	$4,500,000	$365,000	$1,535,000	$1,900,000
Kitt Peak National Observatory	8,331,176	4,144,192	12,475,368	1,137,700	4,561,809	5,699,510	46,000	6,379,000	6,425,000
National Radio Astronomy Observatory	874,300	3,989,700	4,864,000	483,212	6,795,001	7,278,214	675,000	5,125,000	5,800,000
Arecibo Observatory	----	----	----	----	----	----	150,000	1,400,000	1,550,000
National Center for Atmospheric Research	2,041,100	9,758,612	11,799,712	425,000	10,611,736	11,036,737	212,840	11,367,000	11,536,800
Total	12,748,576	18,715,504	31,464,080	5,494,912	23,069,547	28,564,461	1,448,840	25,857,960	27,211,800

MATHEMATICAL AND PHYSICAL SCIENCES

The pressure from the scientific research community for support of research projects in all of the mathematical and physical sciences—mathematics, physics, astronomy, and chemistry—rose sharply during fiscal year 1970. This was attributed largely to reorientation in the priorities of other Federal agencies supporting similar research. Another element adding to the increased pressure on the mathematical and physical sciences from the scientific community was the increased number of proposals from scientists trained in other disciplines. For example, sugar and protein chemistry projects were proposed by biologists, and a number of projects in mathematics was proposed by engineering faculty. Insofar as the total amount of funding available has remained nearly constant, a larger number of the proposals received was necessarily declined.

While the last few years of basic research in the physical sciences have not been easy ones, nonetheless progress continues to be made. While it is never possible for the Foundation to predict what area of research will produce the answer to a particular significant problem, some approaches and techniques appear to have greater possibilities of fruitfulness within a broadly defined problem area. Without receding from its policy of supporting high quality fundamental research across the disciplinary spectrum, certain areas are receiving special emphasis.

A major factor in a whole class of important chemical reactions is catalysts, a group of substances which influence the reaction rate without being permanently changed themselves. Perhaps the most important of these catalytic materials are the enzymes which regulate many of the chemical reactions of living systems. It is believed that most catalysts perform their chemical magic by providing a physical surface which temporarily holds and positions the reacting molecules so as to facilitate their combination. In enzymes, which are themselves large molecules, the catalytic surface is thought to be a particular segment or "active site" on the molecular chain. The physical structure and properties of these active sites can now be studied by a promising new technique known as spin labeling. In this technique, a molecule is synthesized to have properties similar to those of the molecules on which the enzyme operates and in addition to have magnetic properties. Detailed study of the magnetic properties of the artificial molecule when bound to the enzyme gives detailed information about the properties of the active site on the enzyme.

In physics, concomitant advances in astrophysics, general relativity, and gravitational radiation are bringing improved understanding about the universe and the nature of its evolution.

The technological areas associated with physics—long a source of advanced technology and instrumentation for other sciences, pure and applied, and for industry—have advanced steadily. In cryophysics, the study of physical behavior near temperatures of absolute zero, studies made for the improvement of particle acceleration and the detection of gravitational radiation have markedly increased our ability to deal with low temperature phenomena such as superconductivity on a large scale. The latter phenomenon will eventually find major applications in the generation and transmission of heavy-load electricity and in higher speed computers.

Technology relating to the confinement of plasmas—hot ionized gases—has produced several new developments raising hopes for eventual production of electric power by nuclear fusion, a pollution-free technique which also will draw upon hydrogen rather than our diminishing supply of fossil fuel as a source of energy.

In astronomy, new techniques of working in the far infrared—light of very long wavelength merging into the microwave segment of the radio spectrum—have enlarged the scientist's view of the universe considerably. The successful flight of Stratoscope II, a balloon-borne, high-resolution telescope, has markedly increased our ability to study the planets of our solar system—knowledge which will not be improved upon until planetary probes "fly by" these planets in the late 1970's. For the observing astronomer, a new technique of computer-guidance will cut drastically the time now spent in aiming telescopes at desired sectors of the sky and increase efficiency and actual observing time—in some cases by as much as 50 percent. Discovery of the water molecule and several new polyatomic organic molecules in interstellar space has broadened our view about the conditions under which life itself can evolve.

In applied mathematics, which uses the highly abstract tools of pure mathematics for applied ends, new techniques of nonlinear analysis are being applied to problems such as multiple inputs of municipal effluent into the Hudson River and the flow mechanisms of blood. The theory of differential games is being used in economics and in the study of transportation and traffic problems. Statistical theory is being applied to quality control testing in industry, experimental design in the laboratory, and to studies of genetics.

Eventually, many of the abstract relationships discovered in pure mathematics facilitate man's conceptual mastery of real phenomena in all of science, which in turn finds concrete form in physical instrumentation and experiments. Finally, these relationships emerge, with regular and lasting impact, as new processes, new instruments and mechanisms, and new materials. The availability and relative cheapness of paint and plastic, of solid state circuitry, of long distance telephone and television communication, of improved traffic and transportation control all find their roots in basic research in the mathematical and physical sciences.

CHEMISTRY

The Association Reactions of Borane

The relation between the nature of a chemical species and the reactions it undergoes has always been a major research thrust in chemistry. There are two levels at which one can understand a chemical reaction. The first level of understanding involves knowing what stable products are produced from stable reactants under the specified conditions of the reaction. A second and deeper level of understanding is achieved when one can answer the question: What is the detailed motion of the atoms in the chemical species during the course of an overall reaction? An approach to answering this question is to break down a given chemical reaction into smaller steps that can be scrutinized individually.

There are many ways to break down a chemical reaction into smaller steps. One simple and direct way is by detecting intermediate chemical species. These are species which are formed and subsequently destroyed during the course of the reaction. They are neither reactants nor products. Knowing the structure and the speed with which these intermediates react is equivalent to having "snap shots" of the atomic motions which control the total chemical reaction. The identifica-

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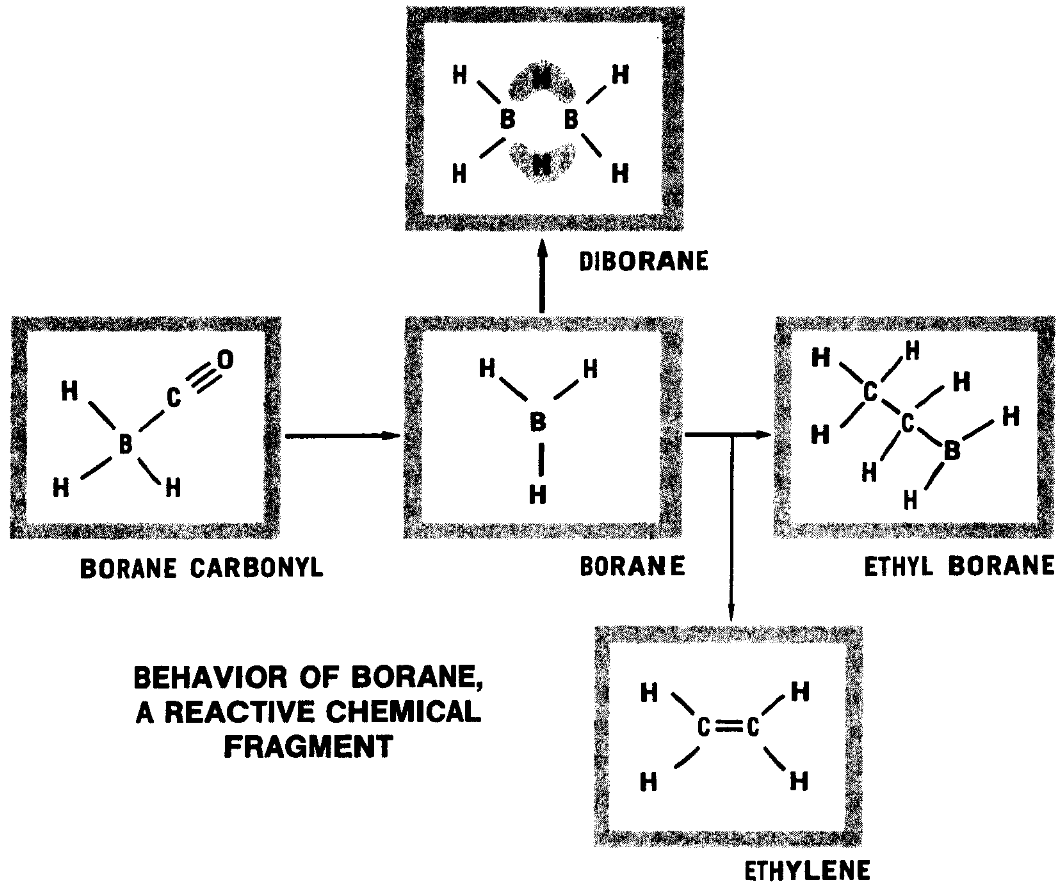


"Snapshots" of the behavior of borane, a reactive chemical fragment. In the reaction on the left, borane is released, along with carbon monoxide, by heating borane carbonyl. It reacts rapidly with another borane fragment to form diborane, with its unusual hydrogen-bridged structure (top). Borane also reacts with ethylene, which has an extra pair of electrons in its central bond.

tion and characterization of important types of intermediates has historically had a large impact on chemistry.

Thomas P. Fehlner of the University of Notre Dame is currently involved with the characterization of a new kind of intermediate, borane (BH_3), and the comparison of its unique qualities with those of related, yet different species. In most stable boron compounds, the boron atom is surrounded by eight electrons, usually shared in chemical bonds with other atoms. Borane has only six electrons, so it seeks other molecules which can share two electrons with it. Because of this characteristic, it is so reactive that it does not normally exist in a free state for a lifetime of more than a fractional part of a second.

Two things were prerequisites to the study of borane: a pure and intense source of borane, and a system suitable for observing its reactions. The first requirement was fulfilled after much effort in qualitatively examining the production and destruction of borane in a variety of systems. By heating complexes where borane was weakly bound to compounds which would readily give up a pair of electrons, Dr. Fehlner produced quite pure borane at relatively high concentrations for long times (0.001 seconds) compared to the measurement time (0.00005 seconds).

Dr. Fehlner was able to observe the reactions of borane by constructing a mass spectrometer system and coupling it directly to a borane production device. The mass spectrometer acts by converting all of the chemical species entering it into ions, which are then separated according to their mass, and counted. The relative numbers of ions of various masses yield information both as to the identity and the number of the species ionized. Consequently, as borane is reacted with various species, this instrument can be used (1) to identify unambiguously the products and (2) to measure the amounts. Finally, the time of reaction can be varied so as to measure the speed of the reaction.

During the past year the Notre Dame group succeeded in observing some of the characteristic association reactions of borane. The first reaction examined was the combination of two borane fragments to form the stable compound, diborane (B_2H_6). As far as chemical reactions go, this reaction is very efficient in that about one out of every ten borane-borane collisions yields the product. The second reaction Dr. Fehlner has examined is the association of borane with electron pair donors to form complexes. The products are already known in most cases, but measurements of the relative reaction speeds will characterize those aspects of borane reactivity involving the acceptance of electrons. The product of the reaction of borane with ethylene, a compound containing a double bond, has recently been observed. The product, ethyl borane ($C_2H_5BH_2$), was itself a previously unknown compound. This type of reaction is important in the synthesis of many new chemical compounds. Dr. Fehlner's work will significantly broaden our understanding of fast reactions in general and the relationship between chemical reactivity and electronic structure.

Nitrogen Fixation

Life on earth would not be possible without the fundamental biological process by which certain plants convert atmospheric nitrogen, which is chemically inert, into ammonia (NH_3). From this ammonia, proteins are constructed which are essential components of all living cells. In nature, the conversion of nitrogen to ammonia is accomplished by nitrogen-fixing bacteria through the agency of a complicated enzyme catalyst called nitrogenase. Industrially, the fixation of nitrogen to ammonia is done by a high temperature (300°–600° C.) high pressure reaction (several hundred atmospheres) known as the Haber process.

Chemists have long sought a way to reduce molecular nitrogen to ammonia under moderate conditions without requiring the high temperature or pressures of the Haber process. Research to date indicates that iron and molybdenum, which are present in many natural systems, seem to play an important transition role in the process of fixation and reduction of nitrogen to ammonia. Apparently, these transition metals form a metal-nitrogen complex which weakens the bond which binds the inert nitrogen molecule together.

Although a number of well-characterized metal-nitrogen complexes have been made, it has not been possible to reduce the nitrogen in these systems down to the ammonia stage. The difficulty undoubtedly lies in the thermodynamic stability of molecular nitrogen and the relative thermodynamic instability of the intermediate chemical species necessary in the successive stages of reduction.

Recently, Fred Basolo and Ralph G. Pearson at Northwestern University made a discovery which bears on the reduction problem and promises to throw light on the requirements for a metal ion catalyst which can reduce molecular nitrogen to ammonia. Drs. Basolo and Pearson prepared two different metal salts, one containing the element ruthenium and the other containing the element iridium each of which contains a nitrogen complex corresponding to one of the apparently required intermediate chemical species. This intermediate product can be reduced to ammonia complexes by mild reducing agents. The secret of success apparently was to start with metal in the reduced (having a surplus of electrons) rather than oxidized (deficient in electrons) form thereby enabling the reaction to proceed towards ammonia rather than reverting back to the stable molecular nitrogen stage.

The new metal-nitrogen complexes have some analogy to the molybdenum-iron system which is presumed to be the catalyst in the enzyme nitrogenase. It will be of interest to see if iron can be used to replace ruthenium. While a system capable of fixing nitrogen in this manner has not been developed, systems are now available in which the several stages of reduction of nitrogen can be studied.

The work by Drs. Basolo and Pearson appears to be a significant step forward in the elucidation of the complete mechanism of biological nitrogen fixation which, once achieved, may ultimately make possible breeding of nitrogen-fixing powers into crops such as wheat and corn, minimizing the problems of run-off of excess fertilizer, a possible cause of river and lake pollution and an uneconomic use of fertilizer.

Chemical Instrumentation

The acquisition of modern instruments is recognized both by the Foundation and chemistry departments at institutions of higher learning to be of crucial importance. During the past year the Foundation received 202 requests from colleges and universities for purchase of chemical instrumentation. Highest priority requests totaled $10.4 million, with lower priority items bringing the total request to over $30 million. The Foundation was able to support 63 of these requests by contributing $1.7 million toward the purchase of $3.39 million worth of instrumentation. The difference of $1.69 million was provided by institutional contributions, which this year were 25 percent higher than the average contribution over the past 6 years. These very significant contributions provide substantive evidence that colleges and universities recognize the importance of complex instrumentation in chemical education and the pursuit of basic chemical research.

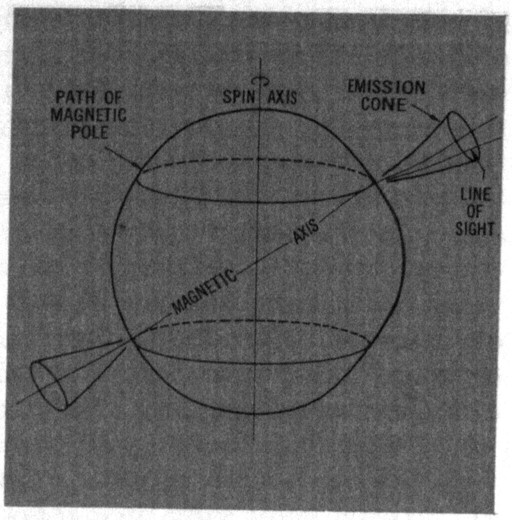
PHYSICS

The Solid State Physics of Pulsars

Pulsars, the recently discovered, rapidly pulsating radio sources observed in the sky, have attracted interest outside the domain of the astronomers who first observed them. These phenomena appear to represent such an extreme form of behavior that what they do and are may be of fundamental importance to our understanding of the basic physical laws of the universe.

Less than 2 years ago, Malvin Ruderman of Columbia University pointed out that pulsars would most likely exhibit phenomena such as superconductivity and superfluidity which are more normally associated with materials that are manipulated by solid state physicists on laboratory bench tops.

Recently, physicists and astronomers have leaned strongly toward the theory that these objects are the long predicted neutron stars (first postulated by the Russian physicist, L. D. Landau, and the American physicist, J. Robert Oppenheimer in the late 1930's). The reason for this is the short time-scale of the "pulsations." Just as a pendulum has a characteristic period which is determined by its length and the gravitational field strength at the surface of the earth, any astronomical object will have pulsation periods which are uniquely deter-

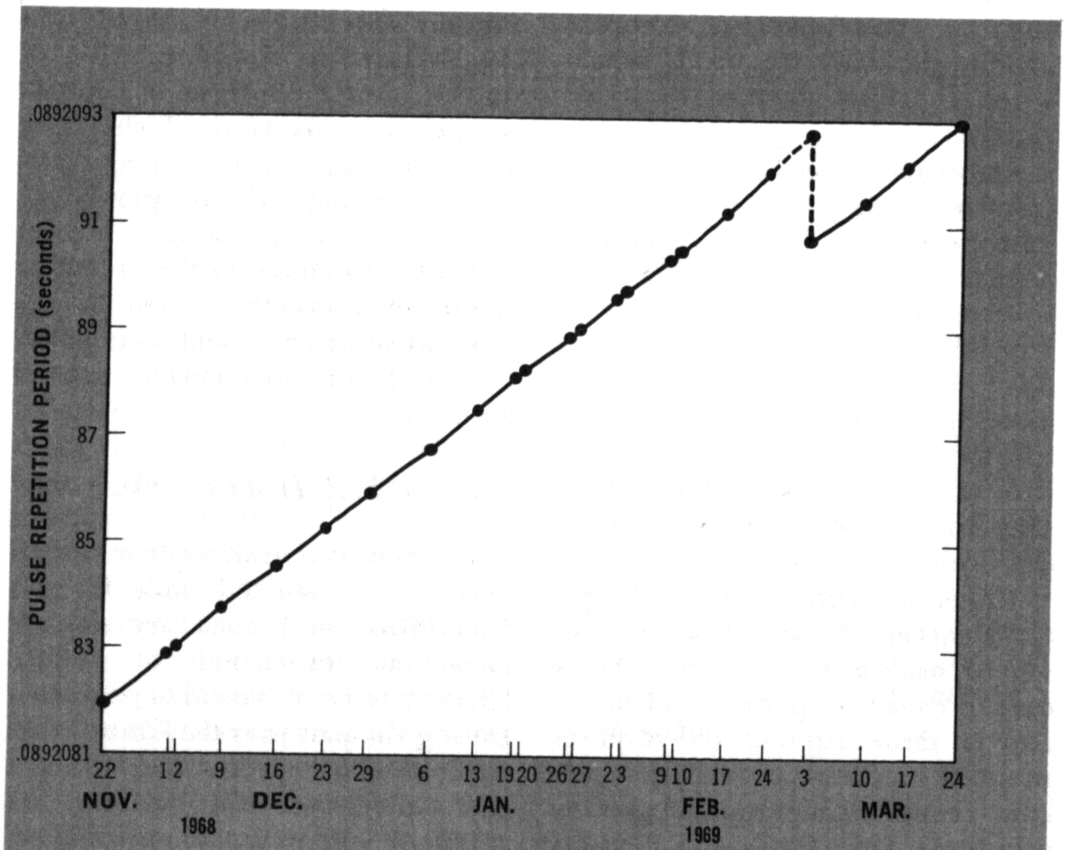


A theoretical model of a pulsar, pictured as a rotating neutron star with magnetic and spin axes out of alignment. It is thought that intense surface magnetic fields in such an object would be responsible for beaming electromagnetic radiation along the direction of the magnetic axis. If the star is properly oriented, this beam would sweep through the observer's line of sight once (or twice) for every rotation of the star, thus giving rise to the "pulsar" effect. Other models which have been suggested differ in detail and involve emission regions further out from the surface of the star and "beaming" perpendicular to the field axis, but all current theories emphasize the rotating searchlight effect as the basic source of the pulses.

mined by its density. In order to pulsate once a second, it must have a mean density of 10^8 to 10^{10} grams per cubic centimeter. The densities of the heaviest naturally occurring elements are of the order of 20 grams per cubic centimeter.

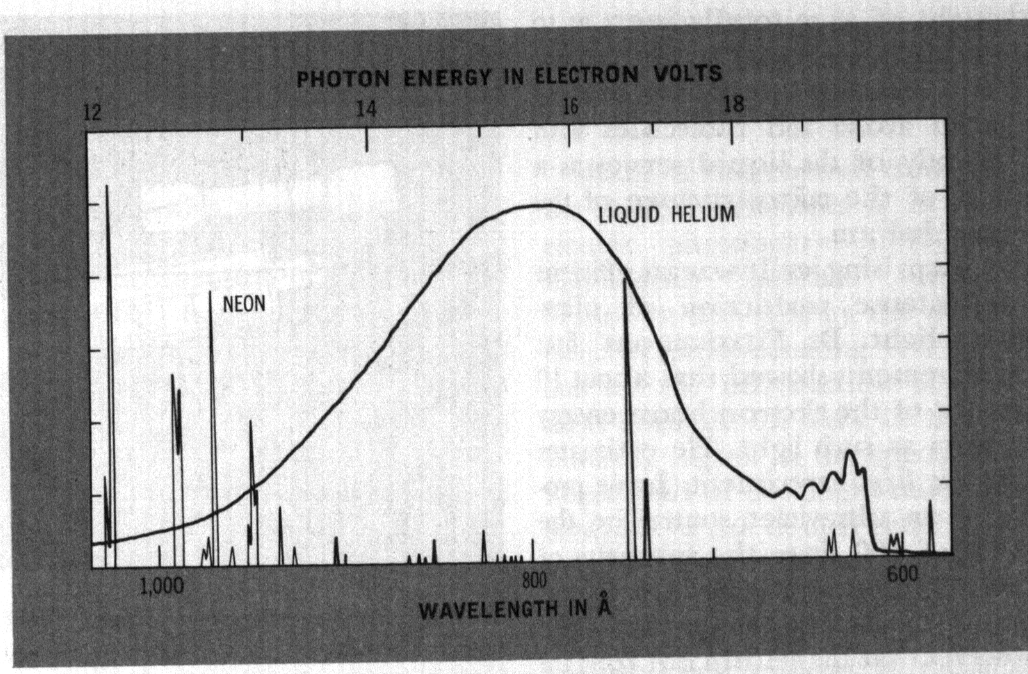
Because of the unique way in which atoms are being "squeezed" at these densities, such an object would not be stable, and it would continue to collapse to a density of 10^{13} to 10^{14} grams per cubic centimeter, at which point the individual nuclei would be touching each other and would cease to exist as separate entities. At this higher density, pulsation periods would be only 10^3 seconds, but such a collapsed star with these properties could easily be in rotation once a second without being disrupted by centrifugal forces, and it is now commonly accepted that it is the magnetic field (which the neutron star is likely to have associated with it if it has evolved from a normal star) rotating with the star which somehow produces the periodic radio bursts.

At these high densities, the individual nuclei are expected to break up, and the most stable form of matter will be a neutron "liquid" with perhaps a few percent of protons and electrons, also in a "liquid" state. The solid state physicist commonly describes the liquid and solid states of normal matter in terms of interacting atoms, but he can also discuss the interactions of large numbers of particles independent of their precise internal nature. Through the use of such techniques, Dr. Ruderman was able to conclude that a typical neutron star should have a core-mantle structure much like that of the earth. In the outermost layer, where the density is not yet as high as the density of the nucleus, one would expect the individual nuclei to form a crystal lattice structure, just as atoms commonly form such structures at normal densities. As one goes further toward the center, the density continues to increase and the number of subnuclear particles or nucleons in each individual lattice nucleus decreases, until finally the lattice is made up solely of unbound nucleons. Deeper into the star, the still higher density of nucleons forces them to have sufficiently large kinetic energy so that they will no longer be fixed on individual lattice sites. The proton, neutron, and electron components



The pulse period of a pulsar in the constellation Vela is plotted as a function of time. Up until February 24, 1969, the period is steadily increasing. One week later it has decreased drastically, and in following weeks again shows a gradual increase at a slightly different rate. If the model of a pulsar is correct, the pulsar had to undergo a sudden increase in rotational velocity during the week of February 29—March 3. This could have been triggered by a "starquake." (Courtesy of P. E. Reichley and G. S. Downs at the California Institute of Technology Jet Propulsion Laboratory) will then all be in the liquid state, and it is highly likely that the neutron component will be superfluid and the proton and electron components will be superconducting.

Two new observations made during the past year and a half have given increasing weight to this theoretical picture. The first of these was the report of the sudden increase in rotational velocity or "spin up" of the pulsar located in the constellation Vela. Observations made 1 week apart indicated that its period had decreased by one part in 10^6, or equivalently, that its rotational velocity had increased by that amount. After this "spin up" occurred, the object was again observed to follow a gradual slowing-down law, but at a different rate than it had prior to spin-up. A sudden change in the moment of inertia of the pulsar appears to be the most likely explanation; a 1-centimeter decrease in the mean radius would be sufficient to account for the observations, and Ruderman and collaborators suggest that the speed-up is due to a "starquake" which occurs in the solid crust of the pulsar when the centrifugal forces which would cause it to bulge after its initial solidification have relaxed enough to make sufficiently large stress. They find that the observed changes in period and rate of slow-down are consistent with this picture, provided they make one additional hypothesis about the viscous forces which tend to damp out motions of the pulsar's crust relative to the fluid core—they must be so small that the core can only be interpreted as existing in a superfluid state. A number of months ago, another pulsar "spin-up," this time of the pulsar in the Crab Nebula, was observed by an NSF-sponsored research team at Princeton University. The observed data were again in agreement with the superfluid model.



Spectrum of ultraviolet (u.v.) radiation observed from liquid helium bombarded by 160 keV electrons, showing the broad range of photon energies emitted. For comparison, the narrow line spectrum of neon (from a calibration lamp) is also shown, to illustrate typical atomic u.v. spectra. For many industrial and scientific applications, a broad emission spectrum and high efficiency are required of a u.v. source.

Ultraviolet from Liquid Helium

Liquid helium is of interest to scientists in widely separated fields because it is the coldest fluid known to man. Liquid helium is also of interest because it is a superfluid; that is, it has no viscosity and no surface tension—which means that it can flow through holes no other liquid can permeate, and can climb the sides of containers in which it is placed. Further, liquid helium is practically a perfect conductor of heat, which makes it an ideal refrigerant for super-cold applications since it quickly removes heat from the object being cooled. Finally, it is of interest to scientists because it shows forms of behavior (superfluidity, superconductivity, etc.) on a gross or "macroscopic" scale that are usually only associated with behavior of matter on an atomic scale.

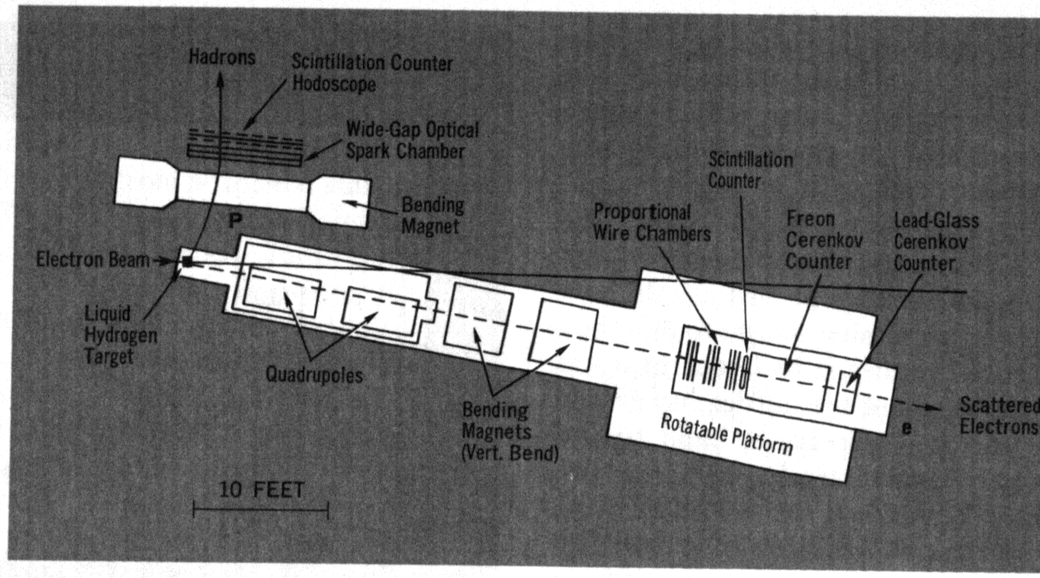
Interested in learning more about the physical properties of this liquid and what it could reveal about the structure of the atoms of which it is made, a young scientist W. A. Fitzsimmons of the University of Wisconsin has been probing the effects of shooting an electron beam into a container of liquid helium. Dr. Fitzsimmons is interested in what the helium does after absorbing energy from the electron beam, since this reveals to him something of the nature of the helium immediately surrounding the atom which has absorbed energy and then released it.

In his apparatus the beam enters the liquid through a thin foil (which separates the liquid from the vacuum of the electron source), and the light then emitted is observed at a 90° angle with a specially designed monochromator, a device which measures the intensity of light at a given wavelength.

The light emitted from the liquid along the path of the beam was found to be characteristic of various excited states of the helium (He) atoms and He_2 molecules formed by the beam. The latter is in itself of interest since helium is usually thought of as so totally inert as to never form molecular combinations. The subsequent interaction of these excited atoms and molecules with the body of the liquid serves as a probe of the microstructure of the liquid helium.

A surprising result was an efficient and intense production of ultraviolet light. Dr. Fitzsimmons' first measurements showed that about 10 percent of the electron beam energy appears as such light. He estimates that his first experiments have produced an ultraviolet source on the order of 100 times the intensity of previous ones operating in this portion of the ultraviolet spectrum. He observes that the helium can tolerate an intense local absorption of energy without boiling because as a superfluid and an unusually good conductor of heat, the heat deposited by the beam is carried away before local boiling can occur.

An ultraviolet source of this novel type would be inexpensive, compact, and efficient. It could be operated steadily, or pulsed on quickly. Its intensity can be easily and continuously changed over a wide range. In addition to a number of scientific uses, this source could be considered for application in industrial processes where it can serve to initiate bulk chemical reactions or to heat the body of a liquid from within or to sterilize liquids.



Experimental arrangement of the 10 BeV spectrometer and wide aperture magnet and spark chamber. This arrangement is used for the detection and identification of deep inelastic scattering electron interactions with production of hadrons.

Cornell Electron Accelerator

Since the Cornell Electron Synchrotron reached its design energy of 10 billion electron volts (BeV) in 1968, a vigorous experimental program has been pursued. This machine is the latest in a group of pioneering electron accelerators built and used at Cornell under the direction of Robert R. Wilson, now Director of the National Accelerator Laboratory in Batavia, Ill.

The Cornell synchrotron, presently under the direction of Boyce D. McDaniel, has a capability which is unique in the world—it produces photon and electron beams of up to 10 BeV energy which are sufficiently uniform in time (compared to the one-thousandth of a second beam bunches presently available in linear accelerators) to permit the detailed study of interactions in which several particles are detected simultaneously.

This property of the accelerator gives Cornell a unique capability to study many interesting fundamental processes. Among the most interesting of these is the phenomenon called "deep inelastic scattering." This is a process in which the scattering of a high energy electron by a target nucleon produces energetic particles known as hadrons. Hadrons are the particles which are involved in the "strong" interactions (one of the four basic interactions of nature, which include also the "weak," the "electromagnetic," and the "gravitational" interactions). This deep inelastic scattering is now the subject of much theoretical investigation because the probability for such scattering occurring is inexplicably substantially higher than for particle collisions without hadron production ("elastic scattering"). One theory to explain this high probability proposes that the target nucleon (proton or neutron) is made up of parts rather than being a single elementary particle. Such a composite structure for the proton would require modifications to our present interpretation of experimental data and major revision of our theoretical ideas, which presently view the proton as a fundamental building block of matter and truly elementary in nature. Hadron states of considerable interest are now being observed at Cornell, providing data on what is now one of the most important unsolved problems in particle physics.

Major Physics Research Facilities

Research in the technology of extremely low temperatures is an essential part of the work of William M. Fairbank, H. Allan Schwettman, and collaborators at the High Energy Physics Laboratory of Stanford University. This has led to major advances in the areas of high efficiency power transfer systems for particle acceleration and large-scale refrigeration near absolute zero with superfluid helium.

Superconductivity is that phenomenon which manifests itself at extremely low temperatures by the disappearance of resistance to the passage of electric currents. Extreme efficiency in power transfer and large voltage gradients, as much as 8 million volts per foot, have already been achieved. The Stanford group has also pioneered in the use of superfluid helium as a refrigerant on a large scale. The high heat capacity and remarkable mass transport properties of superfluid helium lead to applications on a scale impractical with ordinary liquid helium. A closed-cycle superfluid helium refrigerator capable of liquefying 450 liters of helium per hour at 1.8° K. is now in operation, a major advance in low-temperature technology. One possible application of these developments is in the use of superconducting systems for confinement and acceleration of plasmas, with potential consequences of the highest significance for the development of new power sources.

A novel type of beam collection and focussing channel is also being developed at this laboratory to provide high-intensity beams of pi-mesons, particularly suited for cancer radiation therapy. This is being designed in conjunction with the construction of a 500-foot-long superconducting linear accelerator, which represents the fruition of many years of research in low temperature technology, and is a development that will have considerable impact on future particle accelerators. The anticipated performance characteristics are a continuous electron beam with a current of at least 100 microamperes, energy spread and stability of one part in 10,000, and final energy above 2 billion electron volts. The initial stages of this system are now being tested. Beams at intermediate energies will be available for research purposes in 1971.

Work is also progressing on the design of superconducting systems for the acceleration of protons and heavy ions, both at Stanford University and the California Institute of Technology. Preliminary results indicate that these techniques show great potential for a practical solution to the problem of obtaining intense beams of heavy ions.

ASTRONOMY

Kitt Peak National Observatory

Kitt Peak National Observatory (KPNO), with headquarters located in Tucson, Ariz., and telescope installations on Kitt Peak on the Papago Indian Reservation, is operated under contract with the National Science Foundation by the Association of Universities for Research in Astronomy (AURA), Inc.

150-inch Telescopes

Construction of the two 150-inch telescopes—the world's second largest—one for Kitt Peak and one for the Cerro Tololo Inter-American Observatory in Chile has progressed during fiscal year 1970 according to plan. On Kitt Peak, the building and dome are nearing completion and are scheduled for acceptance from the contractor by the end of September 1970. Fabrication of the mechanical mountings for these telescopes is well underway and optical "figuring" on the GE fused quartz mirror blank for the Kitt Peak telescope is almost completed in the KPNO Optical Shop in Tucson. After completion, grinding and polishing of the blank for Cerro Tololo will begin on the same grinding machine.

KPNO Research Projects

Stellar Astronomy

Much of the research done using the smaller telescopes is in photoelectric photometry. KPNO staff significantly increased the capabilities in this field by the development of pulse-counting techniques, and by the introduction of equipment suitable for work in the near infrared region of the spectrum. A major part of the bright-moon time schedule of the 50-inch reflector was used for infrared spectrophotometry, with the auxiliary equipment of visiting scientists. These studies obtained new evidence of radiation from circumstellar dust shells.

The major part of the bright-moon time use of the 84-inch reflector was devoted to spectroscopic studies of the chemical composition of the stars, of their rotational velocities, radial and orbital velocities, and dynamics of their atmospheres. Quasars, galaxies, and faint stars were subjects for study during dark-of-the-moon use of this instrument. During a collaborative study of optical counterparts of radio sources located with the 210-foot Parkes telescope in Australia, an object having a red shift of record size was observed. This object is receding at more than 80 percent of the velocity of light, and the radiation now being observed left the object when the universe was one-tenth its present age.

Solar Astronomy

Continued improvements and new additions to the McMath Solar Telescope make it one of the world's most powerful and versatile instruments for the study of the sun's surface and atmosphere. With the addition this year of the auxiliary mirrors the installation is now really three telescopes in one, and has the capability of providing simultaneous studies of the same solar phenomenon with different tools and techniques. For example, the structures of the solar atmosphere can be photographed with one instrument, their spectral characteristics recorded with a second instrument, and a third can obtain the magnetic fields in the same region.

After 3 years' work, the 40-channel magnetograph has been brought into operation. It worked from the first flick of the switch, and gives detailed maps of solar magnetic fields. Simultaneously the brightness and velocity fields of each area are plotted.

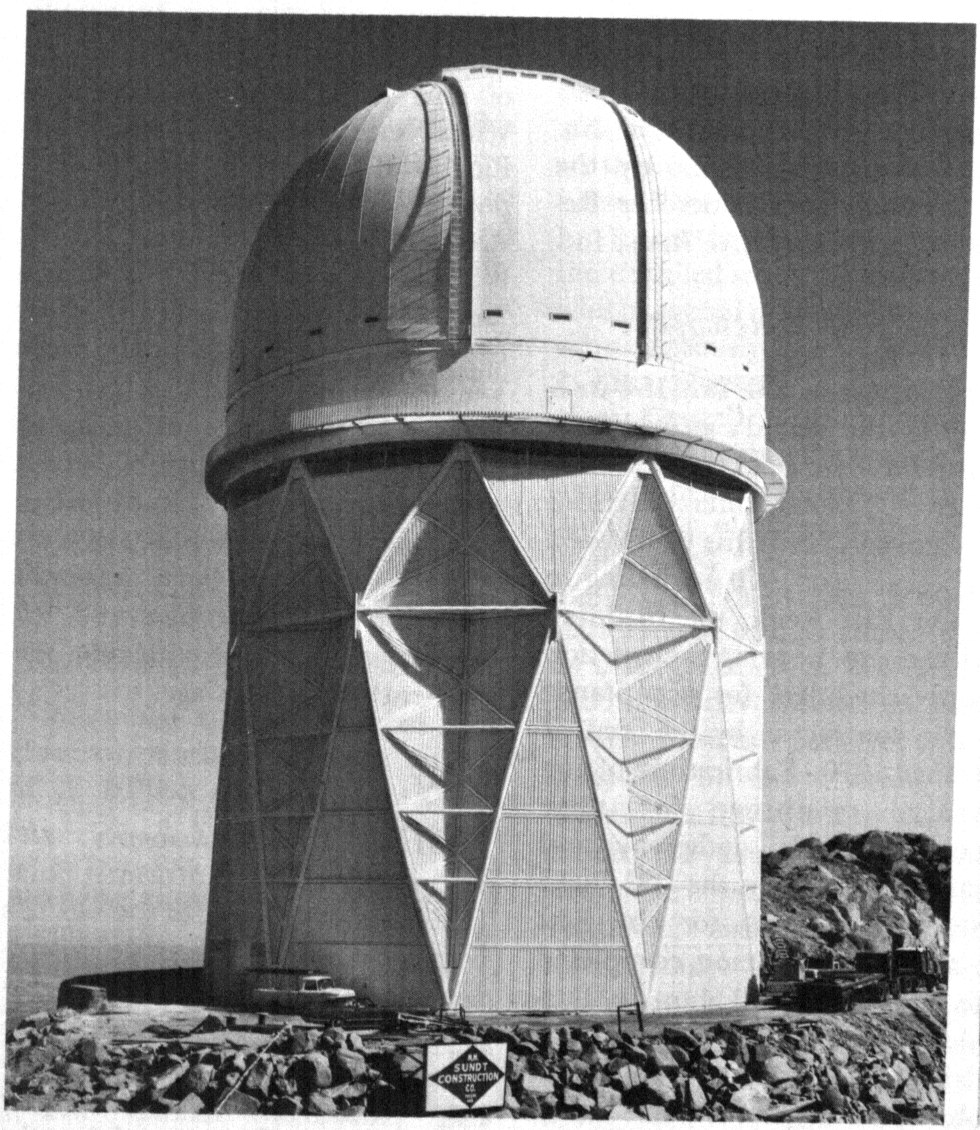
A Harvard University graduate student from Australia detected fluorine in the sun. This is an important observation since it represents the first halogen detected. A search will now be made for chlorine in the farther infrared portion of the spectrum.

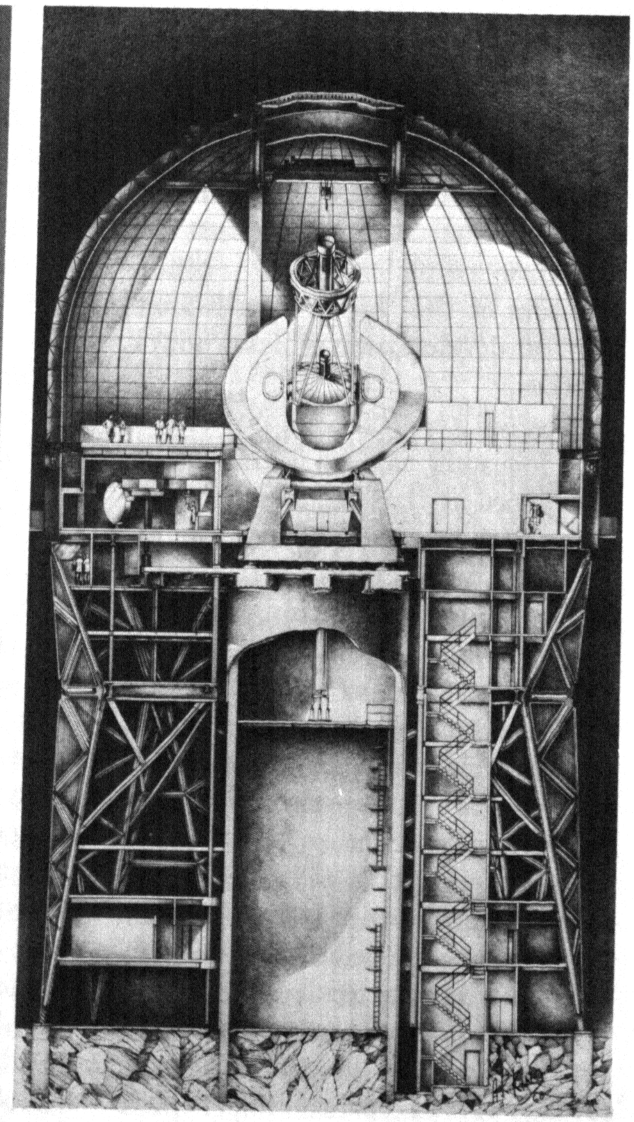
The eclipse of March 7, 1970, was successfully observed by Solar Division staff at instrument sites in southern Mexico and from Kitt Peak.

Planetary Sciences

Although the major emphasis of staff work is on other planetary atmospheres, additional contributions come from a program of terrestrial aeronomy. Investigations included studies of the production and transport of atomic nitrogen and nitric oxide in the upper atmosphere, and the maintenance of the earth's nighttime ionosphere. Related rocket flights have observed the day airglow, and twilight observations from Kitt Peak contribute similar information for certain emissions.

Three Aerobee sounding rockets were launched at White Sands Missile Range, N. Mex. Two of these were successful in returning scientific data on galactic x-rays, spectrometry and photometry of dayglow emissions.



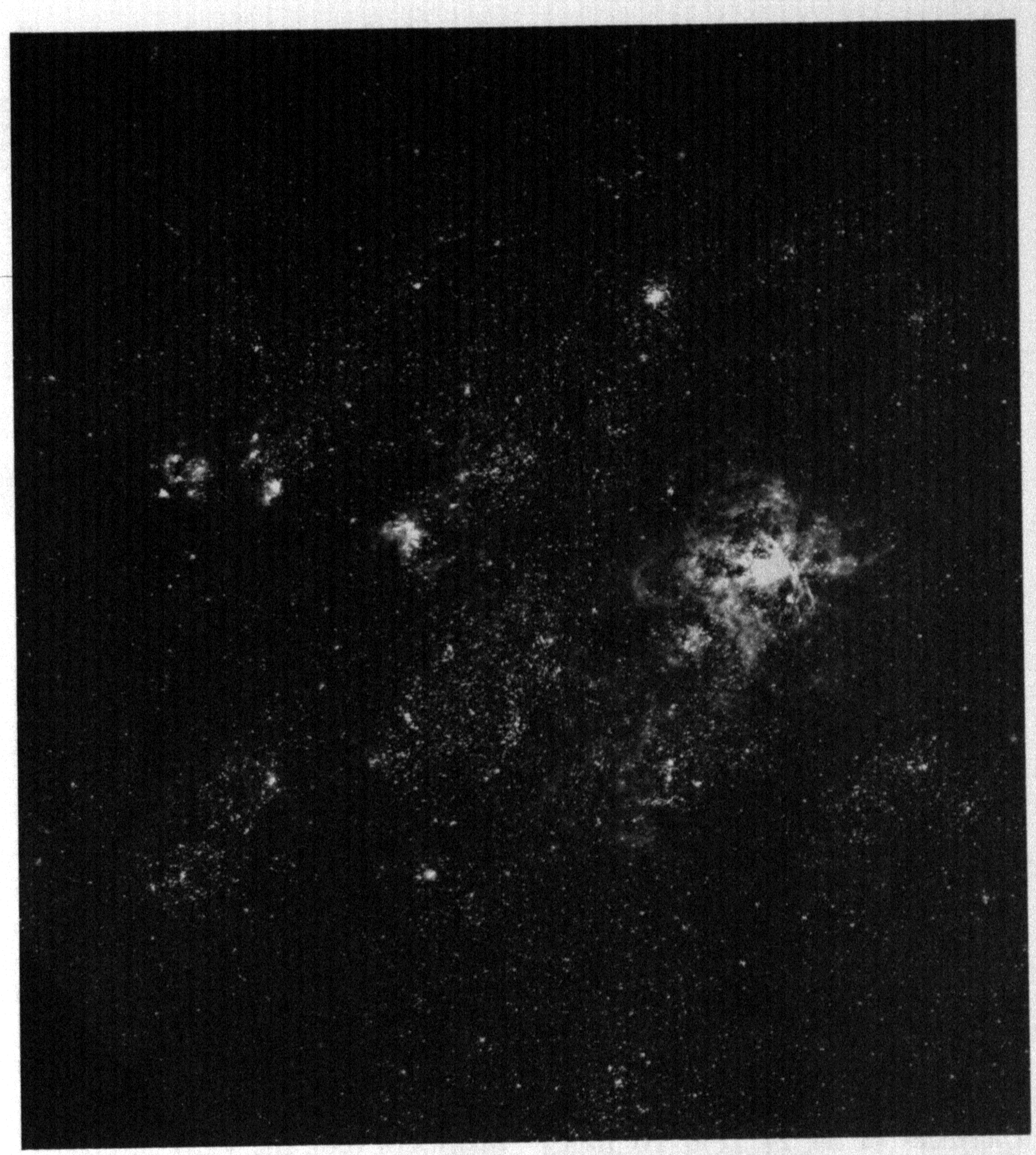


Exterior view (March 17, 1970) and interior cut-away drawing of the 150-inch telescope installation on Kitt Peak. (KPNO photo)

Previous solar rocket spectra of this wavelength region gave questionable photometry, since they were measured piecewise, photographically with different instruments on different rocket flights. Thus, good photometry of this region of the solar spectrum is of particular importance in determining the albedos, the ratio of reflected to incident radiation, of the planets. Although several good UV planetary spectra are available, there is still skepticism that their analysis is satisfactory because of the available solar comparison spectra.

In planetary aeronomy, much of the KPNO work used information from the Mariner and Venera space probes, and from observatory rocket flights by visitors and staff. M. B. McElroy's studies of the thermal structure of CO_2 atmospheres have been fundamental to nearly all recent work on Mars and Venus.

Rocket work, partly by visitors, has produced calibrated ultraviolet spectra of Venus, Mars, and Jupiter. Scattering and absorption by CO_2 dominate the Mars spectrum; for the other two planets it has been shown that scattering by aerosols suspended high in their atmospheres is clearly important.



The Cerro Tololo Inter-American Observatory 60-inch F/7.5 Ritchey-Chrétien reflector was used with a Schulte-designed field corrector to obtain this wide-field photograph (by V. M. Blanco) of the Tarantula nebula in the Large Magellanic Cloud. (Photo CTIO)

Cerro Tololo Inter-American Observatory

The Cerro Tololo Inter-American Observatory (CTIO) was established and is operated in the Republic of Chile by the Association of Universities for Research in Astronomy (AURA), Inc., under contract with the National Science Foundation. At a southern latitude of 30°, CTIO provides astronomers with opportunities to observe scientifically relevant southern sky objects.

The observing facilities are located at an elevation of 7,200 feet on Cerro Tololo in the foothills of the Andean Cordillera. Astronomical observing conditions at Cerro Tololo are superb, as at other nearby sites where other organizations have followed CTIO's example.

CTIO Research Projects

During fiscal year 1970 visitors and staff carried out photometric, spectroscopic, and photographic researches on the moon, planets, asteroids, stars, pulsars, gaseous nebulae, clusters, quasars, and galaxies. For example, T. McCord of the Massachusetts Institute of Technology investigated the optical properties of lunar and planetary surfaces. His observations of the Sea of Tranquility, *Mare Serenitatis,* yield reflectivity properties identical to those found in the Apollo 11 soil samples. M. F. Walker of the University of California at Santa Cruz did a photometric study of faint stars in globular clusters of the Magellanic Clouds. With image tube techniques, he was able to observe stars to visual magnitude 23.7, the faintest so far reached in these nearby galaxies. Finally, an example of the cooperation between CTIO and KPNO is Malcolm

Smith's observation of gaseous nebulae in the Carina region with Kitt Peak's pressure scanning Fabry-Perot interferometer. Dr. Smith's preliminary findings indicate that the great Carina nebula is formed by a single expanding gas cloud, rather than by two or more gaseous bodies in the line of sight.

Facilities

The principal construction effort during fiscal year 1970 was aimed at completion of the building to house the 150-inch telescope. All basic structural work on the building was completed. Fabrication of the telescope mounting is progressing satisfactorily in the United States, and first shipment of mounting parts is expected during fiscal year 1971. The 150-inch mirror blank has been cast, and grinding and polishing will begin as a next step at the KPNO Optical Shop.

Six telescopes were operational throughout the fiscal year. The largest of these is a reflector with a 60-inch aperture, specially designed to be used in a wide variety of investigations. Other telescopes have apertures of 36, 24, and 16 inches (two of the latter) and classical Cassegrain optics. The sixth telescope has Schmidt-type optics with a 24-inch aperture and is on loan from the University of Michigan.

A computer-controlled data acquisition system was developed during fiscal year 1970. The more rapid data collection possible with this system will result in a marked increase in the productivity of the telescopes.

During fiscal year 1970, a total of 69 astronomers and graduate students observed at Cerro Tololo, including 55 visitors from the United States, seven of whom were graduate students. Thirteen of the visitors were from Latin America, principally from Chile and Argentina; these included four graduate students. Altogether, visitors were assigned 68 percent of the total available observing time; the rest was used by the resident staff, KPNO staff, and for maintenance work.

National Radio Astronomy Observatory

The National Radio Astronomy Observatory (NRAO) is a national research facility funded by the National Science Foundation under contract with Associated Universities, Inc. Now in its 14th year of operation as a national center for basic research in radio astronomy, the observatory has two observing sites—Green Bank, W. Va., and Tucson, Ariz.

NRAO Research Projects

Very Long Baseline (VLB) Interferometry

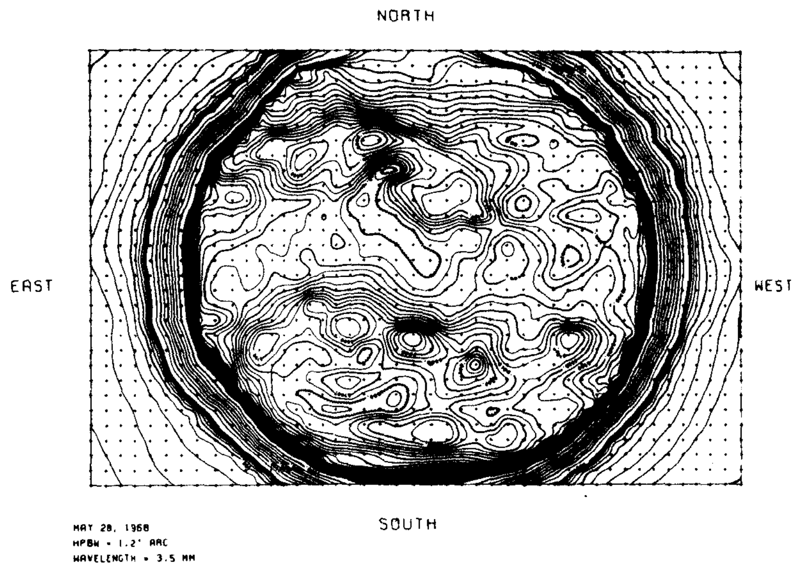
In October 1969, the 140-foot radio telescope in Green Bank was linked together in an intercontinental experiment with a 72-foot radio telescope in the Crimea, U.S.S.R., over 6,000 miles away. For this experiment three NRAO staff members took the VLB equipment into the Soviet Union.

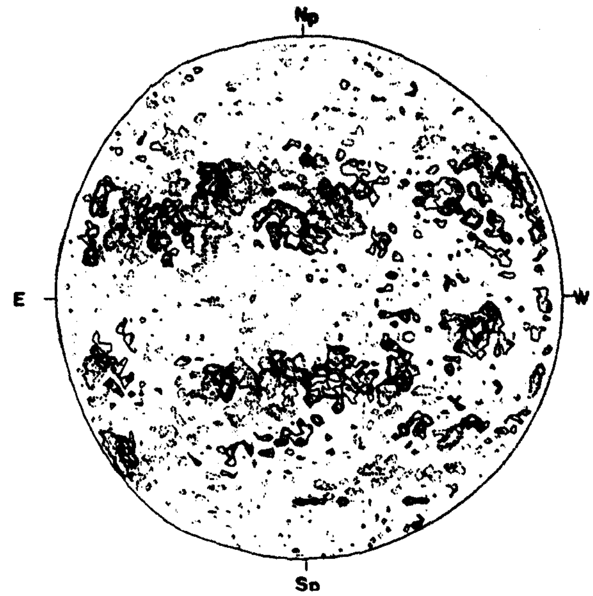
The purpose of the experiment was to observe two dozen quasi-stellar radio sources to determine the angular diameters of the sources and to investigate their fine structure. These radio sources of very small angular size are of great interest because radio sources are apparently born small and expand with increasing age. In order to understand the physical processes associated with the births of strong radio sources, many of which may be located at the edge of the observable universe, it is necessary to know more about their physical properties. From the variations in intensity of many of these sources, it may be inferred that their linear diameters often do not exceed a few light-months and once their angular diameters are measured, their distances can be determined. Then, from observations of their radio spectra, their magnetic field strengths can be calculated.

Discovery of More Interstellar Molecules at NRAO

Following their discovery of the carbon-12 isotope of formaldehyde ($H_2C^{12}O$) in ionized gaseous regions of the Milky Way and in many dark, cool nebulae, David Buhl (NRAO), Lewis E. Snyder (Virginia), Patrick Palmer (Chicago), and Benjamin Zuckerman (Maryland) discovered another concentrated source of formaldehyde containing the carbon-13 isotope, $H_2C^{13}O$, toward the center of the Milky Way and in many of the ionized regions in which the carbon-12 isotope had been found. The normal amount of carbon-13 in our solar system is one atom for every 90 carbon-12 atoms. In our galactic center, however, apparently the ratio is 1 to 10. The investigators believe that the over-abundance of carbon-13 in the center of our galaxy indicates that formation and, later, explosion of massive stars is taking place in our galactic nucleus since large quantities of carbon-13 can be produced in the cores of very massive stars as a by-product of the cycle which converts hydrogen to helium in a stellar interior.

The 36-foot millimeter wave telescope was first used for radio spectrum line work during the spring of 1970. Keith B. Jefferts, Arno A. Penzias, and Robert W. Wilson of the Bell Telephone Laboratories, discovered a radio emission line from carbon monoxide (CO), the sixth atom or molecule to be detected in inter-stellar space, using a receiver built jointly by Bell Laboratories and NRAO. The CO line was seen in the galactic center as well as in a number of other Milky Way sources where other molecules had previously been





The NRAO 36-foot telescope at Kitt Peak was used to record 3.5 mm. contours of the sun. A solar magnetogram is shown at the right for comparison. (NRAO photo)

found. The CO line in the Orion Nebula is exceptionally strong and extends over an angular extent much larger than the nebula itself. The great strength of the CO line shows that the molecule appears in great abundance among many of the stars of our galaxy. The CO line at 115 GHz (2.6-millimeter wavelength) is observable only with a radio telescope that has an extremely precise paraboloidal surface. The 36-foot telescope is the largest such telescope in the world and affords scientists a unique opportunity to pursue the discovery still further. On another telescope run, the same group of scientists discovered a seventh molecule, CN, as well as two other isotopes of carbon monoxide, $C^{12}O^{18}$ and $C^{13}O^{16}$.

Finally, Buhl and Snyder detected an eighth molecule, hydrogen cyanide (HCN) in a number of galactic sources, including the Orion Nebula and the galactic center.

Facilities

The major observatory telescopes include a 300-foot meridian transit telescope that after November 1970 will have a new surface capable of operating down to wavelengths of 10 centimeters; an interferometer which operates at 3- and 11-centimeter wavelengths consisting of three 85-foot telescopes with a portable 42-foot telescope for remote operation; a 140-foot fully steerable telescope that will operate at 1 centimeter wavelength; and a 36-foot millimeter wave telescope that will operate down to wavelengths of 1 millimeter. The 36-foot telescope is located at Kitt Peak, Ariz., while the other systems are located in Green Bank, W. Va.

Each telescope is equipped with an on-line computer for limited analysis of data as they are received. Data are usually recorded on magnetic tape and are later processed in a general-purpose computer.

During the past fiscal year a new traveling feed was installed at the 300-foot transit telescope for use at low frequencies. This new feed moves at the telescope focus in such a way that a radio source can be tracked at transit, trebling the time during which a source can be studied at each meridian passage.

A new dual channel, low noise spectral line receiver was placed in operation at the wavelength of the 18-centimeter OH line which permits any two of the OH lines to be observed simultaneously.

The interferometer was converted during the spring of 1970 to a two-frequency system and is now operated at a 3-centimeter wavelength as well as 11 centimeters. Maps of radio sources may be made at 3 centimeters with a resolution of 2 seconds of arc by aperture synthesis techniques for the study of the detailed structure of astronomical objects.

Computer programs have been completed that enable observers to use the 413-channel autocorrelation receiver to improve baselines and increase the overall efficiency of the receiver. A new antenna measuring instrument has been built and tested that will monitor the shape of an antenna surface using a continuous-wave radar, and promises to be of value in studies of thermal deformations and other surface calibrations of antennas.

Subsequent to the completion of the report "A 300-Foot High Precision Radio Telescope" in June 1969, it was decided to incorporate the principles of homologous design of radio telescopes into a smaller but more precise instrument. In this approach, the defor-

Aerial view of the Arecibo Observatory showing the feed platform (upper center) suspended by cables between three concrete towers 435 feet above the reflector surface. Also shown are the operations, office, and visitors' quarters complex (lower right), and warehouse and maintenance buildings (lower left). (Photo Cornell University)

mation of the telescope due to the pull of gravity, different for different pointings of the instrument, is made use of to bring the reflecting surface to the desired shape to focus the incoming radio beam. A design is being made of a 65-meter (213-foot) diameter, fully steerable paraboloid designed to operate at wavelengths as short as 3 millimeters under stable atmospheric conditions.

Arecibo Observatory

The Arecibo Observatory (AO) located approximately 12 miles south of the city of Arecibo, Puerto Rico, has the largest radio reflector in the world. It was initially constructed with funds supplied to Cornell University by the Advanced Research Projects Agency, Department of Defense. Commencing in October 1969, the National Science Foundation assumed sponsorship of the AO and it was designated a National Research Center with Cornell University continuing to operate and manage the AO. The AO itself provides on-site scientific management and administration, with additional administration and planning conducted by the Arecibo Project Office at the Ithaca campus of Cornell University.

Research Projects

Planetary Radar

The program of detailed mapping of the surface of Venus has begun and the first map is now available. Since the atmosphere of Venus is optically quite impenetrable, radar holds out the best promise of obtaining information about the structure of its surface. The resolution obtainable is only limited by the precision with which the echo power can be analyzed. With an improvement of the AO facilities, one can expect such maps in the future to have a resolution much higher than those now being obtained and therefore to show the nature of the topography of Venus.

Pulsars

In radio astronomy, work on pulsars has been a major occupation at the AO. After the discovery of the pulsar in the Crab Nebula and the further discovery that the frequency of the pulses decreased with time, much more attention has been paid to this object. In addition to giving the hint that the energy source for the high energy particles in that nebula is to be found in the rotational energy of a neutron star, the detailed observations of the Crab Nebula have now given much information about these high density and high energy regions in the universe. Details of the variations in rotation speed of this and other pulsars are carefully recorded, and slight changes in the number of free electrons in the line of sight from us to the pulsars are also measured.

Facilities

The AO makes available to atmospheric physicists and to astronomers a major research instrument which can function either actively as a radar telescope, or passively as a radio telescope.

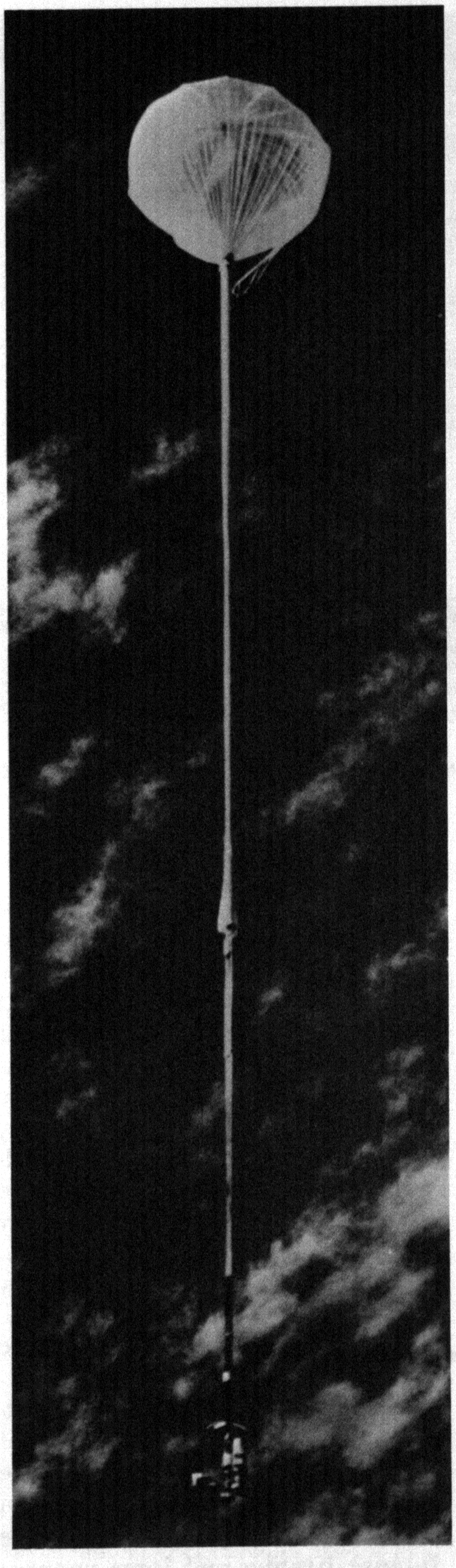
As a radar telescope, the instrument transmits a pulsed signal, and receives that portion of the signal which is reflected back by electrons in the ionosphere, or from the moon, or the planets Mercury, Venus, and Mars. Planetary radar studies at AO have revealed the previously unknown rotations of Mercury and of Venus, as well as giving most precise distances accurate to about 1 kilometer for these planets. Surface properties and topography of the moon and planets can also be investigated, and a beginning is being made to obtain a detailed map of the surface of Venus.

The beam of the antenna—located at a position of 18° north latitude—can be swung over an angle of 20° in any direction from the zenith. About 40 percent of the sky can be surveyed and the sun and the planets can be observed on approximately half the number of days in each year.

The AO is the only operational spherical antenna system in the world. It has shown itself to be relatively cheap to construct, and convenient and versatile in operation. The general development of this type of antenna system will be influenced by the progress made at the AO.

In a spherical antenna many feeds can be used at the same time; thus, AO has a large number of different frequency feeds permanently mounted, and it also has a multibeam system where ten beams can be used simultaneously to speed up a detailed survey of the sky.

During fiscal year 1970, a total of 21 scientific visitors from 12 different organizations utilized the AO facilities. At present, a majority of the telescope operating time is used by graduate students in residence and observatory staff.



At launch, 210-foot main balloon is retained in sheath to prevent "sailing" in the wind. Sheath is ripped by expansion of helium at high altitude. (Photo Princeton University)

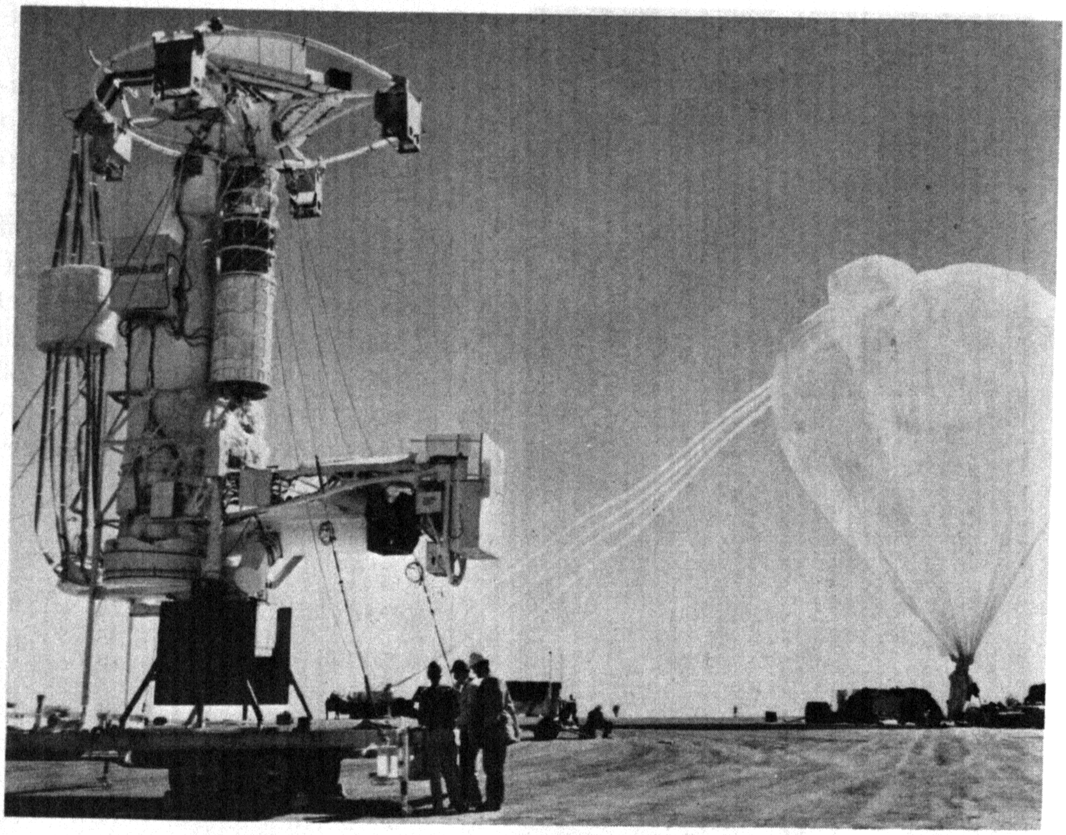
UNIVERSITY RESEARCH

Stratoscope II—The Airborne Observatory

Perhaps the single greatest problem encountered by astronomers using telescopes on the ground is the earth's atmosphere. Turbulence, pollution, and absorption of light at certain wavelengths severely limit the resolution of even the largest and most carefully constructed telescope mirrors.

To a very great extent this difficulty has been overcome for at least one telescope which observes astronomical phenomena while floating at an altitude of 80,000 feet suspended from a giant plastic balloon. The telescope, Stratoscope II, has a 36-inch mirror and, with the use of photographs with guidance and radio command from the ground, is able to obtain a resolution of 0.1 second of arc. This resolution, roughly equivalent to the ability to distinguish between two golf balls 30 inches apart at a distance of 1,000 miles, is close to the theoretical limit for a telescope of this size.

After several flights during the past few years in which technical difficulties hampered astronomical observations, Stratoscope II was successfully launched from the National Scientific Balloon Flight Station in Palestine, Tex., the night of March 26, 1970, under the direction of Martin Schwarzschild and



Airborne 36-inch optical telescope is completely remote-controlled from the ground. (Photo Princeton University)

Robert Danielson of Princeton University. Dr. Schwarzschild has been director of the Stratoscope II project and its predecessor, Stratoscope I, since inception of the latter in 1956. The project is co-sponsored by the National Science Foundation and the National Aeronautics and Space Administration, following initial support by the Office of Naval Research.

During the flight of the night of March 26–27, Stratoscope II obtained photographs of unprecedented sharpness of both the planet Uranus and of the nucleus of a rare Seyfert galaxy. Both sets of photographs will markedly increase the state of our knowledge of the two celestial objects.

A Seyfert galaxy—in this case the one known as NGC 4151, about 30 million light years from the earth—has a very small but extremely bright nucleus characterized by variability in light intensity, emission of radio waves, and a spectrum of broad bright lines produced by extremely hot gases in rapid motion. The sharpness of the Stratoscope II photographs establishes the upper limit of the diameter of the nucleus at about 12 light years. This volume of space in the immediate vicinity of earth contains five stars, including our own sun. In contrast, the same volume in the Seyfert galaxy contains around ten billion stars. One implication of this high density of stars is that there must be collisions between stars on the average of every 4 months, which may account both for the very great brightness and the observed variability of the light from the nucleus, since such high-speed collisions between stars can be expected to produce intense heating and large amounts of radiation.

The photographs of the planet Uranus are the sharpest yet obtained. They reveal none of the surface features of the planet occasionally reported by visual observers, but do reveal the planet as a slightly flattened disk, somewhat less bright around the rim. Measurement of the latter phenomenon, called limb darkening by astronomers, will provide a test of a theory that Uranus—unlike Jupiter and Saturn—has no clouds in its atmosphere. The photographs will be further enhanced by combining several of them by means of an electronic computer, which will compensate for the known optical properties of the telescope. This analysis should conclusively establish whether or not Uranus has surface features.

University Astronomy Research Instruments Program

The erection of the new 120-foot radio telescope at the Vermillion River radio observatory of the University of Illinois was begun on July 9, 1970. The 120-foot steerable reflector is near completion, with the mechanical and electrical components purchased and in a final state of assembly. The radio telescope will be used for sky surveys, continuum mapping, and spectroscopy of the OH molecule. Polarization studies of galactic sources will be possible, and observing time will be available to guest investigators.

A 60-inch optical telescope for the Hale Observatories (Carnegie Institution of Washington) is set to be completed in 1970, and there is auxiliary equipment for modern operation of this telescope on Palomar Mountain in California.

The fiscal year 1970 funds for astronomy facilities and equipment included support of spectrographs for the New Mexico State University and the University of Oregon, a spectrum scanner and a three-element aperture synthesis radio interferometer for the Massachusetts Institute of Technology, modernization of the 150-foot solar telescope of the Carnegie Institution on Mount Wilson, and facilities for photographic plate storage at Swarthmore College.

MATHEMATICS

Technique for Statistical Analysis

In almost all real life situations, there is an element of randomness to the behavior of parts of the system. That is to say that even if all other factors are relatively constant, as for example, a group of people of the same age, sex, ethnic, socioeconomic, and geographical background, some element of chance will enter into their choices, actions, and answers to questions. If this behavior is truly random, and if the sample is large enough, the mathematical laws of statistics describe accurately certain things about the distribution of their actions, i.e., a certain number of the group will behave in a given manner, another number in a different manner. These laws of statistical analysis have proved valuable in making decisions where there is an element of randomness in the selection, evaluation, or compilation of data. Recently, a new method of testing has been developed which should considerably improve the decision process.

Suppose we wish to make a decision (e.g., drug B should be adopted in place of drug A; or a machine should be stopped and adjusted). First we establish a criterion in the form of a hypothesis that drug B is more effective than drug A; or that the items produced by the machine are out of tolerance. An experiment is then designed to select and evaluate samples, and a method of computation of the results established to accept or reject the hypothesis. In practice, the hypothesis and computations are designed so that if the computed average of the samples is positive, the hypothesis is rejected; if it is zero or negative, the hypothesis is accepted. In the design of the experiment, a certain confidence level—a probability that the decision is correct—is prescribed. In all tests in current use, the probability of rejection has a small value when the computed sample average is close to zero. The probability of rejection approaches a certainty when the computed sample average gets very large. This means if the average is positive but small, the probability of rejection will be close to the prescribed confidence level. However, there is no way of testing the hypothesis at a given confidence level which can take into account the possibility of future observations. Thus, for example, if we repeatedly test a hypothesis at a given confidence level with fresh sets of data from the same process, we are sure to reject it due to the cumulative effects of errors in the data and the continuity of the computation method for the probability of rejection.

Herbert Robbins, at Columbia University, has developed a theory of testing which is of a radically different nature. His procedure starts in the traditional manner, but he has a new method of computing the probability of rejection in such a way that rejection will be certain for every computed sample average greater than zero, while the probability of rejection for any average not greater than zero will be less than the (small) probability for a zero average. The heart of this new technique lies in finding a sequence of numbers with certain mathematical properties and such that the probability that a zero average will be rejected is less than the given confidence level. Such sequences have been known to exist, but it has not previously been possible to evaluate the probability that a zero average would be rejected, and thereby permit testing at a given level of confidence.

To illustrate the advantages of this new method, consider the following example. A machine produces an item which must be within certain tolerances. Samples are drawn to test the hypothesis that the machine is working properly. Assume that the machine works perfectly forever. Under any tests currently in use, the machine will be stopped once every hundred tests, say, because the hypothesis is rejected. Under the tests developed by Robbins, there is only a probability of one in one hundred that the machine would *ever* be stopped.

The new method has a wide range of applications in such fields as quality control, drug testing, etc., and will possess considerable advantages over current methods in other important practical problems.

BIOLOGICAL AND MEDICAL SCIENCES

During fiscal year 1970, the effects of reorientation and cutbacks in the support of research in the life sciences by other agencies of the Executive Branch have become apparent in proposals to the NSF. At the same time, the number of proposals which were successful in obtaining NSF grants in biology dropped from 1,173 in fiscal year 1969 to 1,072 in fiscal year 1970.

More proposals have been received from investigators who were previously supported by the National Institutes of Health, the Office of Naval Research, the Air Force, Army, and the Atomic Energy Commission. Since the number of grants which NSF will be able to make in 1971 will not be substantially larger than in 1970, it is anticipated that the fraction of proposals which it will be possible to fund will drop substantially below the figure of 50 percent which has prevailed in the past few years. The next few years will clearly be a time when the National Science

Foundation should maintain the maximum flexibility in deploying its funds in order to be able to respond to a changing pattern of support by other agencies.

In spite of the current difficulties and the uncertainty about the long-term future, biologists are excited about the strides their science has made in the last few years, and a variety of new fields and approaches which are clearly ripe for further exploration. Within the biological programs of the Foundation, it is planned to place further emphasis on environmental research. Major increases in ecological research will occur within the International Biological Program (IBP), bringing the desert, deciduous forest, and coniferous forest biome studies to a fully operational level, and initiating an integrated research project on the evolution of ecosystems. Both within the IBP and in other programs, increased attention will be given to the biological control of populations. Some of this research will be directed toward improved understanding of the factors which operate generally to influence the balance between different species of plants and animals, while other research will be designed to promote particularly promising approaches to the biological control of pests of particular economic importance.

Other planned programmatic efforts include an increased emphasis on psychobiology and neurobiology, reproductive biology, the molecular biology of the human cell; and the development of an improved base of support for resource centers such as museum collections, genetic stock centers, and controlled environment laboratories.

These initiatives on the part of the Foundation are matched by counterpart trends within the scientific community. The "invisible college" centered on a given problem area is not new to biology, but an increased willingness to formalize such arrangements is appearing. One example is provided by the organization of the Integrated Research Projects of the International Biological Program. Another example is provided by the formal organization of systematic biologists with the objective of producing a Flora of North America and at the same time cooperating in the development of a computer-assisted system for handling taxonomic data of this type. A more recent grouping has emerged among molecular biologists who are proposing to coordinate their efforts in order to make an effective attack upon the problems of the molecular biology of the human cell.

The prospects in psychobiology and neurobiology seem particularly exciting because it now appears to be possible to approach problems of learning, memory, behavior, and perception at the level of mechanisms. The techniques for measuring parameters of behavior have been greatly refined, recording of electrical events can be made from highly localized regions in the central nervous system, the mapping of functional regions and pathways has progressed to a very substantial extent, and tools are available for examining the chemical basis of structure and function. The identification of sensory pathways and events has opened the exciting possibility of direct stimulation of the central nervous system with the electrical output of a sensory prosthesis—an artificial sense organ. Although recognized as possible in a speculative sense for many years, such an undertaking is now clearly possible with predictable improvements in our understanding of the functional anatomy of the central nervous system and the normal electrical output of sense organs. Thus, by substituting an artificial sensor, coupled appropriately with the central nervous system, it will be possible to restore some degree of sight to the blind or hearing to the deaf.

At the molecular level, we can now anticipate a developing understanding of the chemical basis of learning and memory, and the basis of chemical effects on behavior. Many such chemical effects have been identified as a part of the normal regulatory processes of behavior and as desired or undesired effects of drugs, but we do not yet understand the mechanisms by which these chemical effects are mediated. There is, for example, no understanding of the mechanisms responsible for drug addiction or dependence, and until these mechanisms are understood, there is no hope of dealing in an effective way with this frightfully expensive social problem.

Remote sensing techniques have been applied by ecologists for studies of the distribution of animals and plants as rapidly as they have had access to this technology. There is great interest in the expansion, improvement, and increased access to these techniques because it is clear that they will be essential to effective ecological studies of any substantial magnitude, as well as to improved wildlife management, forestry, and agriculture — when coupled with the required fundamental research.

Finally, although the National Science Foundation cannot propose to greatly expand support of tropical biology in the near future, we wish to recognize the necessity of continuing with the modest investment in this area. Aside from the inherent interest of the rich flora and fauna of the tropics to biologists, the tropics also represent the greatest undeveloped potential for food production. The use of extensive monocultures, which has been so effective in the temperate zones, has been less effective or actually disasterous in tropical agriculture.

Insights currently being developed into the differences between tropical and temperate ecology suggest the possibility of using multicultural farming methods in the tropics—the technique of raising several food crops simultaneously on the same plot of ground. Perhaps in this way, food production may be greatly increased without inviting ecological catastrophe in tropical areas.

INTERNATIONAL BIOLOGICAL PROGRAM

The International Biological Program (IBP) has as its worldwide theme "The Biological Basis of Productivity and Human Welfare." U.S. participation in this international program has taken the form of multi-investigator integrated research projects dealing with two of the important topics facing mankind in a world of burgeoning population—scientific management of biological resources and human adaptation to the stresses of the physical environment.

Rational use of the environment requires a better understanding of how ecosystems operate. Such an understanding has long been sought by individual investigators probing important aspects of plant and animal ecology. The new dimension added by IBP is the integrated attack on complex ecological systems by teams of investigators representing a variety of disciplines and, often, many institutions. Each investigator pursues his own specialty, but shares his data with scientists in neighboring fields. The objective is to achieve a fuller understanding of the processes and rates of nutrient cycling, water movement, energy flow, and population dynamics in natural and man-dominated ecosystems than can be obtained by individual investigators working alone. This additional knowledge is essential if man is to cope adequately with the twin challenges of producing enough food and fiber to feed a hungry world and of maintaining and enhancing the quality of the environment.

The problem is being attacked through intensive studies of ecosystems in four distinct life zones, or biomes: deciduous forest, coniferous forest, grassland, desert. The intensive study of the Grassland Biome moved from the planning and preparatory stage into full operation during the year; expanded field research in the Desert Biome began in May 1970. Planning was completed for the other biome studies, and they are expected to begin operations during fiscal year 1971.

In addition to the biome studies, IBP includes a wide range of other environmental research. An integrated research program in biological control of insect pests began during the year under the direction of Carl Huffaker of the University of California at Berkeley. Emphasis will be put on natural factors regulating key groups of insects, with the aim of learning how to maintain pest populations at noneconomic densities in such a manner as to optimize cost-benefit relations and to minimize environmental degradation. Collaborative research is being undertaken in the ecology of upwelling areas, which comprise only about 1 percent of the sea surface but are responsible for the productivity of perhaps half of the world's fisheries. Comparative studies of upwelling in the Pacific off Peru and in the eastern Mediterranean are in progress.

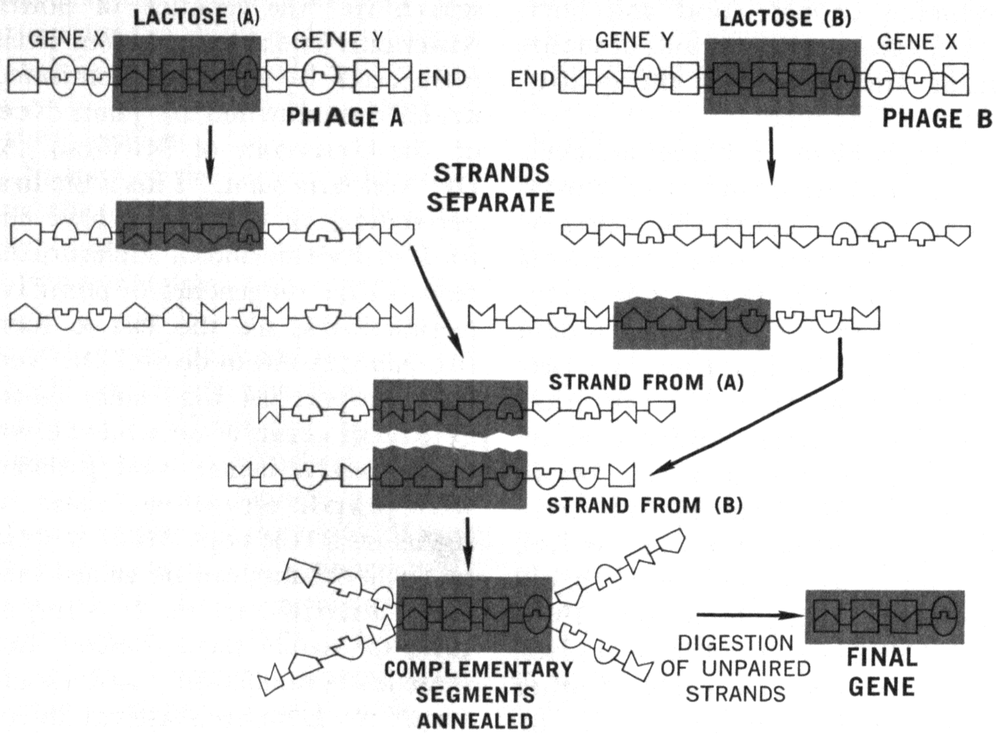
The human adaptability component of IBP has developed more slowly than the ecosystem research. A collaborative research effort involving anthropologists, archeologists, geologists, and marine and terrestrial ecologists was begun to study the adaptations of Aleut Indians to the changing conditions of the Bering Sea land bridge during and since the Pleistocene. Research in the genetics of South American Indian populations little influenced by Europeans continued under the direction of James Neel of the University of Michigan. As Dr. Neel has put it, "This is the first generation of scientists to have the tools to do this kind of sophisticated research in the genetics of primitive populations, and the last to have the opportunity to do so." Dr. Neel has pointed out that since man's genetic diversity arose while he was living as a hunter and gatherer with simple agriculture, many insights into the population genetics of civilized man can be gained only from primitive tribes. It is important to study them before their genetic constitution and social structure have been altered by extensive contact with other populations.

Molecular Biology

Two of the most exciting achievements of the year arose from studies on the molecular biology of the gene. A chemist, starting with simple molecules, and a geneticist starting with living cells accomplished in principle the same result. The end product of their respective experiments was, in tangible form, a single gene.

In the fall of the year, Jonathan Beckwith and his co-workers at Harvard Medical School reported the successful isolation of a gene from the bacterium *Escherichia coli*. More recently, H. Gobind Khorana (recipient of the 1968 Nobel prize for his contributions to unraveling the genetic code) and his colleagues at the University of Wisconsin synthesized a gene from elementary chemical units. In essence, the two groups exploited the chemical properties of DNA, the genetic material to achieve their goals (but from opposite starting points).

The Watson-Crick model of DNA is a long molecule consisting of two intertwined "strands" held toegther



In the Beckwith isolation of a single gene, DNA from two different bacteriophages is uncoiled, and single molecular strands from the two sources mixed. The complementary sections of the two strands which together make up the lactose region are annealed and the unpaired strands digested enzymatically to leave only this region. The diagram is highly schematic.

throughout their length by specific pairs of chemical units, the nucleotide bases. The sequence of these units in one strand defines the chemical code for a given gene. Because of chemical considerations, the sequence of bases on one strand dictates the sequence of bases in the opposite strand. With careful manipulation, the two strands of intact molecules of DNA can be separated. If separated strands are mixed and placed under conditions which allow accurate reassociation, a strand finds its complementary partner and reforms a normal two-stranded DNA molecule.

In essence, Dr. Beckwith and coworkers performed surgery on the genetic material of the bacteria using a bacteriophage (virus which infects bacteria) to dissect out and carry the bacterial gene to the experimenters' test tube. Upon infection of bacterial cells, certain types of phage are capable of exising small pieces of the host cell's DNA, incorporating it into their own genetic material. As the phage multiplies, this DNA is replicated together with the phage DNA.

Specifically, the Harvard investigators used two different phages, both of which are known to carry in their chromosomes different bacterial genes and a single region —common to both—that participates in the metabolism of the sugar lactose. The principal difference between the two types of phage—and this is the key to the success of the experiments—is that in one type the bacterial DNA is incorporated into the phage DNA in a left to right direction while in the second type the bacterial DNA is inverted by being incorporated into the phage DNA in a right to left direction.

The experiments performed by the Harvard investigators consisted of extracting the DNA of the two types of phage separately and treating each DNA preparation so that each of the double-stranded molecules uncoiled, permitting the strands to separate. They then brought one strand of DNA from each type of phage together under conditions in which reassociation could occur thereby restoring the double-stranded state of complementary DNA chains. Since the region of the DNA strands representing the bacterial lactose gene was the only opposite mirror image or complementary region, only this part of the mixed chains came together immediately to form double-stranded DNA. The neighboring DNA segments remained dangling as single strands and were digested by an enzyme that degrades single-stranded DNA. This resulted in a preparation of purified bacterial DNA segments that represented only the lactose gene.

Dr. Khorana's synthetic assembly of a gene also depended on the complementarity of DNA strands, but his experimental approach was quite different and involved an additional property of DNA. The information encoded in DNA is used as a template and transcribed by living cells into a chemically related class of molecues, RNA. The RNA molecules are also complementary to the strand of DNA transcribed, so if the sequence of bases in the RNA is known, one can deduce the sequence of bases in the template DNA strand. Given the sequence of one DNA strand, it is possible to predict the composition of the complementary partner strand by the base-pairing rule.

Several years ago, Khorana began experiments starting with alanine transfer-RNA from yeast. The sequence of the 77 nucleotides in the RNA was known from the work of Robert Holley (see NSF Annual Report, 1969), and it was a simple enough matter to visualize the expected sequence of the 154 paired nucleotides in the corresponding segment of DNA which constituted the gene that codes for the transfer-RNA.

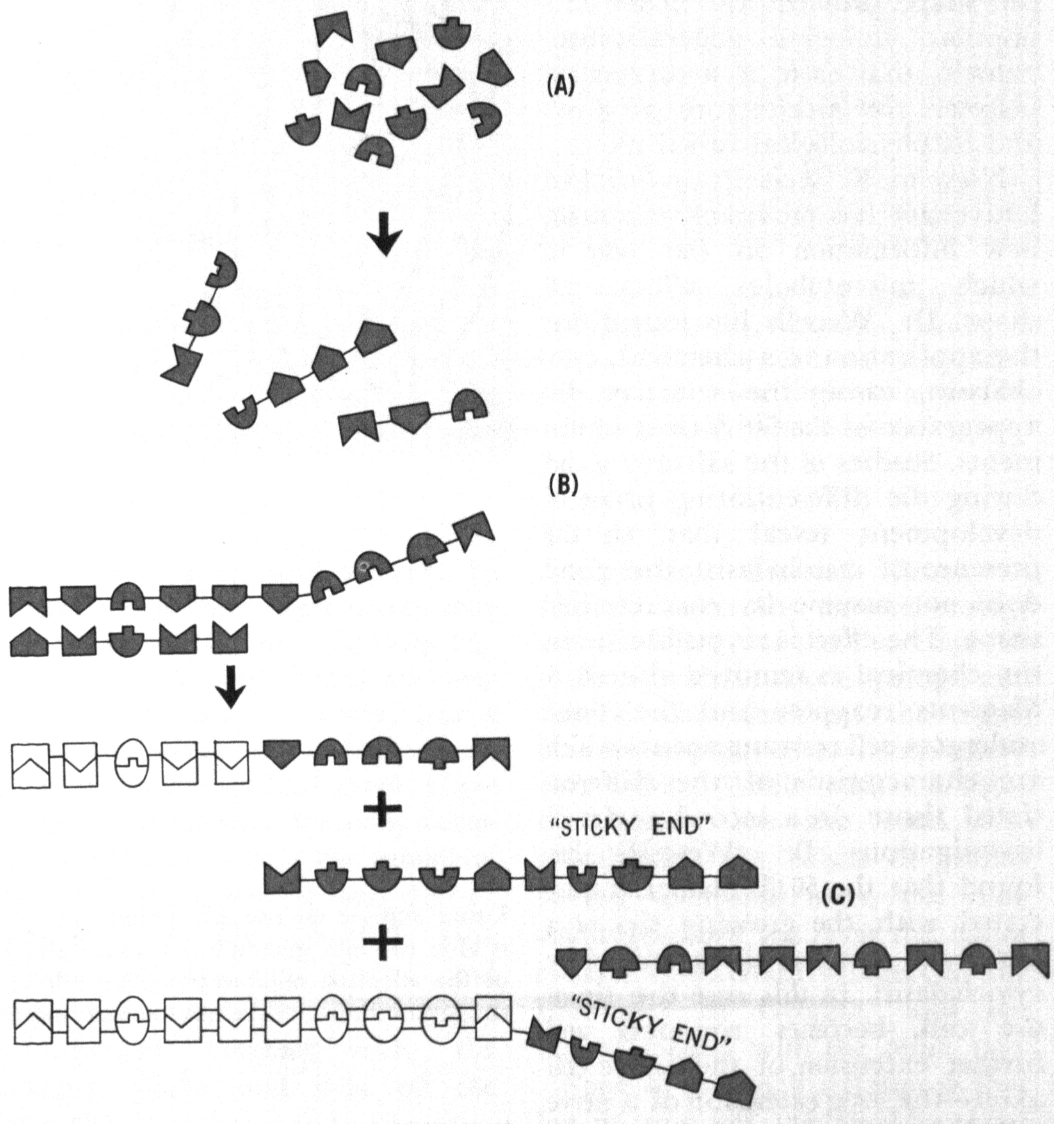
To achieve the synthesis of this segment of DNA, however, was far from simple. Starting with the simple chemical building blocks, Khorana synthesized short lengths of strands of correct sequence, and for each such sequence, produced a strand of partial complementarity. This partial complementarity was crucial to the success of the experiment. Pairing of the short strands produced a DNA segment with a two-stranded middle portion where the base sequences were complementary and at each end an unpaired strand remained. Enough of these partially two-stranded pieces of DNA were synthesized to mimic the entire sequence of the nucleotides in the gene. Thus, when pieces that occurred in consecutive order were mixed, a single strand of one complemented a single strand of the other. By mixing the pieces in successive order, pairing between the overlapping ends produced progressively longer two-stranded segments. After base-pairing had ordered the short segments of DNA, an enzyme was used to form the chemical linkage between adjacent ends, resulting, finally, in the intact synthetic gene for alanine transfer-RNA.

It remains to be shown that these isolated genes can be reinserted into a cell and express their chemical information. However, these successes provide biologists with techniques to allow the test tube study of gene action to proceed at a highly sophisticated level. It becomes possible to imagine that we shall soon have considerable new biochemical information on how genes are regulated in living cells.

Microtubules

In the last 20 years, the view of the cell as an undifferentiated bit of protoplasm containing a few specialized microscopic organelles has given way to a picture of a highly structured system whose parts are intricately interdependent. Improved techniques such as microsurgery and better observational instrumentation such as the electron microscope have enabled biologists to see and work directly with the components.

The study of one such type of structural component has bloomed so rapidly that "microtubule biology" might now be called a subdiscipline of biology. This area of work deals with a variety of filament-like structures which have a seemingly ubiquitous distribution in cells. These structures are assemblies of macromolecules and have been named on the basis of their diameters: the largest, greater than 200 Ångstrom (Å) units, are called microtubules; the next sizes, simply "100 Å filaments" and "50 Å filaments." (An Ångstrom unit is equal to about four one-billionths of an inch.)

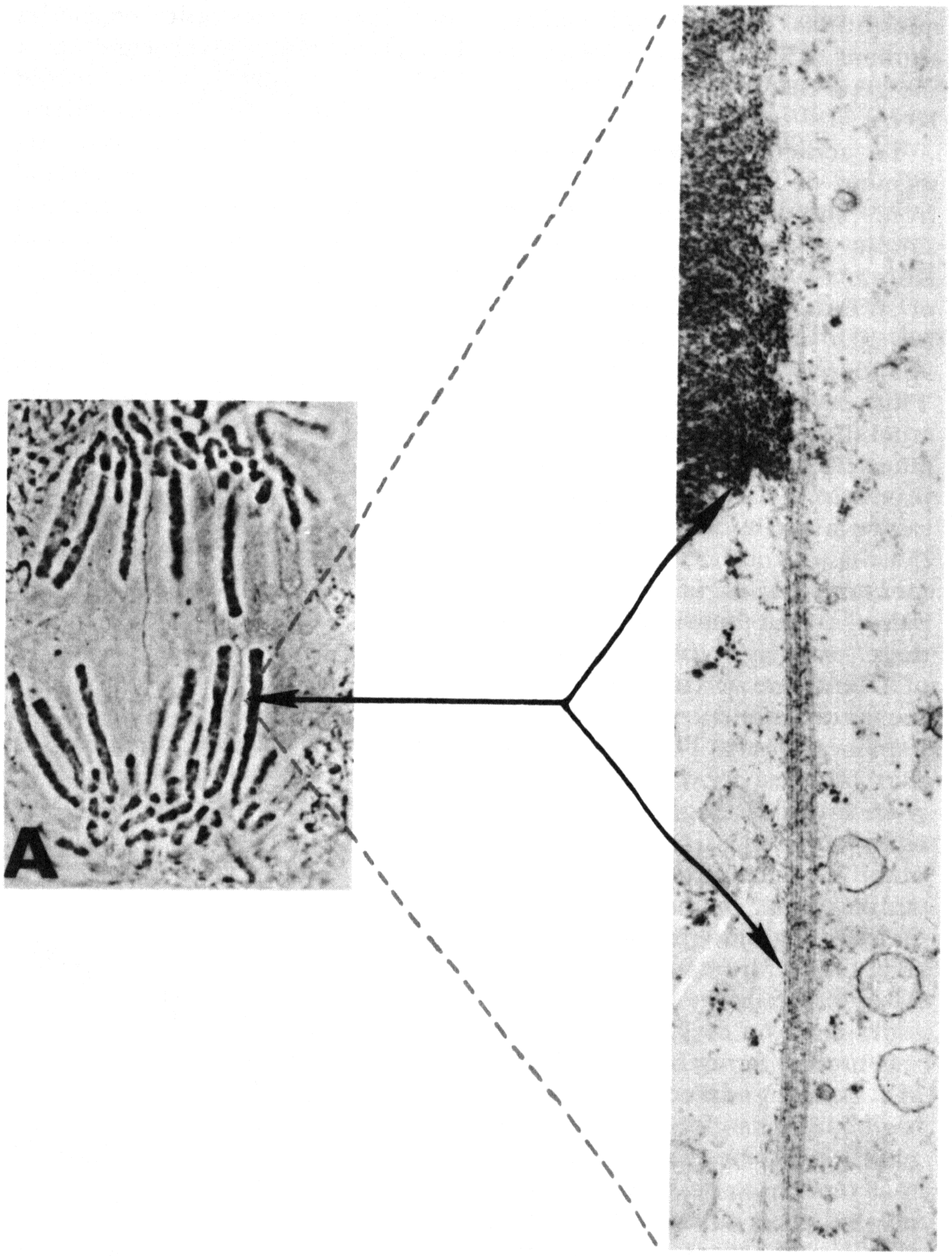


Starting with individual nucleotides (A) Dr. Khorana synthesized short lengths of nucleotide chains (B). Using complementary base pairing, he annealed part of a longer chain to a short chain, leaving a "sticky end" to which to anneal a third short length, again leaving a "sticky end" and so on (C). The overlapping produced progressively longer two-stranded segments which were enzymatically linked to form the complete gene of 77 nucleotide pairs. The diagram in this case is intended to show regions of double-stranded DNA as open symbols and those fragments not yet base-paired as darker symbols.

The filaments are of special interest because of their probable role in influencing the shape and movement of living cells either in migration or displacement of cells from one location to another or in movement of materials within cells.

The problem of cell shape has tantalized biologists for many years. How a definitive cell shape is acquired is a central question in differentiation, the event in embryonic development which, generally, is the time when a cell attains its characteristic adult function. The cell shape problem also bears on a popular biological generalization; namely, that there is a correlation between the architecture of a cell and its physiological function.

Norman K. Wessells at Stanford University has provided important new information on the way in which microtubules affect cell shape. Dr. Wessells has found that the application of a chemical, cytochalasin, causes the selective disappearance of the 50 Å class of filaments. Studies of the salivary gland, during the differentiating phase of development reveal that in the presence of cytochalasin, the gland does not assume its characteristic shape. The effect is reversible; when the chemical is removed the 50 Å filaments reappear and the tissue undergoes cell rearrangements which are characteristic of the differentiated tissue. In a second series of investigations Dr. Wessells has found that the 50 Å filaments associated with the growing tip of a nerve cell are also disorganized by cytochalasin. In this case the tip of the cell becomes rounded and further extension of the nerve cell axon—the long extension of a nerve cell that conducts nervous impulses away from the cell body—is inhibited. Interestingly enough, the microtubules in the axon of the nerve cell remain intact and except for the tip, the cell retains its characteristic shape. If a second chemical, colchicine, a drug used in the treatment of gout, is applied simultaneously with cytochalasin to the nerve culture, the microtubules also become disorganized and the entire cell becomes rounded.



Using refined microscopic techniques, Dr. Andrew Bajer at the University of Oregon is able to trace microtubules from the light microscope level to the fine structure level of the electron microscope. (The cell shown is *Haemanthus,* the African blood lily; the arrow indicates the microtubule and associated (darker) chromosomes.)

Howard Holtzer at the University of Pennsylvania has found that application of cytochalasin also inhibits division of the cytoplasm of cells. In each of the foregoing examples, the 50 Å filaments appear to have a functional association with the cell membrane, yet in each case the biological event affected is unique to the given cell type.

The understanding and control

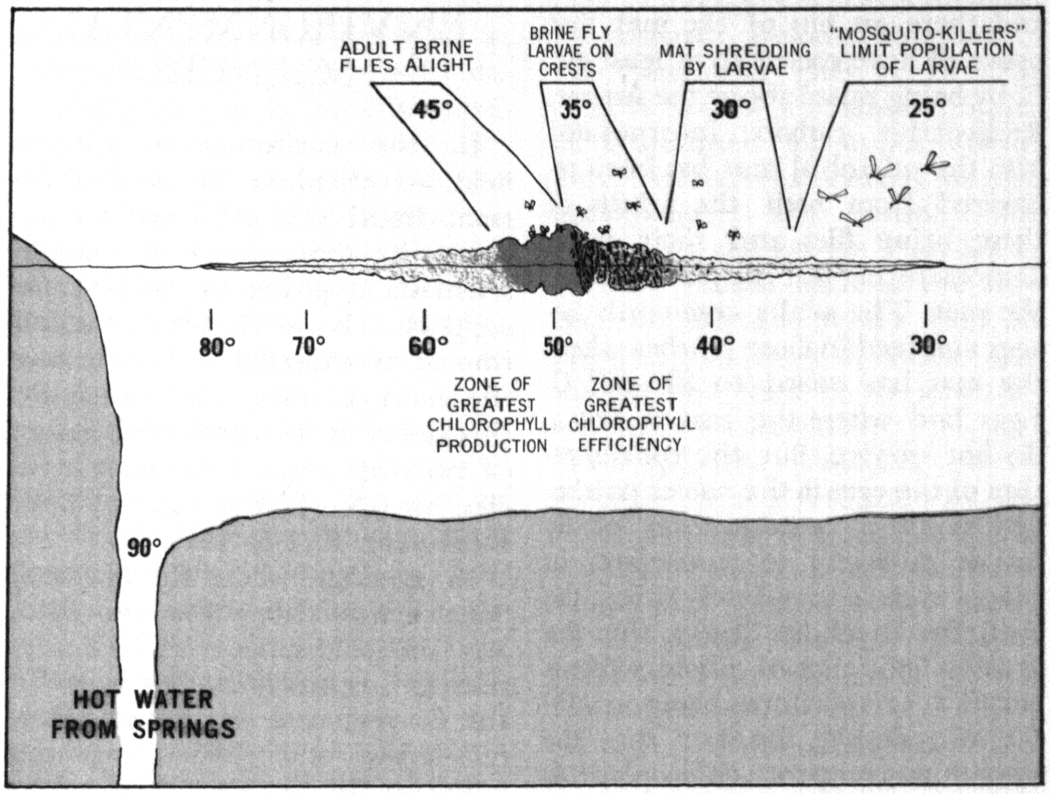
over the development and movement of cells gives the biologist a profound and important tool for further advances in embryology and perhaps, in the far future, presents possibilities for directing the regeneration of damaged tissues and even organs.

Ecological Gradients

In disentangling the complex net of relationships in natural ecological systems, the techniques of controlled manipulation, so common in laboratory science, have so far been extensively used only in lakes and ponds where manipulation of the fish stocks can modify the composition and functioning of the entire ecosystem.

A generally more useful strategy for the ecologist pursuing terrestrial studies has been to analyze the properties of the system whenever it is disposed along a measurable gradient, a change in some value per unit of distance in a specified direction, in the physical environment. The addition or removal of a single species population wherever its limit of tolerance is reached can cause a modification in the entire system. Should this happen, the nature and extent of the modification suggests the ecological role which that species plays within the system.

The marked gradient in water temperatures within hot springs such as those of Yellowstone Park provides opportunity for employing this strategy in the understanding not only the ecophysiology—organic processes specifically related to adaptation to a particular environment—of the thermophilic or "heat loving" organisms inhabiting the hot springs but also the community dynamics of the limited life forms of this environment in which most freshwater organisms would perish. The water is hottest where it issues



Temperature gradient extends both downstream from hot spring and upwards from water surface as algae-bacterial mat cools. Perforation of mat by grazing larvae increases efficiency of photosynthesis, so maximum growth occurs at lower temperature than that of maximum production of chlorophyll. At still lower temperature, population of brine fly larvae is limited by predators. Vertical scale in the diagram has been exaggerated to show detail.

from its underground source. In some springs the hottest water may be above 90° C.; only certain filamentous and unicellular bacteria can exist in such hot water, just a few degrees below the boiling point. But photosynthetic blue-green algae mixed with bacteria flourish, forming thick mats, where the temperatures range between 50° and 75° C. These mats are colorful — the browns, yellows, rich greens, and blue-greens where blue-green algae predominate contrast with the oranges, pinks, and reds of the bacteria.

Richard Castenholz of the University of Oregon has been extending his field studies of the blue-green algae by examining the growth of these simple plants under controlled laboratory conditions simulating those of the field. The research of Thomas Brock of Indiana University on the ecology and physiology of the thermophilic bacteria of Yellowstone springs, and that of Castenholz on the algae, have been planned to complement each other. While each of these investigators has also been concerned with the effects of grazers on the microbial mats, the community ecology has been the major concern of Richard Wiegert of the University of Georgia, who has worked closely with the other two.

None of the small arthropods that live in and on the algal-bacterial mat—ostracods (small freshwater crustaceans), mites, and flies—occur where the temperature is over 50° C. In the Yellowstone springs, the most common animal seen on the mats is a brine fly, the adults of which can be seen alighting here and there on bits of the mat that prove to have cooled to at least 45° C. by being raised above the surface. Radioactive carbon incorporated into the microbial mat has been recovered from both the adults of these brine flies and their larva, demonstrating that they do consume the mat. The adults commonly lay eggs and feed in those patches where the mat has cooled to 30°–40° C. Eggs laid where the mat is hotter do not survive. But the concentration of the eggs in the cooler patches results in a concentration of fly larvae sufficient to corrugate, in places even to completely shred, the mat. Dr. Brock has shown that the greatest efficiency of photosynthesis occurs at temperatures between 40°–50° C., despite the fact that the maximum crop of chlorophyll is produced between 50°–60° C. He believes that the greater efficiency at the lower temperature range is due to the grazers' perforation of the still cooler (30°–40° C.) part of the mat above the water surface. These perforations promote circulation of the nutrient-laden water and, in part, help the mat to maintain its integrity in spite of patchy grazing.

At a lower temperature level on the thermal gradient where the microbial mat grows less well, it is often saved from excessive consumption by brine fly larvae because these grazers are subject to predation by another species of fly, one that becomes a conspicuous member of the community where the mat becomes cooler and the brine fly larvae more numerous. This dolichopodid (literally, "long-legged" fly), locally known as a mosquito killer, by eating the eggs and larvae of the brine fly, stabilizes the community by controlling the excessive development of the population of these insect grazers which might otherwise destroy the energy-fixing basis of the system.

ENVIRONMENTAL SCIENCES

In the environmental sciences field, as elsewhere in the Foundation, fiscal year 1970 saw an upswing in the number of research scientists applying to the NSF for support. Also, as elsewhere, the full impact is expected to be felt over the next 2 years. The reason for this delay is the continuing nature of existing grants from other agencies, which will not run out until fiscal year 1971 or 1972.

In geology, where the National Science Foundation has been virtually the sole support of university research, retrenchment elsewhere in the Government was not so deeply felt—most other Federal agencies with an interest in field geology have in-house capability. In other areas, however, requests for support were up 50 percent over the previous year. It should be noted that new requests in all fields were of the same or higher caliber as the previous year.

In spite of handicaps, the fields dealing with the environment have made substantial gains during the past year, and clear lines of possible advance for the future were identified.

In the atmospheric sciences, there has been a definite trend towards working on physical rather than statistical concepts of weather phenomena, particularly through the process of comparing predictions from theoretically derived models to actual results, and using the results of this comparison to improve the model. Meteorologists are investigating methods of monitoring effluents on a national and global basis. The subfield of atmospheric chemistry has been very active in devoting its attention to pollution-related research.

In weather modification, a major program is being launched to learn how to mitigate the destructive hailstorms of the Great Plains. Scientists are also interested in learning more about warm fogs and warm clouds in general. Methods of producing precipitation from cold clouds and dissipating cold fogs are well known, and many techniques are operational and in commercial use. This is not true of those warm clouds where the water content is above the dew point.

The earth sciences are moving ahead rapidly in organic geochemistry, a relatively new field, and in seismology. Many aspects of the earth sciences are rapidly being pulled together by the unifying concepts of global tectonics—the theory of continental drift and sea-floor spreading. The resounding successes to date of the Ocean Sediment Coring Program have added to the mounting evidence in support of this theory and also to our knowledge of the geology of dry land.

There is a growing awareness on the part of urban planners of the importance of input from the earth sciences in planning for the most beneficial and efficient use of land for our new cities. It is estimated that by the year 2000, tens of billions of dollars worth of new engineering structures will be built in areas of known earthquake activity. Knowledge of the local geology applied to the siting and engineering of these structures could result in reducing earthquake losses by up to 50 percent.

New experimental techniques are becoming available which permit subjecting materials to high temperatures at pressures—accurate to within 1 percent—of up to 150 kilobars (150 times atmospheric pressure —about 1,000 tons per square inch). These temperatures and pressures are equivalent to those deep in the earth's crust which cause the metamorphosis of minerals to various crystalline rock formations. The technique has been developed for geological experimentation but should have profound impact on research and possible synthesis of new "mineral-like" materials of exceptional properties.

In oceanography, new techniques are coming to the fore such as a systems approach using theoretical models, particularly through the use of on-board computers which simultaneously record and operate on multiple sources of data. Oceanographers see the results of their experience with their traditional integrated team approaches to research producing even better results and affecting the methodology of scientists in a variety of other fields. New techniques for measuring the physical parameters of the ocean are continuously being developed and tested.

POLAR PROGRAMS

Fundamental to the National Science Foundation role in polar activities was the assignment to it in fiscal year 1970 of the responsibility for the development of a national Arctic Research Program and for the coordination of the research activities among the several Federal agencies having an interest in Arctic research. The Office of Antarctic Programs was redesignated the Office of Polar Programs to handle the new responsibility. The second half of the year was devoted to an assessment of current arctic work and the development of a long-range plan. The Arctic Research Program will focus on seven areas: polar pack ice, the delicately balanced tundra ecosystem, perennial ground ice, glaciology, the active polar geomagnetic field, the geological structure underlying the area, and the complex interrelations between man and his activities and the arctic environment.

The unpredictability of antarctic weather was forcefully demonstrated at the opening of the last austral season when unusually heavy deposits of snow were dumped at McMurdo Station, completely deranging plans for the orderly movement of the parties into the field.

The highlight of the season was the discovery in the Transantarctic Mountains of a large number of tetrapod fossils confirming the evidence for the theory of drifting continents and the existence of Gondwanaland, the hypothetical ancestral supercontinent that broke up to form the land masses we know today. Coalsack Bluff, the site of the discovery, is by far the most productive fossil locality in Antarctica discovered so far, and undoubtedly will be the focus of further paleontological investigations.

The oceanographic program suffered two setbacks during the season: the first was the inability, as a result of very heavy sea ice, to recover the current buoys emplaced in the Weddell Sea in 1967–68, the second was the damage suffered by the Argentine icebreaker, *San Martin,* which prevented her from joining the icebreaker, *Glacier,* in the International Weddell Sea Oceanographic Expedition 1970.

At Byrd Station the cable suspending the drill in the deep borehole had to be cut when recovery of the drill bit which stuck in the 1968–69 season proved to be impossible. The entrapped atmosphere of past ages was taken from the upper section of the hole as well as from other drill holes at the station for radio-carbon dating and for assessing changes in atmospheric composition since the Great Ice Age.

In the 1969–70 season, 65 individual field projects were carried out by 193 scientists and technicians representing 47 institutions and Government bureaus. The geographic range of the projects was widespread over West Antarctica. Three U.S. exchange scientists accompanied foreign expenditions while 14 foreign scientists joined the U.S. Antarctic Research Program.

In November 1969 at 75°55′S. 83°55′W. a new U.S. station, Siple, was established for upper atmospheric research particularly on the plasmapause. The station was named after the late Dr. Paul Siple, who first gained fame as the Boy Scout on Admiral Byrd's 1928–30 expedition to Little America, and who devoted most of his scientific career to the Antarctic.

Ionospheric rockets were launched for the first time by the United States at Byrd Station to obtain information on particle bombardment, geomagnetic effects and ionospheric structure. Balloon launchings were also made for the same purpose.

The R/V *Hero* completed its second year of activity in the Antarctic Peninsula and southern South America areas. Logistic support was provided by *Hero* for cooperative projects in biology and geology with Chilean and Argentine scientists during the course of the year. The USNS *Eltanin* continued her circumnavigation of Antarctica with multidisciplinary cruises in the Pacific and Indian Ocean areas.

U.S. Antarctic Research Projects

Antarctic Vertebrate Fossils

One of the most significant scientific events during 1970 was the discovery of fossils of land-dwelling amphibians and reptiles in central Antarctica, in rocks of Triassic age. This fossil deposit was found by David Elliott of the Ohio State University and Edwin Colbert of the Museum of Northern Arizona. The fossil locality is in cross-bedded sandstones of the Beacon Formation at Coalsack Bluff in the central Transantarctic Mountains. Several of the fossil types, particularly the reptilian genus *Lystrosaurus,* are especially characteristic of the lowest Triassic period in South Africa. *Lystrosaurus* and several of the other fossil types, including genera of the amphibian group, Labyrinthodont, are key fossils for this particular period throughout the ancient supercontinent of Gondwanaland. The presence of the same genera of land-dwelling and freshwater-dwelling amphibians and reptiles in various parts of Gondwanaland, and in particular, in Antarctica, which is so widely separated from any other continent by deep ocean basins, would seem to definitely indicate the former existence of Gondwanaland as a single continent, made up of all or major parts of present Antarctica, Africa, South America, India, and Australia. Gondwanaland broke up and the fragments drifted apart subsequent to Triassic time, and some of this continental drift seems still to be underway.

Productivity of Antarctic Waters

The study of the productivity of the Antarctic waters could have profound significance with regard to the world's food supply. It is well known that the food chain in the Antarctic waters is simple and direct. Baleen whales thrive mainly on a shrimp-like organism named krill *(Euphausia superba)*, which also furnishes food for a vast host of animals, including winged marine birds as well as penguins, crabeater seals, squid, and fish. These krill are in turn supported by phytoplankton, free-floating microscopic marine plants. Thus, the productivity of these waters resides primarily in the food-building activities of these minute plants.

In studying food chain relationships in the Antarctic ecosystem, it is imperative to know the amount of carbon fixed annually by the marine phytoplankton. Based on the extensive observations made in the Atlantic and Pacific sectors of the Antarctic during the past 5 years, Sayed El-Sayed calculated the annual production of the Antarctic waters as 3.03×10^9 tons of carbon. This estimate does not take into account the amount of organic production in the pack ice region—a region which fluctuates between 10 million square miles (in late winter) and 1 to 2 million square miles (in late summer). Recent investigations on the productivity of the water in the pack ice regions, using icebreakers, suggest that it is much higher than hitherto suspected. The enormous bloom of phytoplankton off the Filchner Ice Shelf (in the southeast Weddell Sea) encountered during the International Weddell Sea Oceanographic Expedition (February 1968), seems to bear this out. Dr. El-Sayed's primary productivity studies in the Antarctic underscore the striking differences between the productivity of the oceanic (offshore) and neritic (inshore) regions. This had led to the conclusion that the proverbial richness of the Antarctic waters is true only with regard to coastal and inshore regions, but not with regard to the oceanic regions.

ATMOSPHERIC SCIENCES

National Center for Atmospheric Research

The breadth of activity at the National Center for Atmospheric Research (NCAR) allows scientists from diverse disciplines to join in attacking complex atmospheric problems. Interdisciplinary study and combined observational techniques are necessary to deal with atmospheric processes whose dimensions vary widely and escape definition from a single viewpoint. During fiscal year 1970 NCAR concentrated much effort on theoretical research and on the development of measuring systems to deal with atmospheric problems on scales appropriate to their complexity.

NCAR continues to be involved in activities to attract students into the atmospheric sciences and to include visiting scientists in its research activities. Predoctoral and postdoctoral fellowships are offered to scientists from the United States and abroad, and nine NCAR scientists serve as affiliate or adjoint professors in university research and teaching. The Research Aviation and Computing Facilities hold work study programs to teach students practical research skills. Each summer the Advanced Study Program sponsors a colloquium to explore some topic related to atmospheric science—in 1970 the topic was microphysics and dynamics of convective clouds.

NCAR is sponsored by the NSF and operated by the University Corporation for Atmospheric Research (UCAR), a nonprofit consortium of 27 universities which have graduate programs in the atmospheric sciences. The principal laboratory is at Boulder, Colo.

Research on the Atmospheres of the Earth and Sun

Global Modeling. — Numerical simulation of atmospheric motions and weather behavior has progressed steadily at NCAR to include an increasing number of interacting processes. A new method for treating the effects of mountain ranges on large-scale flow patterns has added realism to the diagnosis of high and low pressure areas. Expansion of the model to six vertical layers has allowed closer study of motions in the lower stratosphere, and has improved the simulation of tropospheric motions by depicting, for example, the separation of the westerly and polar jets. The model is used with observational data for studying short-term weather processes, and for exploration of special problems such as the influence of southern hemisphere meteorological data on weather predictability in the northern hemisphere.

Progress in modeling oceanic circulation continued in preparation for developing a combined atmosphere-ocean model applicable to studies of climate change. NCAR ocean models now include the main features of the North and South Pacific ocean flow, the Antarctic circumpolar current, and the effects of ocean bottom topography. During the summer of 1969, NCAR held a symposium on physical oceanography to gain a unified view of recent research trends in a field that has grown increasingly specialized.

Tropical Convection.—The tropics often develop massive downdraft systems which bring cool, dry air to lower levels and cause sharp contrasts in temperature and dewpoint; warm updrafts in turn accelerate the rate of heat and water vapor transfer from sea to air. Studies of tropical disturbances, using satellite and conventional data, showed that the water and energy budgets of updraft and downdraft cycles closely resemble those of a Midwest squall line about 300 kilometers in length; further exploration of these parallels can thus reveal important details about the transfer of energy through deep layers of the tropical atmosphere.

Turbulence.—Accurate measurement of turbulent air motions whose wavelengths are larger than 1 or 2 kilometers was for the first time made possible by an airborne system developed jointly by NCAR and the University of Nevada Desert Research Institute. Installed on NCAR's Buffalo aircraft, the system can measure air velocity to an accuracy of 10 centimeters per second for the duration of a flight. External sensors measure angles between the airstream and the aircraft, true airspeed, and temperature; an inertially stabilized reference platform is coupled to the sensors and continuously measures the velocity and orientation of the aircraft. The system has already been used in two research programs.

External ducts on NCAR Sabreliner jet aircraft bring air samples to the filter and impaction collectors located inside the cabin. Measurement and analysis of particulate matter in the atmosphere is necessary to characterize the global distribution of natural trace constituents and manmade pollutants. (NCAR photo)

Theoretical studies of turbulence have shown that in some important respects the large-scale atmosphere behaves like a two-dimensional rather than a three-dimensional fluid. Two-dimensional turbulence theory therefore allows simpler but no less rigorous exploration of many of the atmosphere's characteristics. One of its important applications has been the investigation of how errors grow in predictions of the flow field, a topic crucial to assessing the general limits on long-term atmospheric predictability.

Atmospheric Chemistry.—Ground-based laser equipment

Cloud physics investigators at NCAR fly in and around mountain wave clouds to study basic cloud processes. Wave clouds are convenient natural laboratories because they remain stationary but continuously lose and replenish their moisture content. During the winter of 1969–1970 investigators from NCAR flew missions at several altitudes to study clear-air turbulence associated with mountain waves. (NCAR photo)

and aircraft sampling devices were used to study the stratospheric sulfate layer which lies over most of the earth at an altitude of about 18 kilometers. Some investigators have questioned whether the layer is predominantly sulfate, and various sources have been suggested to account for particulate accumulation at such a high altitude. Airborne sampling, carried out in cooperation with the USAF Air Weather Service, verified that most particles consist of sulfate, and that most are formed in the stratosphere by oxidation of sulfur dioxide gas from manmade sources and volcanoes.

In addition to collecting and analyzing air samples over several continental and maritime regions, NCAR chemists completed a detailed study of the trace chemistry of moist tropical air in Panama. A primary objective of the study was to determine the amounts and variability of constituents in the atmospheric nitrogen and sulfur cycles, and their correlation with meteorological conditions.

Wave Cloud Experiment. — NCAR studies of the processes that lead to precipitation from convective clouds require broad application of theoretical, field, and laboratory research, including investigation of nonconvective clouds. A series of flight operations has demonstrated that mountain wave (lenticular) clouds can serve as steady-state cloud "laboratories" for a variety of aerosol and cloud physics experiments. Lenticular clouds form at the peaks of large waves that frequently develop when strong winds blow across mountain barriers. These clouds remain at relatively stable positions but lose moisture on their downwind sides and are replenished on their upwind sides. Air operations have shown that prolonged flights in and around these isolated clouds are feasible. Release of chemical vapors from aircraft on the upwind side was found to retard the rate of droplet evaporation on the downward side. This technique provides a tracer for investigating cloud droplet migration; it has also given support to the theory that surface impurities may affect droplet lifetimes.

Granules.—Granules on the surface of the sun's visible disk are frequently thought to represent convection cells flowing upward at their bright centers and horizontally outward away from their centers. To determine the average flow pattern within a granule, NCAR investigators devised a new technique of "velocity-grams" averaged for 1,100 observed granules which yielded a picture of the flow pattern accurate within 20 meters per second, and allowed separation of the vertical and horizontal motions of material. Upflow had been established observationally before, but the existence of outflow has now been clearly established for the first time. Maximum upflow velocity was found to be 0.5 kilometer per second, and maximum outflow velocity 0.3 kilometer per second.

Facilities Operations

The Scientific Balloon Facility conducted theoretical and experimental studies of balloon design, flight dynamics, and inflation and deployment systems. Eighty large superpressure balloons were launched for university and Government scientists in support of astronomy and physics programs.

The Computing Facility published the first of four atlas volumes on the climatology of the southern hemisphere, and added to its computer-assembled set of microfilm analyses and grids. A 26-minute computer-generated film derived from the atlas was made available for purchase or loan.

The Field Observing Facility supported numerous field programs during fiscal year 1970; the largest of these were the High Altitude Observatory eclipse expedition to Mexico in March 1970, and Colorado State University's VIMHEX field operation in Venezuela from May to October 1969. Both involved logistics support and field management.

Extensive testing by staff of the Global Atmospheric Measurement Program (GAMP) at its Christchurch, New Zealand, flight station showed that constant-level balloons are capable of flying for longer than 6 months in the stratosphere above 100 millibars (53,000 feet) to measure large-scale circulation patterns. Nine constant-level balloons were flown from Ascension Island in the equatorial Atlantic in preparation for testing a balloon-satellite location system.

A paper mill at Port Angeles, Wash. (far left), is emitting cloud condensation nuclei and water vapor into the air. Effluent from the mill fills the river valley in the center of the picture for many miles. Regions adjacent to paper mills in Washington State have been found to have exceptionally high rainfall in recent years. (Photo Alistair B. Fraser, University of Washington)

WEATHER MODIFICATION

Unintentional Modification of the Weather

The effect of man's activities upon the weather is receiving increasing attention following the observations that rainfall patterns appear to have changed in the wake of large urban and industrial development. The University of Illinois has started a search of climatological records of eight urban and industrial areas to determine whether changes similar to those discovered at La Porte, Ind., and St. Louis, Mo., have occurred. The University of Washington has conducted a series of aircraft measurements using nuclei counters, and has determined that paper mills and other industrial plants are prolific sources of cloud condensation nuclei. Clouds are often observed to form downwind of these industrial sources and particles large enough to fall as rain appear to form readily in them. A comparison of precipitation and stream flow records in the State of Washington for the period 1929–46 with those for 1947–66 has shown that areas in the vicinity of these large industrial sources of cloud condensation nuclei have experienced a mean annual precipitation during the second period which is 33 percent greater than that during the first period. However, the inference that the precipitation increase is a direct consequence of industrial development requires further study.

Hail

Although hail can occur anywhere, it achieves its most dramatic—and most destructive—form over the great farming plateau of the Great Plains. During the summer months, hot air formation over the mountains in the late afternoon frequently combines with abundant moisture at high altitudes to produce the towering white convective clouds commonly called thunderheads. From these, tons of hailstones can come slashing down to rip leaves off growing corn in Nebraska, and to beat the heads off harvest-ready grain in the Dakotas. One hailstorm in Rapid City, S. Dak., on July 10, 1969, caused over $2 million in property damage alone.

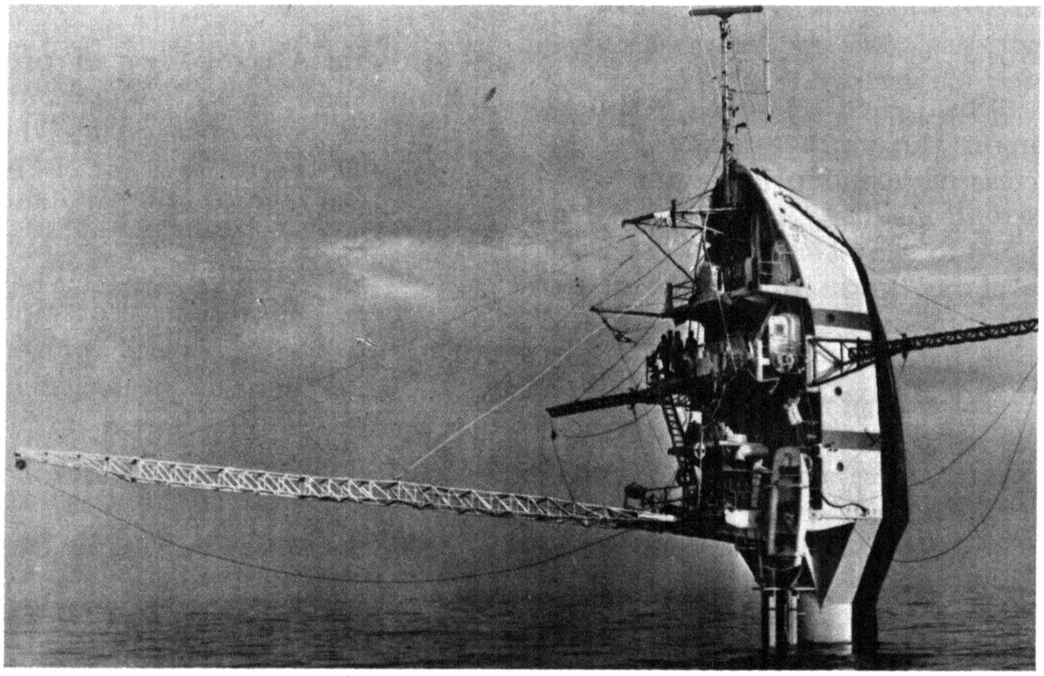
During 1970, the Foundation established the National Hail Research Experiment in northeastern Colorado under the field management of the National Center for Atmospheric Research (NCAR). This experiment is designed to provide a coordinated and intensive study of hailstorms which occur over the Great Plains of Colorado in order to determine how the hail-forming mechanisms of severe storms may be modified to reduce hail damage on the ground. The field phase of the experiment will begin in the summer of 1972 with the cooperative participation of the Departments of Commerce, Agriculture, Interior, Defense, and Transportation, the National Aeronautics and Space Administration, and the Atomic Energy Commission. Support has been provided to the South Dakota School of Mines and Technology, the University of Wyoming, and Colorado State University to provide specialized aircraft measurements of the convective cloud systems, and a unique dual wave radar—which can differentiate between water and ice—is being developed jointly by the University of Illinois for detecting the presence of hail and estimating the liquid water content of the storm. Measurements on hailstorms in the vicinity of Rapid City, S. Dak., by the South Dakota School of Mines have resulted in a mathematical model of a typical Great Plains hailstorm 15 miles wide, and 10 miles high, which ingests approximately 5 million tons of water vapor per hour from the surrounding atmosphere. The updrafts at the center of these large hail-bearing clouds have been estimated to reach velocities between 30 to 100 miles per hour. The National Hail Research Experiment will consult such mathematical models to estimate the proper time and place for the injection of silver iodide into the storm to limit the growth to harmless size hailstones. The critical areas of the storm will be seeded by rockets fired by jet aircraft which will be accurately positioned by ground and airborne radar. Rocket delivery systems are presently being developed and tested by the Colorado State University and NCAR.

Public Acceptance

Regardless of the state of readiness of technology for modifying the weather, its eventual employment for social and economic benefit must consider public opinion. The Foundation has requested the University of Colorado to find out what rural Americans think about plans to conduct weather modification experiments to produce more rain or snow in the areas where they live. Sociological researchers from the University of Colorado have carried out studies of this and related questions in such areas of the United States as western New York, Montana, and Utah. Most citizens believed that, in general, scientific experimentation was beneficial to mankind. This view seemed to carry over to the consideration of weather modification experiments. By the end of the experiment, only 9 percent of these rural residents were opposed to local weather modification experiments.

Global Atmospheric Research Program

The Global Atmospheric Research Program (GARP) is an international program designed to study the transient behavior of the atmosphere and the factors that determine the statistical properties of the atmosphere's general circulation. Oceanographic and Meteorological Experiment (BOMEX) was carried out from May 1-July 31, 1969, in the Atlantic Ocean east of Barbados. BOMEX was a field experiment designed to explore the interactions at the air-sea interface and above, which govern the transfer of momentum, heat, and water vapor between the tropical ocean and the atmosphere. In 1970 the total Foundation support for GARP from research funds was approximately $1.5 million. These funds supported studies on several aspects of GARP, including analysis and interpretation of data observed during BOMEX.



Floating Instrument Package (FLIP) was made available for BOMEX by the U.S. Navy and Scripps Institution of Oceanography. FLIP, which looks like part of a ship attached to a long tube, is 355 feet long and weighs 600 tons. The platform has no motor power of its own but is towed in horizontal position to the site where it is to be used. The crew then floods the ballast tanks that make up 85 percent of her length, and as the tanks fill the 50-foot prow section lifts abruptly from the ocean surface. (BOMEX photo)

Analysis of BOMEX data has proceeded throughout the past year culminating in scientific reports that have been given by a number of investigators at two symposia devoted to BOMEX results, one at the University of Washington, Seattle, one at the American Geophysical Union meeting in Washington, D.C. Several other meetings of specialists have also been held.

GARP has as one of its operational goals the improvement of long-range weather forecasting through numerical prediction methods that use inputs and data from field experiments such as BOMEX. One of the less complex models of the general circulation of the atmosphere was that developed by Yale Mintz and Akio Arakawa of the University of California at Los Angeles. Their model has been used by other scientists such as Robert Jastrow of the Goddard Institute for Space Sciences in New York City and Jules Charney of the Massachusetts Institute of Technology to investigate effects on the dynamics when simple parameters are changed.

In March 1970 a planning conference on GARP was held in Brussels. It was the consensus of that conference that an experiment to investigate the atmospheric energy cycle in the tropical atmosphere and, in particular the convection in cloud clusters, should be planned in the eastern Atlantic for the fall of 1974.

At least eight nations will take part using up to 24 ships, aircraft, balloons, buoys, and satellites as measurement platforms.

METEOROLOGY

Weather Predictions

A major goal of meteorological research is to improve short-term prediction of local or regional weather. This involves not only the gathering and presentation of data from which forecasts can be made but also the analysis and interpretation of the data.

Generally nowadays, the structure of the atmosphere is represented in pressure coordinates and the analysis of its motions are conducted in these terms. At the University of Wisconsin, Donald Johnson and Frank Sechrist are reviving the idea of representing the atmosphere in terms of its entropy, a thermodynamic variable related to the energy content of a weather system, so as to understand better how storm systems form, develop, and decay.

From an analytic point of view this results in a more vivid representation, in three dimensions, of the evolution of the atmospheric structure. From a diagnostic point of view the result is to reveal simpler relationships between the variables which govern the dynamical processes. This technique is well suited to the type of data provided by satellites, as well as the formulation of equations and relationships which describe the transport of mass, momentum, angular momentum, and energy in the atmosphere.

The University of Wisconsin team has demonstrated the advantages of this technique by a case study of the role of the strong upper-level wind known as the polar jet stream in triggering a line of severe storms—a squall line —and in the development of a cyclone in April 1968. While satellite pictures indicated the proximity of the polar jet to the severe weather, it was through the analysis of equations cast in terms of entropy that the conditions for squall line formation were clarified and the role of the polar jet was established. Such a role was never noted using the conventional pressure coordinate system for analysis because the interactions of the dynamic components of the weather system were then not so clearly delineated.

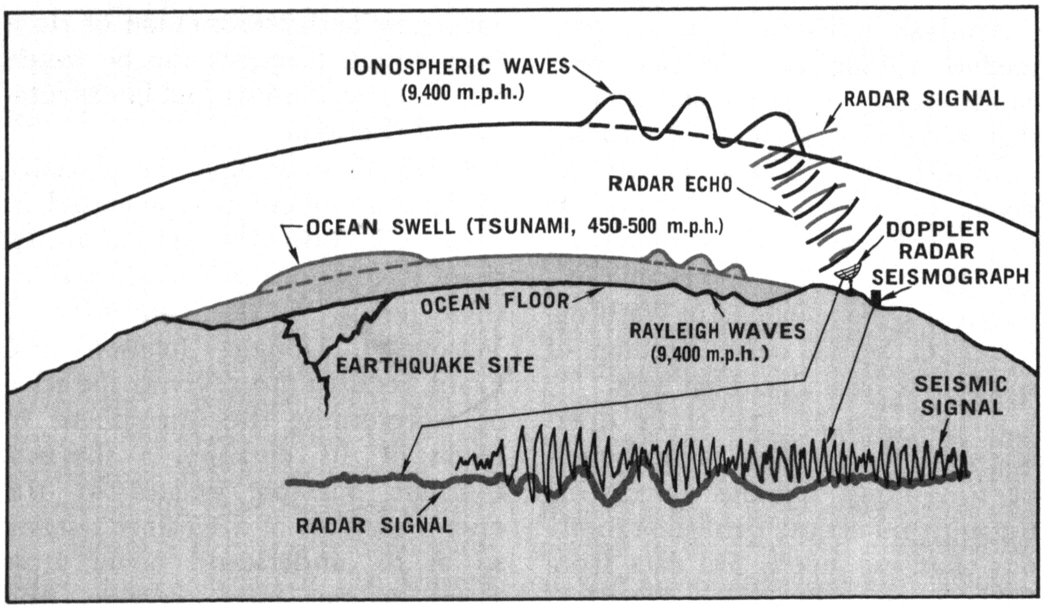
How much data does a meteorologist need to make a forecast? The economically important answer to this question depends in part on the physical conditions of the atmosphere, the skill of the meteorologist, and possibly by the way in which the data are handled. The latter variable was the object of a study at the University of Michigan undertaken by Edward Epstein, Allan Murphy, and Glenn Trapp in collaboration with staff members of the Department of Psychology.

Two alternative forecasting systems were tested on experienced weather forecasters who were presented with sequences of weather information taken from historical records. In one system known as POP (Posterior Odds Processing) which represents the forecasting system in use at present, a forecaster interprets the data directly, in the customary manner, and forms a subjective judgment, for example, about the probability of precipitation. In the other system called PIP (Probabilistic Information Processing) the forecaster interprets the data by assigning levels of significance or diagnostic impact to the information he has, and then the computer is used to make an objective forecast using mathematical decision theory. The hypothesis being tested by comparison of the results of applying both systems is that forecasters working intuitively without the aid of computer products tend to be conservative and require more data before making judgments.

The preliminary results of a pilot experiment indicate that forecasters using the PIP system may indeed require fewer data, but may not necessarily produce more accurate forecasts. A more definitive statement about the PIP and POP systems must await the completion of the analyses of the results of the experiment as well as the results of experiments conducted at the Detroit Metropolitan Airport in a truly operational setting. Studies such as that being conducted at the University of Michigan emphasize the broad role meteorological research plays in increasing our understanding, measurement, and prediction capability of atmospheric processes which affect our whole environment.

Aeronomy

Earthquakes and the Ionosphere



Rayleigh waves generated by submarine earthquake propagate along sea floor and are transmitted acoustically to sea surface and ionosphere. Rate of travel of these waves is around 9,400 m.p.h., while tsunami travels at about 450–500 m.p.h. Doppler radar signals, damped by atmosphere, show only major motions, in comparison to more complex seismic signal. (Tsunami damage occurs when wave builds up on reaching land.)

Seismic waves produced by earthquakes on the ground can produce measurable motions of the ionosphere, and this fact is being exploited for practical purposes by Paul Yuen and his colleagues at the University of Hawaii. This unusual blend of normally independent geophysical phenomena in aeronomy and seismology promises to be useful in the early identification of and warning on ocean-borne tsunami waves, which can bring catastrophe to shoreline victims thousands of miles away from the earthquake source.

Using a very sensitive radiosounding technique for continuously monitoring changes of height of the E and F layers (the two principal layers of the ionosphere containing free electrons) by the Doppler shift of reflected frequencies, Dr. Yuen has a constantly available measure of motions at heights as great as 300 kilometers. A Doppler shift is the change in the frequency of received waves caused by a changing path length from the source of the observer; an example is the apparent change in pitch of a railway horn as it passes an observer at a crossing. Although the ionospheric measurements primarily give detailed information on atmospheric motions relating to charged particles, they also reveal the rise and fall caused by the pumping action of an earthquake displacement. Vertical air motion at ground level is translated upward into much larger motion at the lower pressures at high altitude, giving characteristic Doppler shifts at certain frequencies.

As the seismic Rayleigh wave—one of the two principal types of earthquake waves which travel on the surface of the earth—travels outward along the earth's surface at speeds between 3 and 4 kilometers per second, the resulting ionospheric displacement travels similarly at ionospheric heights. Because of the acoustical filtering of the atmosphere, the recorded Doppler wave loses most of the confusing short period components present in seismograms, and the identification is not only quicker, but simpler.

Both waves travel many times faster than the destructive tsunamis and can therefore provide early warning. Ionospheric waves have been observed in Hawaii from the Kurile Island earthquake of August 1969, the Japanese earthquake of May 1968, and the Alaska earthquake of March 1964. These aeronomic research techniques are being developed as a multifaceted tool for obtaining basic information on the coupling of atmospheric motions, learning the nature of deep-ocean Rayleigh waves, and providing a working new method for early warning of tsunamis.

Solar-Terrestrial Research

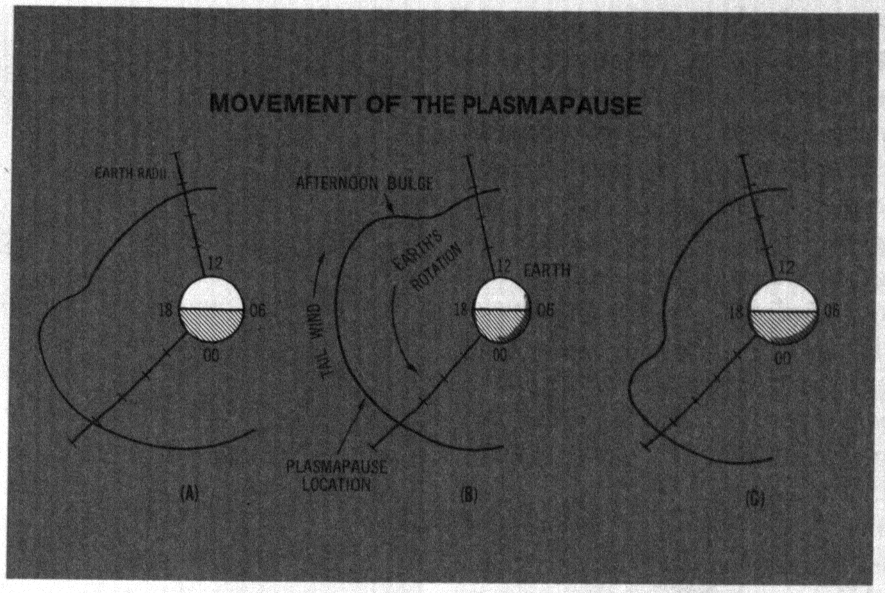
The Plasmapause

The space between the earth and the sun is not a vacuum but a highly tenuous plasma. A plasma, sometimes called the "fourth state of matter," is a gas consisting of ionized particles and electrons. The importance of plasma has received recent attention because of its role in future controlled thermonuclear fusion reactions as a source of electric power.

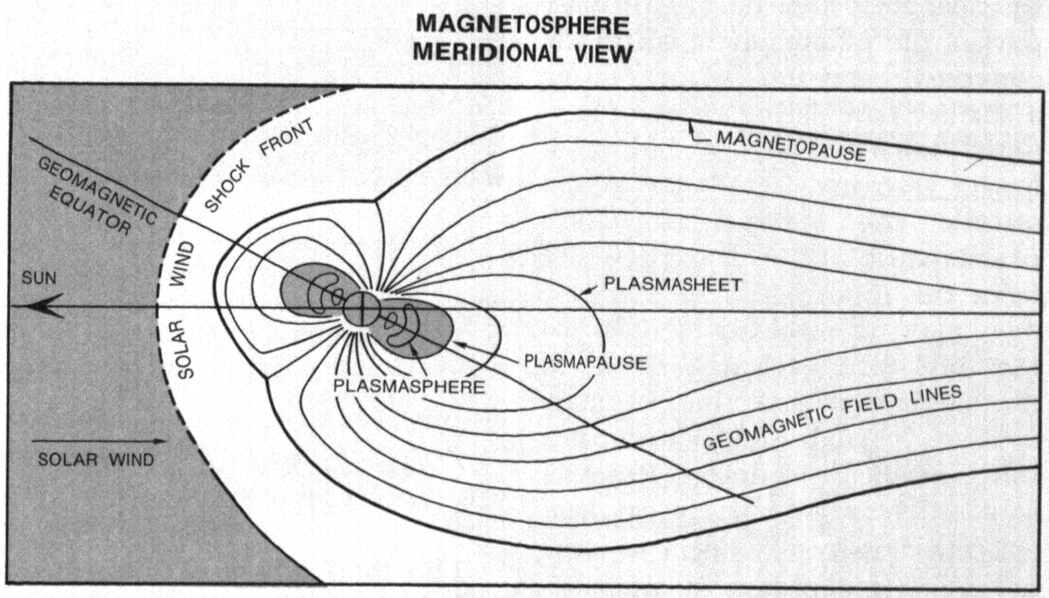
In the early 1960's, Donald Carpenter at Stanford University, using ground-based measurements, and K. I. Gringauz of the U.S.S.R., using rocket-borne probes, discovered that the density of plasma in the atmosphere which immediately surrounds the earth decreases abruptly beyond a border region called the plasmapause, which surrounds the earth as a shell several times the earth's diameter. This boundary fluctuates because it is sensitive to the solar wind—a stream of energized particles, itself a plasma, flowing from the sun—and it transmits energy to the earth in the form of electric currents, particles, and fields.

The plasma within this boundary has been investigated through study of whistler waves—radio signals produced by lightning near the earth's surface which arch out into space along the lines of the earth's magnetic field and are modified by the medium through which they pass. The results of these studies and satellite measurements sampling this environment show that the plasmasphere has a relatively large bulge in the late afternoon hours. The earth's magnetosphere—that portion of space influenced by the earth's magnetic field has an elongated tail which always points away from the sun and is therefore over the "night" side of the earth. The afternoon bulge in the plasmapause location is believed to arise from large-scale motion of the plasma within the boundary of the magnetosphere which is referred to as "magnetospheric convection."

The plasmapause and magnetospheric convection.—In the outermost regions of the earth's magnetosphere the solar wind flowing away from the sun is the dominant influence. It drags the plasma very near the magnetosphere boundary away from the sun, and this in turn establishes a return flow toward the sun within the magnetosphere. On the afternoon side of the earth, this return flow opposes the clockwise flow of plasma which is produced by the rotation of the earth. The interaction between these opposing flows produces a large "backwater" or eddy which is observed as the relatively large bulge in the location of the plasmapause during the late afternoon and early evening hours. The above model, proposed by Neil Brice at Cornell University in 1967 has now been substantially verified. However, recent measurements indicate that the convective plasma flow, like the solar wind, is far from steady, but tends to occur in gusts. The whistler measurements referred to above have shown that when the "tail wind" from the night side increases in intensity, it blows the afternoon bulge in the plasmapause forward into the early afternoon hours, while a sudden decrease in the "tail wind" allows the earth's rotation to sweep the bulge into the night time hours.



The afternoon bulge in plasmapause location arises from the opposing counterclockwise rotation of the earth and the "tail wind" blowing from the night side of the earth. During steady conditions, the bulge is seen at about 6 p.m. (18 hours) (a). If the tail wind increases in intensity, the bulge is blown forward into the early afternoon hours (b). A decrease in tail wind allows the earth's rotation to sweep the bulge into the night hours (c).



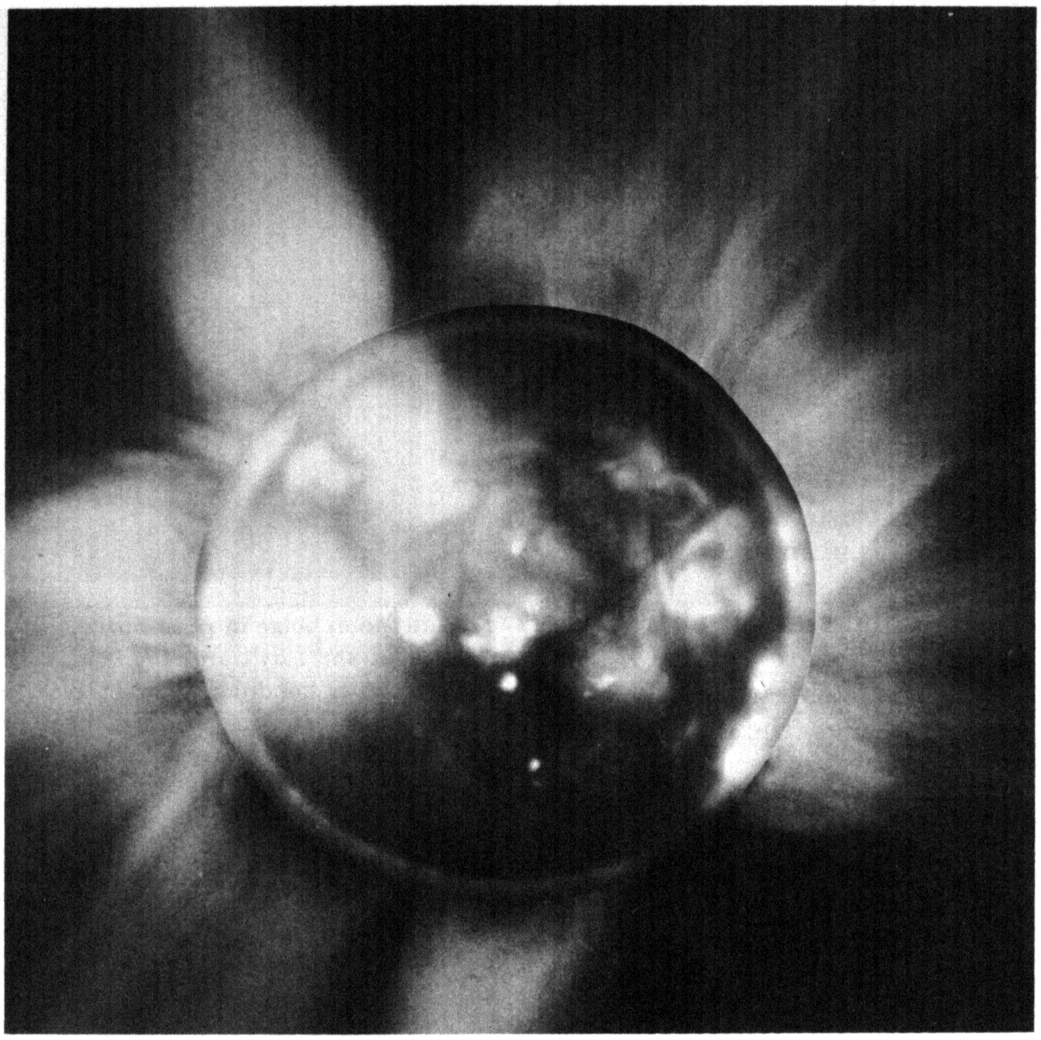
Sudden increases in the "tail wind" are associated with "magnetospheric substorms." This term was introduced by Dr. Brice and

Kinsey Anderson and co-workers at the University of California at Berkeley to emphasize their conclusion that increases in geophysical disturbance activity occurred simultaneously throughout the entire magnetosphere. Magnetospheric substorms occur when energy that has accumulated in the magnetospheric tail is released abruptly, producing widespread aurora over the polar regions and causing disruption of some radio communication circuits.

Some of the substorm energy goes to increasing the intensity of the Van Allen radiation belts and to producing a "ring current" of lower energy charged particles moving around the earth.

New results on the dynamic behavior of the plasmapause.—When the earth's environment is subjected to a magnetic disturbance, the outer part of the plasmasphere is initially convected away into space, leaving a smaller core during times of magnetic storms. During the much longer recovery period, the region outside the reduced storm-time plasmapause radius is replenished from the ionosphere below. Many days may be required to refill the tenuous outer region back to its normal extent, and thus in intermediate periods the plasmapause can be difficult to detect. Processes which depend sensitively on local electron density may begin to occur in the latter phases of magnetic storms while the electron density rises and the storm-time boundary is gradual and irregular.

These and other insights into the structural and dynamic behavior of the plasma surrounding earth increase the value of this "laboratory" to those interested in the generalized behavior of plasmas for eventual application, and provide deeper knowledge of the manner in which energy is transferred from the sun to the earth.



X-ray emitting areas on the sun photographed outside the March 7, 1970, eclipse shadow from a NASA Aerobee rocket are shown superimposed on a picture of the white light corona. The relation of the out-flowing coronal streamers to the active X-ray regions on the solar surface is evident. (Photo courtesy of American Science and Engineering Inc., and the High Altitude Laboratory)

Coordination of the 1970 Solar Eclipse

The total eclipse of the sun on March 7, 1970, was an unprecedented success in regard to wide scientific participation and the near-perfect weather conditions prevailing over most of the path which crossed Mexico and most of the eastern seaboard including Canada. The Federal Council for Science and Technology, in setting plans for these studies, asked the National Science Foundation to coordinate Federal activities relating to this eclipse.

The coordination was accomplished through conferences, negotiations, publications, and other exchanges of information. The cooperation which developed allowed the Foundation to serve not only Federal activities but also to a considerable extent the serious participation by academic, amateur, and foreign groups. The final *Eclipse Bulletin* reports over 200 projects representing 17 nations.

Research techniques used by U.S. scientists included ground-based optical, electronic, and acoustic equipment of many kinds, two instrumented jet planes, 12 gun-launched probes, nearly 70 rockets, and the ESSA Applications Technology Satellite ATS-3. As soon as 1 day afterwards, reports from Mexico to Canada made it clear that the coordinated exploitation of the 1970 eclipse was a success. The quick and total removal of solar energy input not only had revealed new features of the solar corona reaching out to extreme distances from the sun, but had also shown solar influences on marine organisms, on constituent gases of the atmosphere, on temperatures, winds, and clouds, on airglow emission, and on the electrically charged layers of the atmosphere which allow radio communication.

Five teams of investigators from NCAR's High Altitude Observatory (HAO) obtained excellent observations from a mountain field site in southern Mexico. HAO scientists spent over a year preparing the special instruments for experiments which examined the fine structure of solar prominences and spicules and the mechanisms by which they condense from the solar corona; the magnitude and direction of coronal magnetic fields and their role in determining coronal structure; temperature distributions, transient wave phenomena, polarization of major emission lines, and excitation of ions in the corona; and the infrared spectrum of the T-corona, composed of small particles of interplanetary dust.

Scientific publications and international conferences over the following year will present detailed results, and planning will commence for exploiting the few minutes of eclipse totality over central Africa on June 30, 1973.

OCEANOGRAPHY

Ocean Sediment Coring Program

Activities under the Ocean Sediment Coring Program during the past year consisted of a Deep Sea Drilling Project being conducted by Scripps Institution of Oceanography from the Drilling Vessel *Glomar Challenger*. The purpose of the project is to explore the floors of the deep ocean basins by means of coring through the sedimentary layer. Following publication of the first volumes of the *Initial Reports of the Deep Sea Drilling Project*, distribution of samples of the core material was started, making them widely available to scientists for pursuit of individual research projects.

The initial 18-month term of the drilling project was completed in February 1970. It had generally been acclaimed as an exemplary scientific and technological success. The initial term comprised several traverses across the Atlantic and Pacific Oceans and adjacent seas. The term of drilling was extended to provide an additional 30 months' work, and the activities continued then without interruption. Plans for the extended project include a broader geographic range (including the Indian Ocean and Mediterranean Sea) and a closer investigation of continental margins in the Atlantic and Pacific.

The re-entry cone is hoisted over the side of D/V *Glomar Challenger* into the Atlantic Ocean during Deep Sea Drilling Project re-entry trials. The cone is 16 feet in diameter and 14 feet tall. The three sonar reflectors are visible. After the cone was submerged to a depth of 22 feet, it was keel-hauled to the opening in the middle of the vessel, directly beneath the drilling derrick, and sent to the bottom on the drill string. (Photo Scripps Institution of Oceanography)

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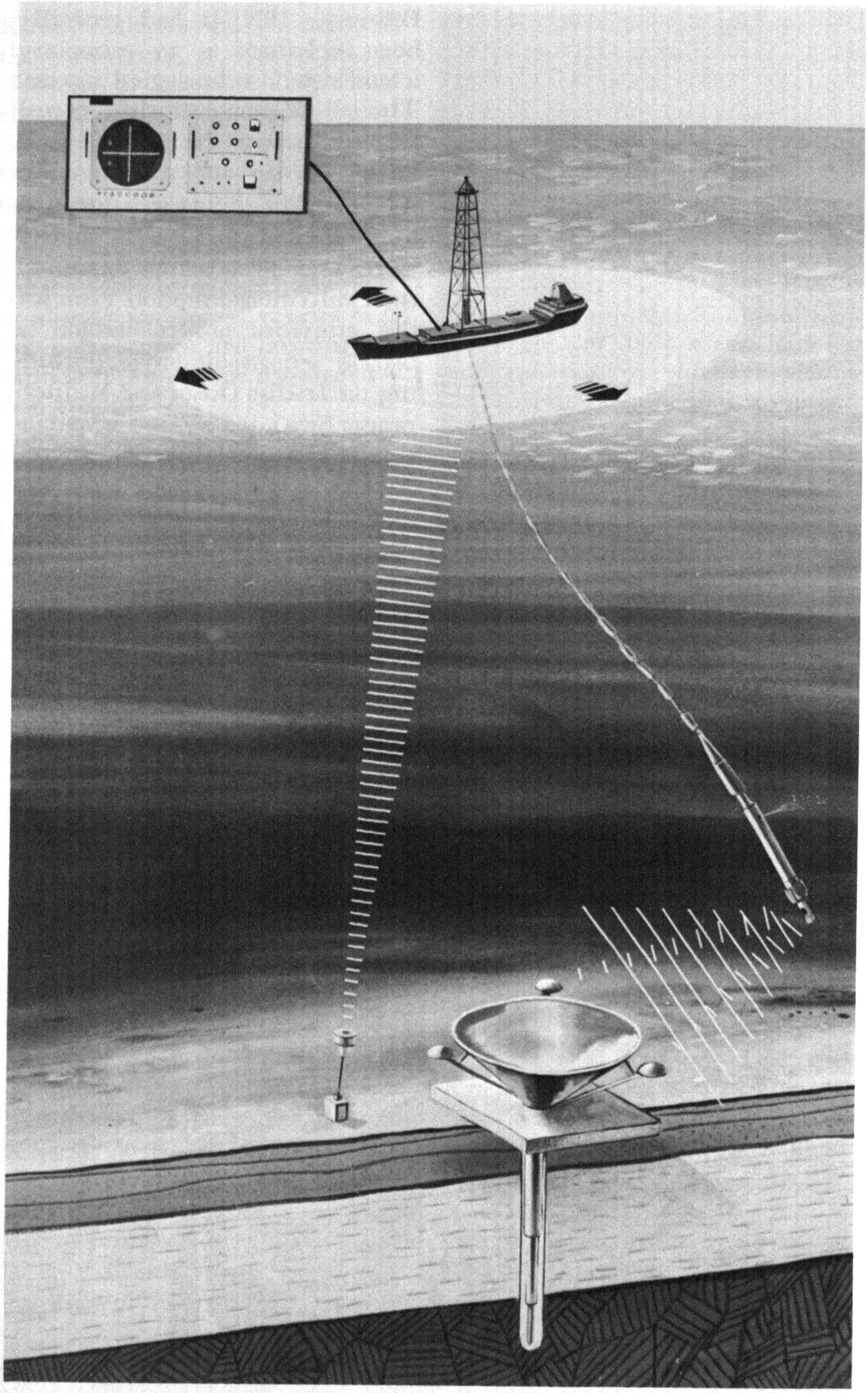


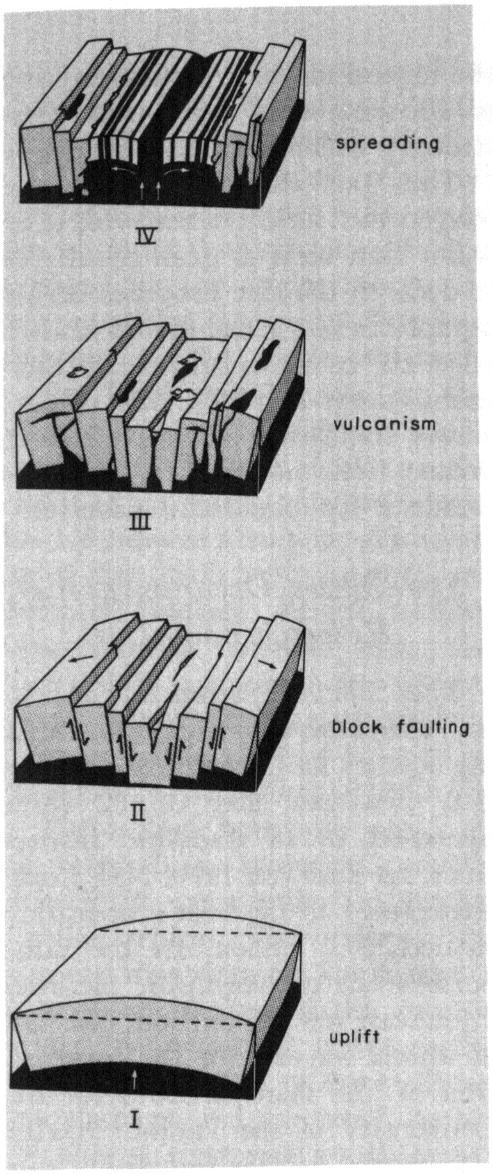
Diagram shows how re-entry sytsem was successfully tested in 10,000 feet of water on 14 June, 1970. A transducer is lowered on a conductor cable through the core-hole in the bit, and the transducer scans 360 degrees in search of the cone. Reflections are displayed on a scope mounted on the ship's bridge. The bit can then be maneuvered over the cone by moving the vessel and by "jetting" or pumping water down the pipe and expelling it through a small hole just above the bit. (Photo Scripps Institution of Oceanography)

At the completion of the initial 18-month program, the vessel had drilled 149 holes at 84 sites, drilled a total of 87,919 feet below the sea floor and recovered 21,983 feet of sediment cores. She had drilled in 20,146 feet of water, suspended a drill string of 20,760 feet, and had penetrated to 3,231 feet below the ocean floor. Subsequently, a new penetration record of 3,320 feet has been established.

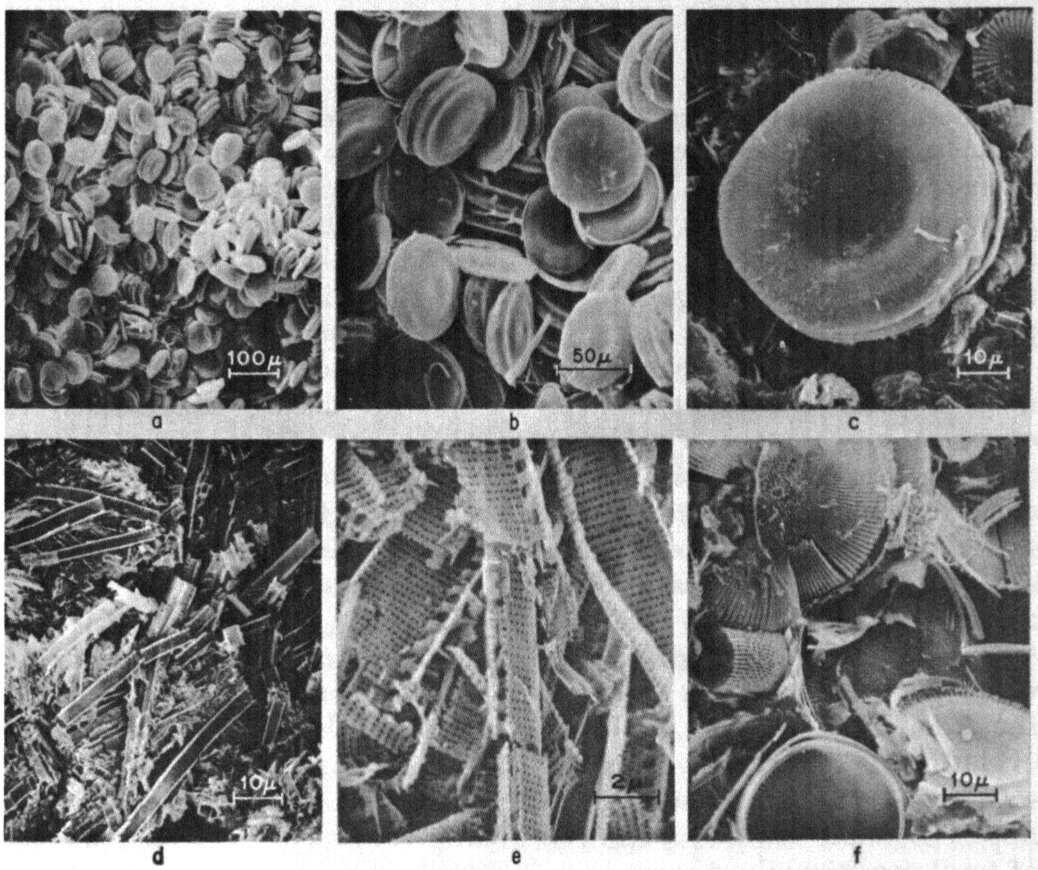
The latter part of the 18-month program was concerned with drilling in the Pacific Ocean where 140-million-year-old sediments were recovered. Further evidence for continental drift or seafloor spreading was acquired in the Pacific by dating of ocean floor sediments.

During the first 4 months of the program extension, the Gulf of Mexico and western North Atlantic basins were drilled. In the Gulf of Mexico it was established that the water has been deep for the past 100 million years, suggesting that if subsidence from a shallow saline basin occurred it was prior to the late Cretaceous, the period during which the Rocky Mountains were formed. In the western North Atlantic, the oldest sediment recovered from the deep ocean, middle Jurassic limestones (160 million years old), overlies basalt, which is probably basement. The limestones appear to have been deposited in increasing deep water through time, suggesting that the early Atlantic was a shallow-water sea. Minerals such as native copper, zinc sulfide, and iron carbonate were recovered.

Coring in the young, soft sediment has proven to be exceptionally rewarding, but within the older sediments, penetration and recovery have been thwarted by the presence of widespread hard chert (flint) layers. Consequently, our knowledge of the early history of the ocean basins still remains fragmentary. A system to replace worn-out drill bits was needed. A review indicated



Stages in evolution of an oceanic rift. (Photo Woods Hole Oceanographic Institution)



Diatoms in sediments of Lake Tanganyika. (Photo Woods Hole Oceanographic Institution)

that a hole re-entry capability would best meet this need. The necessary technological development was accomplished, and resulted in a successful re-entry test in 10,000 feet of water, 180 miles southeast of New York on June 14, 1970.

Oceanography on Lake Tanganyika

The mid-ocean ridges are long scars of global proportions that run down the center of the sea basins and mark the zone where the seafloor is spreading apart, widening the oceans, and separating the continents. The Red Sea and the Gulf of Aden basins are a rift that started to open about 25 million years ago and a new ocean basin may be in the making. Some American geophysicists believe that this great split continues into Africa, forming the deep East African lake systems of which Lake Tanganyika is the most outstanding one.

Building on the experience and results of the 1966 and 1969 expeditions to the Red and Black Seas by Woods Hole Oceanographic Institution, a joint cruise on Lake Tanganyika was undertaken in April 1970 by the U.S. Navy Underwater Sound Laboratory at New London, and three scientists from Woods Hole, E. T. Degens, R. von Herzen, and H. K. Wong. The objectives were twofold. The first objective was to determine the structure of the lakes. Are they simple grabens or are they like an oceanic rift which typically goes through three developmental stages—uplift, block faulting, and volcanic and hydrothermal activity? Since the lakes of East Africa are likely a southern extension of the Red Sea and the Gulf of Aden, which show spreading of the seafloor, the geologic structure of the lakes has broad regional implications.

The second objective of the cruise was to ascertain the sedimentation history of Lake Tanganyika as it relates to the paleoclimatology and ecology of the lake.

The work was accomplished successfully despite the acute logistics problems attendant to working in remote areas with antiquated ships. Seismic profiles gave clear evidence that the topography of the lake bottom is strictly controlled with graben-type basins at the north and south ends of the lake—separated by an uplifted block in the middle which is also structurally produced. Magnetic surveys revealed no magnetic lineations which are typical of rifting. The observed magnetic pattern is structurally controlled and gives no evidence for active seafloor spreading in the past or the present.

Sediment fill in the lake is very massive and may reach thicknesses of several kilometers. The sediments are stratified and almost entirely composed of organic matter and the skeletal remains of diatoms, which are a type of algae. Because the sediments are almost entirely biological in origin, changes in the fossil inventory are undoubtedly linked to the chemical and, in turn, biological evolution of the lake. By means of scanning electron microscopy, it is hoped to relate changes in the type of fossil organisms to changes in the chemistry of the sediments which, in turn, will provide evidence on the paleoclimatology of the area.

Deep-Water Formation in the Mediterranean

Improved instrumentation and research from submersible vehicles have increased our knowledge of life on the very deep sea floors. Since these organisms need oxygen to maintain their life, from where, how, and when the dissolved oxygen reaches the deep ocean is an important question for oceanographers. Since future undersea human habitats may need to utilize the dissolved oxygen in sea water for life support, the dynamics of dissolved oxygen may become of direct concern to human welfare.

The source of all oxygen in the sea including the deep-sea oxygen is the surface region of the ocean where oxygen produced by phytoplankton—free floating microscopic marine plants—and atmospheric oxygen are dissolved in the water. This oxygen-laden surface water then either sinks down as a body or mixes with deep water, a process often triggered by the onset of winter. The cooling of seawater increases its density, causing it to sink.

One of the most exciting oceanographic observations recently carried out is the direct observation of the beginning of the formation of oxygenated deep water in the Mediterranean during later winter. A sinking rate of about 200 meters per day down to 1,400 meters was observed by Henry Stommel of Massachusetts Institute of Technology and his coworkers.

Aboard R/V *Atlantis II* of Woods Hole Oceanographic Institution, the U.S. scientists made a hydrographic survey south of the Gulf of Lyons late in January 1969. During the survey period, the weather was quite calm and the surface mixing zone, where atmospheric oxygen penetrates with ease, extended to a depth of only 200 meters. On February 3, 1969, the *Mistral,* the cold, dry, winter northerly wind of southern France, began to blow. After 7 days of strong wind, the oceanographers observed that the surface mixing layer extended to a depth of 1,400 meters whereas 1 week earlier it was less than 200 meters deep.

Oceanographic data from British R/V *Discovery* and French R/V *Charcot* also showed a deep mixed layer at about the same latitude but at different longitudes. Therefore, it appears that intense vertical mixing occurs in a narrow band 10 to 20 miles wide in north-south extent, and somewhat larger in the east-west direction. By the end of February, this deep mixed layer had been driven down to within 100 meters of the bottom, but with moderating winds in March it was quickly sealed off at the surface by a thin layer of fresher water which overlays the surface everywhere except at the small region of deep mixing. It will be an interesting theoretical problem to explain the smallness of the region in which vertical mixing is allowed, since the winds blew strongly over a much larger region.

The fact that the mixing of oxygen-rich surface waters with deep water can occur as dramatically as it does in this case provides oceanographers with valuable new knowledge of ocean dynamics. Furthermore, areas in which this mixing occurs regularly could prove rich in ocean life, providing a valuable resource for commercial fisheries.

Specialized Oceanographic Research Facilities

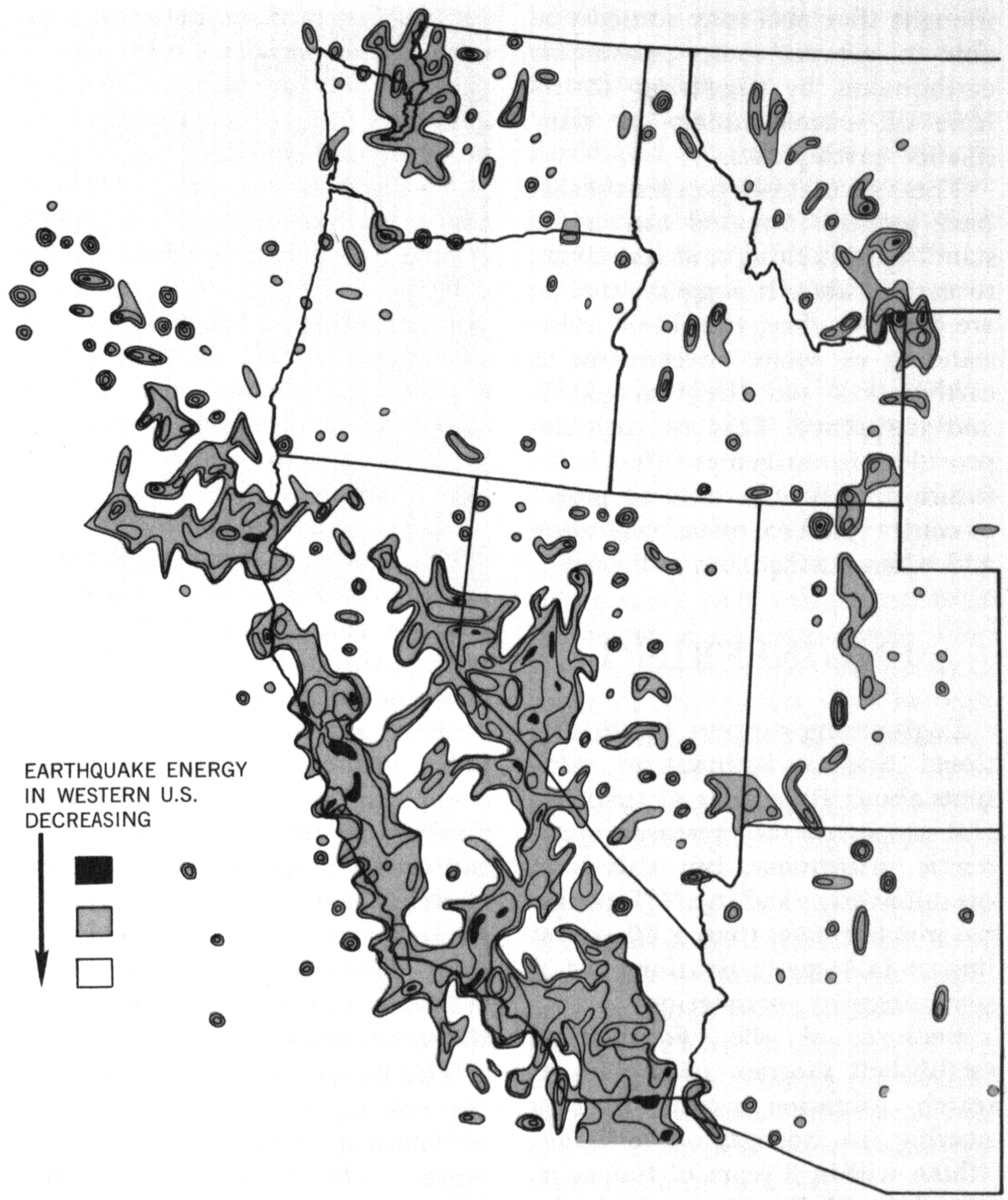
The National Science Foundation continues to be the major funding agency for the operation of the U.S. academic fleet of 32 ships operated by 18 academic institutions. In fiscal year 1970, NSF funds committed to the fleet's operation totaled $7.4 million. In the same period, the oceanographic facilities allotment was $0.2 million, one-half of which was used for the construction of the shore facilities for the University of the Pacific Marine Laboratory and the remaining sum for the purchase of several minor shipboard research facilities for other institutions.

EARTH SCIENCES

Earthquake Hazards

The recent flurry of predictions of a major earthquake and landsliding in California into the Pacific Ocean has generated widespread interest, and even alarm, at the possibility of geologic catastrophies in this country. Although these predictions were without direct scientific basis and major disasters failed to materialize, the dangers of earthquake hazards are attracting increasing public attention. That earthquakes of relatively low magnitude may produce major damage, or even collapse of modern structures, points up the urgent need for a further detailed study of earthquakes, their cause and effects.

In order to understand why and how earthquakes occur it is necessary to study the mechanics of what happens at the original focus, or source, of the earthquake. Previous theories on the origins of earthquakes have relied heavily on the "elastic rebound" theory, which considered that the shock at the source of an earthquake came from the two sides of a fault-line rebounding as the strain between them was abruptly released. Recent studies have shown, however, that the theory does not account for all the energy released by an earthquake.



James Brune, Clarence Allen, and associates at the California Institute of Technology have been conducting research on movements along active fault zones in the California-Nevada region. They noted, for example, that along the San Andreas fault system, rupture of the earth's surface is associated with earthquakes too weak to produce vibration damage and too small to be felt except over very small areas. These earthquakes have magnitudes as low as 3.6 on the Richter scale, where 8.5 represents the strongest shocks so far recorded. The fault displacements included both slippage accompanied by earthquakes, some of which were predicted in advance, and others by slower creeping movement without accompanying earthquakes. Either sudden or slow displacements may cause structural damage.

In the laboratory, Drs. Brune and Allen studied the effects of certain types of physical shock that produce rock fracture on a microscopic scale. They have discovered a variety of initial shock conditions where, as the microfractures in the brittle rock propagate themselves, they produce a seismic event sequence similar to that of a natural earthquake, i.e., foreshocks, a main event, and a decaying sequence. This has opened the door to meaningful study of earthquake mechanisms by carefully controlled laboratory experiments.

Earthquake prediction with a scientific basis and the triggering of earthquakes are relatively new fields of study. Jack Oliver and associates at Lamont-Doherty Geological Observatory are exploring this important problem in a series of microearthquake studies. By studying the source mechanisms of the frequent minor earthquakes which occur in seismically active areas such as Iceland, the rift valleys of eastern Africa, and the islands of the South Pacific, they are able to compress into short periods studies that would ordinarily take many years, or tens of years of observation. The Lamont studies along with those of Alan Ryall at the Mackay School of Mines, University of Nevada, have shown that even minor changes in forces such as the earth tides, caused by the sun and moon, affect the frequency of earthquakes. Ryall and his colleagues have also discovered that nuclear detonations in southern Nevada can trigger natural earthquakes in nearby areas. Such observations have led to the exciting thought that man may someday be able to prevent some catastrophic earthquakes by triggering the release of seismic energy by many smaller earthquakes.

These several independent studies have greatly increased our understanding of faulting and its relation to earthquakes. It suggests that we are drawing closer to a basic understanding of source mechanisms of earthquakes and their magnitude and frequency. This in turn also provides encouragement that in the future man may be able to predict or control on a scientific basis where and when earthquakes will occur.

ENGINEERING

Engineering support by the National Science Foundation represents about 10 percent of total Federal support of such research in academic institutions, but this is an overall average and the NSF portion has much greater than a 10 percent impact in some institutions and in some areas of engineering.

Because of the Foundation's established program of making research initiation grants in engineering to younger investigators (those within 3 years of having received the Ph.D.), the general tightening of funds is not selectively affecting younger investigators in terms of research support. Younger faculty members are making innovative contributions to research in areas of current concern.

Many engineers see their profession as being one by which the fruits of scientific research are put to human use, and this philosophy is reflected not only in the schools of engineering, but in the basic trends of engineering research in the country today. In the engineering schools, much thought is being put to the orientation of future engineers in the social sciences to increase their understanding of the societal interactions between engineering and social sciences. This is not easy because of the immense amount of engineering material to be covered as well.

An interest in relating research results to human and social needs is emerging more strongly in the research proposed to the Foundation. Not surprisingly, the most marked occurrence of this phenomenon is among the proposals for research initiation grants, whose younger proposers are the source for many new ideas and approaches.

Many proposals for research which have societal interaction tend to fall into systems engineering. Current research at the Massachusetts Institute of Technology in this area includes the development of systems for the optimization of police cruiser utilization and scheduling, and analysis of ambulance services. At the University of California at Berkeley, engineers are studying systems for more efficient removal of automobile wreckage from roadways after throughway accidents and of traffic diversion for the duration of these emergencies.

The field of biomedical engineering has drawn on electronics and mechanical engineering for many years. The bypass equipment, heart-lung machines, and artificial kidneys, without which organ transplants and the long surgical procedures they entail would be impossible, are the product of skilled engineers working with medical personnel in pursuit of solutions to specific problems. Materials engineering as well has contributed to medicine through the development of materials for implantation in the body—artificial heart valves, pacemakers, bone pins, and other prosthetics—which have both the engineering strength and durability required for lifelong service and are physiologically acceptable to the host body.

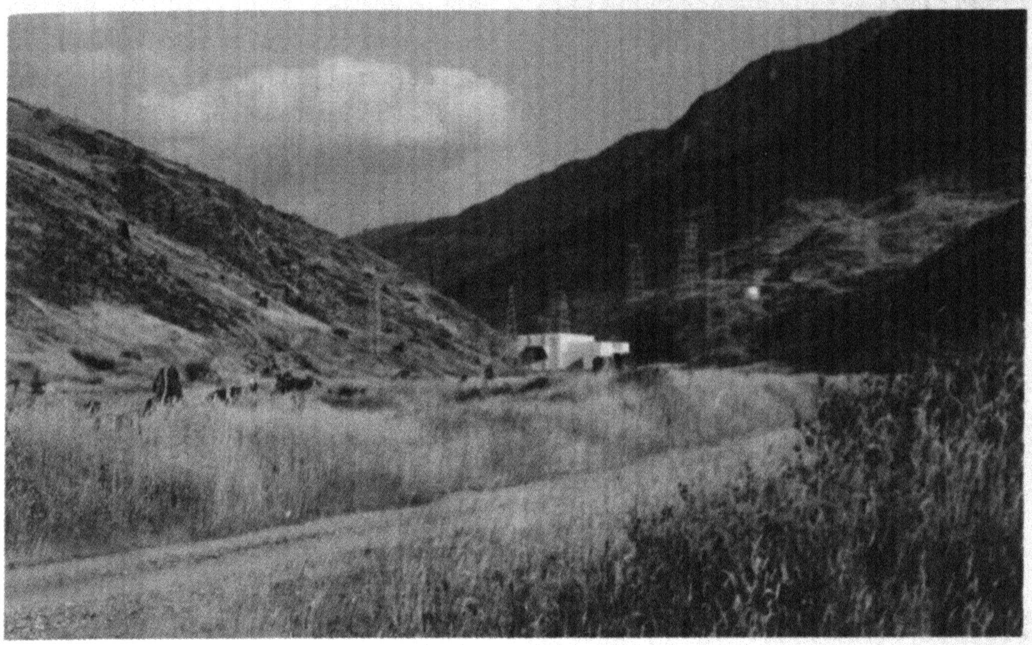
Other trends in engineering involve design of better and stronger buildings. Recent discoveries, stemming from scientific analyses of damage done by the 1970 tornado which hit Lubbock, Tex., indicate that the destructive forces of high winds have effects not unlike ground shaking during earthquakes. Earthquake engineering studies may be expanded to include effects of wind forces to permit better designed structures that can successfully withstand both sorts of damaging forces.

In the field of engineering chemistry, the future may well see the development of the subdiscipline of enzyme engineering. Enzymes, the catalysts of chemical reactions within living systems, are now well enough understood that synthesizing them lies within the realm of possibility. When this becomes a reality, the industrial use of enzymes to catalyze a series of reactions for the synthesis of edible protein food for human use may become economically feasible, and a major new source of food for a hungry world would become available.

Effects of Forest Clearcutting on Slope Stability

Clearcutting is a timber harvesting procedure in which all the vegetation is felled in a selected area. This is the usual logging practice in the redwoods of the North Coast ranges of California and in the vast tracts of Douglas fir in the Cascade Range of Oregon and Washington. Denudation is made more awesome and complete by burning the slash remaining after a logging or cutover operation. Controlled slash burning is justified by various arguments, the foremost being that it eliminates a potentially serious fire hazard later on.

What impact do clearcutting,



View of transmitter station, U.S. Naval Radio Station, Arlington, Wash. Transmitter building is threatened by slowly moving hill mass shown on left. (Photo University of Michigan)

road building, and other forest practices have on slope stability? What is the role of a forest cover and other types of slope vegetation in preventing soil erosion and mass soil movement? These are timely and important questions because pressures are mounting from many sides to increase allowable timber cuts and to accelerate construction of access roads in our national forests.

A forest cover appears to affect deep-seated stability in two principal ways: by modifying the hydrologic regime in the soil mantle and by mechanical reinforcement from its root system. This is a difficult problem, but it is partly amenable to slope stability analyses based on principles of soil mechanics and on knowledge of soil-water-plant interactions. Current research under the direction of Donald H. Gray of the Department of Civil Engineering at the University of Michigan is developing a theoretical analysis which should make it possible to predict stability of a forested slope and assess the probable effects of denudation.

The conventional slope stability analysis in current engineering practice relies upon information of *in situ* (in place) soil information such as moisture content and distribution, moisture stress, strength parameters, physiochemical properties and structure, both microscopic and macroscopic. The real problem lies in determining how much and how quickly these change after clearcutting. To this end, Dr. Gray is instrumenting and sampling actual logging sites in the Cascade Range of central Oregon which have histories of slope instability. On these sites, he has installed inclinometers — instruments which measure and record miniscule slippages in the soil—to indicate incipient instability in the slope. Other field measurements include the installation of recording tensiometer-piezometers, which give a record of stresses produced by soil moisture during and after major rainstorms —and soil core sampling and analysis. This allows the physiographic data as well as the usual field and laboratory determination of engineering soil properties to be correlated as input into the mathematical model.

The data which Dr. Gray records should add significantly to the store of available quantitative knowledge on slope stability and allow advance prediction of the long-term effects of clearcutting on mountain slopes.

Neural Mapping with the Scanning Electron Microscope

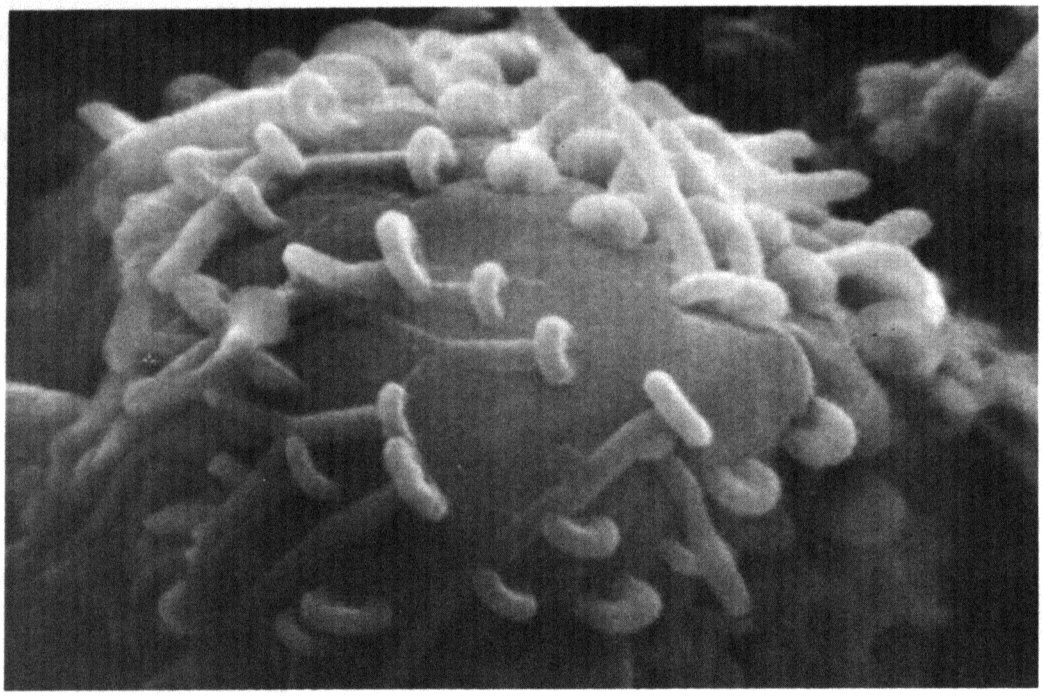
In order for neurophysiologists—scientists concerned with the growth and development of nerves—to be able to work with and extend their knowledge of nervous systems, they need to know what the physical layout of the system is. The lack of good maps for nervous systems—or of methods for obtaining them efficiently—has been one of the major obstacles to progress in this field.

Edwin R. Lewis at the University of California at Berkeley has been applying a scanning electron microscope in search of a solution to this problem and has obtained a wealth of micrographs showing the beautiful and mysterious world found in a spot of biological tissue no bigger than the point of a pin.

The research team, which is in the Department of Electrical Engineering, is using the scanning electron microscope to examine specimens of nerve tissue taken from the abdomen of a marine snail, *Aplysia californica*, chosen because of the simplicity of its nervous system.

They have obtained the first photographs of what are identified as synaptic knobs—the crucial point where the nerve impulse is passed along from one cell to another.

These photographs, taken at magnifications of about 20,000 times life size, show with remarkable three-dimensional clarity a number of such knobs at the ends of fibers



Synaptic knobs in nerve tissue taken from the abdomen of a marine snail, *Aplysia californica.* (Photo University of California, Berkeley)

which seem to lie across each other like a random pile of logs. Other photographs at lower magnifications show complex bundles of such fibers and knobs lying together in clusters at the point where a large "trunkline" fiber from one cell meets a similar fiber from another cell.

The engineers noticed that the knobs seemed to have five or six spots which were firmly attached to other knobs or nerve tissue. A montage of photographs taken as the microscope moved along the specimen traced the complete linkage from cell to cell. The conclusion that the knobs serve a synaptic function (that is, that they form the communications junction between nerve cells) must remain tentative until additional evidence is obtained.

Use of the scanning electron microscope for biological studies is less than 10 years old. Such studies in the past have been limited almost entirely to the conventional light microscope, which has useful magnifications of surface features to only about 100 times life size, barely reaching down to the level of the cell, and to the transmission electron microscope, which offers magnifications of several hundred-thousand times life size but must use extremely thin slices of tissue, and produces a two-dimensional shadow image of the specimen, much like an x-ray.

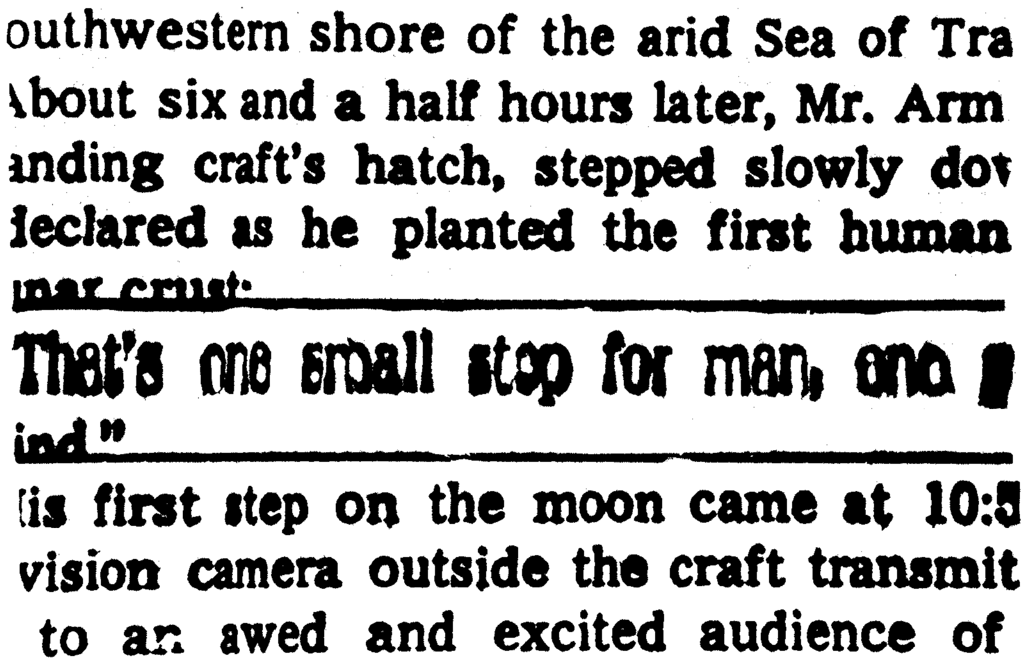
The scanning electron microscope, on the other hand, sees only the surface of specimens, and produces images and photographs with three-dimensional qualities. The techniques developed by this group point to the possibility of developing neural maps on a cellular basis. From this knowledge of neural anatomy, a whole new branch of medicine and surgery, microneurosurgery, could spring.

Partially Crystalline Polymers

In a number of practical applications, polymers, such as polyethylene, are extruded through dies to form desired shapes. A polymer is a large molecule synthesized by linking together many smaller, identical subunits and is the basic kind of material of which modern plastic is made. Because of the scientific complexities involved in the extrusion processes, relatively few studies have been on the flow properties of partially crystalline polymers. And yet study was needed because of the fundamental importance and practical importance of flow in partially crystalline systems.

Roger Porter at the University of Massachusetts has been investigating what unusual structures and properties might be achieved by shearing polymers near their melting points. His initial studies provide guidelines for producing very strong and clear polyethylene. Capillary extrusion was conducted over a sensitive temperature range near 138° C. Crystalline filaments could be continuously extruded which had both unusual clarity—complete visual transparency—and conventional tensile strength over six times that of higher temperature extrusion of the same polymer. The unusual properties are the result of pronounced molecular extension, orientation, and crystallization in the entrance region of the capillary extruder. X-ray, calorimetry, and a variety of other techniques have shown that the perfection (84 percent crystalline) and orientation of the polyethylene crystals are as high as has ever been documented. The axes of the molecules and of the crystals are in virtually perfect alignment along the filament length, and the unusual properties result from this feature. This research has provided the first documented example of a transparent and extended chain crystal structure in polyethylene.

Dr. Porter also found that the transparent material was relatively tough, and resisted fracture at extremely low temperatures, while the opaque material was brittle and broke easily. These improved engi-



A strand of the special morphology polyethylene is shown over a section of conventional newsprint. The high clarity and lens effect are apparent. The same polyethylene prepared under conventional conditions is entirely opaque. (Photo University of Massachusetts)

neering properties can be achieved at virtually no increase in processing costs over that for producing conventional polyethylene. Polyethylene is already used in a variety of applications as a packaging film and as a structural plastic, and these improvements will increase the number of uses to which this useful material can be applied.

SOCIAL SCIENCES

The number of research proposals from the disciplines which make up the social sciences rose markedly from 823 in fiscal year 1969 to 1,087 during fiscal year 1970. This increase reflects not only changes in the ways by which social science research is conducted but also an increased awareness of the possibility of Federal support for the social sciences through the National Science Foundation, in large part stemming from the Foundation's new mandate to strengthen its efforts to improve the social sciences.

Despite the fact that the current trend in actual Federal support for the social sciences has not matched the interest evidenced in what the social sciences can do, the social sciences themselves are surging forward in substance, partly as a result of a methodological revolution. Prior to a very few years ago, social scientists designed their experiments so as to minimize the number and complexity of calculations they would have to perform—always a massive and time-consuming job where large data bases are involved. However, with the advent of the computer and the availability of relatively cheap computational ability, social scientists now no longer need avoid the massive computational loads and much of the field is rapidly becoming more quantified and more scientific in its outlook and methodology.

It is difficult to generalize about the social sciences as a group or even about some of the disciplines within that group. But it is certainly true of all these disciplines that, insofar as basic research in the social sciences bears directly on human social welfare, the advances and breakthroughs in knowledge in the field, while they may be modest with respect to the total problem, constitute a real and lasting benefit. (For example, improvement in public and private policies resulting from research in economics which would increase the gross national product by only one-tenth of 1 percent would add $1 billion yearly to our nation's economy.)

While law as a discipline has not traditionally been considered as one of the social sciences, it is nonetheless closely related to them and is essential to social change and social regulation. Law and the traditional social sciences have had many points of contact in sociology (for example, criminology), social psychology, and economics. This trend toward cooperative research is continuing, and the Foundation has helped to foster interaction between the two fields and is supporting both lawyers and social scientists who are doing research on social problems involving both legal and social scientific operations.

Recent public interest has drawn attention to the study of social indicators — strategic and identifiable measures which indicate significant social changes. "Replication studies" in which sociological research is repeated after 10 or 15 years on a subject, such as the relative prestige of certain job categories, or the influence of education on income make it possible to determine if there has been any basic change. In fact, many such surveys now being conducted for the first time are being designed so as to permit exact replication in the future. A larger number and variety of such measures would supplement the base of our current understanding of change in America which we have from data such as the Census and economic indicators and enhance our knowledge of social phenomena.

Increasingly, problem-focused research draws its personnel from a variety of disciplines and traditional disciplinary work has broadened to accommodate new problems. This is particularly true of urban problems and of foreign area studies. The bulk of NSF research grants in geography, for example, is no longer for the exploration and mapping of exotic lands; geographers are intimately involved with urban planning, with the spatial distribution of income, with community locational decision, and with the perception of neighborhood by individuals. Grantees are affiliated not only with departments of geography but also with schools of design and departments of regional science and of urban planning.

As part of its effort to strengthen scientific research in the social sciences, the Foundation supports work in or related to foreign areas. Some of this research is inherent in the nature of the disciplines—notably anthropology, geography, and linguistics—but much reflects the strong interest in techniques of comparative studies and in problems of social development which is burgeoning in contemporary economics, sociology, social psychology, and political science. While research on foreign areas is of value to those who are interested in the subject areas themselves, it is also a useful means of acquiring a better general scientific understanding of human beings and social behavior.

International Trade and the Balance of Payments

The trade problems which the U.S. economy has encountered in the postwar period are well known, but the causes and cures have been inadequately understood. Hendrik S. Houthakker at Harvard University and his associate, Stephen Magee, have developed a number of valuable insights into our chronic balance of payments difficulties by their studies of the role of income elasticities in international trade. Income elasticity is the degree to which changes in the quantity of a commodity demanded are related to changes in income.

If we consider just two countries with balanced trade and constant prices, and if income growth is the same in both countries, then the trade balance between them can still change through time if their respective income elasticities of demand for the *other's exports differ*. Thus, a country with a higher income elasticity for its imports than the corresponding income elasticity for its exports will sustain more rapid import growth than export growth. Ultimately, this may be followed by a deterioration in its trade balance and eventual pressure on its exchange rate.

Based on this model, Drs. Houthakker and Magee have investigated the demand elasticities for both imports and exports with respect to income and price for selected countries over the period 1951–66. In addition to the analysis of total imports and exports by country, more detailed studies were made of U.S. trade by country of origin or destination and by commodity class.

Drs. Houthakker and Magee's studies indicate that the U.S. income elasticity of demand for total imports is about the same as that of the other developed countries, but that the income elasticity of other countries' demand for U.S. exports is unusually low. Therefore, the U.S. trade balance — other things equal—will tend to worsen over time.

The prospective deterioration in the U.S. trade balance will probably be especially marked with respect to Japan and Canada, according to Drs. Houthakker and Magee, unless these countries develop much higher rates of growth or inflation than the United States. On the commodity side, the United States-Japan pattern particularly manifests overall U.S. trade problems. We have become, in the case of Japan, a net importer of finished manufactures ranging from cars to electronic goods. Our sales to Japan, on the other hand, contain an increasing proportion of agricultural commodities. Although we are still the world's leading industrial nation, we are gradually becoming on a worldwide scale a net importer of finished manufactures. The reasons are to be found, at least in part, in the differing long-term elasticities which Drs. Houthakker and Magee have discovered to exist among the major classes of commodities.

Better understanding of the nature and quality of pressures on the U.S. balance of payments is, of course, not the end of the story. Rather, it offers a framework of fact and analysis for other research in progress on alternative monetary arrangements. It is reasonable to expect that the latter will lay the groundwork for a more stable means of international adjustment and, ultimately, an alleviation of our balance of payments difficulties.

Early Irrigation Patterns

Since the dawn of civilization, man has had to struggle with and control his environment. As time has gone by, many of the techniques he has used to manage the world around him have become more sophisticated, and older methods have been discarded and forgotten with the passage of time.

The science of archeology can help to determine what these discarded patterns were and—how well they succeeded, as compared to the patterns which supplanted them. This perspective over a very long time scale can often provide valuable knowledge of the limitations as well as the unrealized potential of environments for constructive human uses that may not be easily seen from recent and current experiences.

As an example, in his archaeological investigation of Hay Hollow Valley in eastern Arizona, Fred Plog of the University of California at Los Angeles has found evidence of prehistoric irrigation in three localities. These irrigation systems include ditches, canals, a check dam, and basalt walls which probably were a device to slow slope wash as it approached a series of sand dunes. On the basis of radiocarbon dating, these features range in time from about the 10th to the 18th century.

The topography of the valley varies considerably from one point to another, and the old irrigation systems appear to have been designed in response to these differences. For example, the southwestern exposures of what is called Point of the Mountain have trapped great quantities of windblown sand. These dunes, which catch surface water from Point of the Mountain, were used for dune farming. Structures—like the basalt walls—which slowed water down as it came off the mountain or which protected plants from the wind were far more adaptive to farming in these circumstances than canals would have been. In Hay Hollow Wash there is characteristically a difference of several meters between the flow of the channel and its banks, except where such channels flow over bedrock, and most of the points where water was taken out of Hay Hollow Wash are ones where the wash has a bedrock bottom.

Forms of surface water available in the area depend at any time on weather patterns. Slope wash occurs when rain falls in the valley; the main wash runs when water is falling to the south of the valley, and tributary arroyos (or gulches) run when rain is falling to the west of the valley. Given the classic southwestern thunderstorm pattern, a single thunderstorm rarely covers all the possibilities, and the variation in locations and structures of the old irrigation systems seem to have been geared to the diversity of meteorological as well as topographical influences.

Plog's findings have significant implications for modern farmers in the area where communities generally occur sufficiently close together for them to share water resources, reservoirs, and some main canals. Because the streams tapped are characterized by flash flooding, dams are frequently washed out. None of the contemporary irrigation systems are differentiated as the old systems seem to have been. Arroyo runoff is largely unexploited since it is rarely sufficient to provide water for a whole community. However, it is apparent that for a single farm or a few farms, arroyos could be tapped with minimal technological and capital requirements. Based on the conclusions of this archaeological project, it would appear that further large-scale irrigation projects may be less efficient than concentration on small-scale water resources, modeled on some of the ancient patterns.

INTERDISCIPLINARY RESEARCH RELEVANT TO PROBLEMS OF OUR SOCIETY

Fiscal year 1970 marked the initiation of a new program of Interdisciplinary Research Relevant to the Problems of Our Society (IRRPOS). The IRRPOS program was explicitly designed to mobilize the intellectual skills of the nation's scientists to conduct research on major societal problems. Through the IRRPOS program, the Foundation seeks to support interdisciplinary research needed to provide a fuller understanding of major societal problems and to develop new and improved ways to deal with them.

The IRRPOS program does not replace nor merely supplement existing Foundation programs for the support of problem-oriented research; nor does it in any way represent a change in the Foundation's objective to support fundamental scientific research. The IRRPOS program is intended instead to supply a focus within the Foundation for the encouragement and support of scientific research on complex societal issues that require the contributions of diverse scientific disciplines.

Between December 11, 1969, when the program was announced and the end of the fiscal year, over 200 preliminary proposals were submitted to the Foundation. A total of 42 formal proposals requesting over $18.5 million were reviewed, and 21 awards for $5,984,099 were made. Among these are included such projects as:

- The Oak Ridge National Laboratory is conducting research into the potential for genetic mutations in man resulting from the introduction of manmade chemicals into the environment. Oak Ridge is developing several approaches for mass screening of mutations in man. Other studies will develop techniques for performing overall ecological evaluations of the environment, increasing public awareness of environmental quality, projecting the costs and consequences of alternate environmental policy actions, and development of a computer simulation model to predict the influences of alternate environmental policies in the Tennessee River Valley. Additionally, Oak Ridge is investigating possible methods of moderating energy demand and beneficial use of waste heat in a regional energy system.

• Drawing on the disciplines of engineering, applied mathematics, economics, political science, and city and regional planning, the Environmental Systems Program at Harvard University is conducting research on the technical, economic, social, and political aspects of problems of environmental quality. Major aims are to develop an improved framework for analysis of urban environmental problems and to train graduate students and postdoctoral fellows in the conduct of interdisciplinary research.

The research program involves the collaboration of the School of Public Health, the Graduate School of Design, and the John F. Kennedy School of Government. It includes analyses of environmental management institutions; economic analysis of the household as an individual decision unit; studies of municipal financing of environmental control system; expansion of current studies of solid waste disposal; and studies of the epidemiology of urban fires. The program involves graduate students and postdoctoral fellows from a variety of specialist backgrounds in order to develop the talent required for intelligent management of environmental quality.

• In collaboration with the Rand Institute of New York City and with the cooperation of public agencies of Nassau and Suffolk Counties, the Urban Systems Engineering group of the State University of New York at Stony Brook is initiating a program of interdisciplinary research on the flow of solid wastes and on fire protection.

Data obtained from existing literature and a case study of the sources and disposal of solid wastes are being used to construct a benefit-cost model of the waste disposal system.

Building on the experience of the Rand Institute with research on fire protection, the Urban Systems Engineering group is using operations analysis techniques to deal with problems of fire protection in an area characterized by rapid urbanization. Computer simulations will be used to develop estimates of benefits and costs associated with alternative systems.

The aims are to develop the analytical investigations that are likely to be of immediate benefit to public agencies, to develop a close working relationship with the Rand Institute, to strengthen the interdisciplinary research resources of the Urban Systems Engineering group, and to construct a series of models describing the essential features of selected urban systems. The research is closely tied to a graduate program involving students in engineering, economics, and physical sciences.

• The University of Illinois and Colorado State University are investigating the sources and magnitude of lead pollution in the environment. The Illinois project emphasizes the study of lead from gasoline but will also include study of the movement of all forms of lead through the environment. The Colorado State project will stress a systems approach for studying environmental contamination, and the techniques developed should have broad application to studies of other contaminants such as mercury, combustion-produced carcinogens, and pesticides.

Science Education Support

Since the start of its activities in science education, the Foundation has been concerned with the training of enough scientific and technical manpower of high quality to meet the nation's needs. Science and technology have become, however, such integral parts of our society that an understanding of their processes is now recognized as essential even for those who are not and do not expect to become professional scientists or technologists. Clearly, the improvement of the nation's scientific research potential, through the education of scientists, continues as a priority goal for the Foundation. But fiscal year 1970 has seen new emphasis on efforts to educate all citizens in both the uses and the limitations of science and technology, particularly as these bear on the analysis of societal problems, finding of alternative solutions, and rational decision making. Thus, the Foundation's science education programs are evolving toward meeting the two goals of educating the nation's scientists and technologists and improving the quality of education in the sciences for all students.

Science education is a cumulative process which begins at the first-grade level and may extend beyond the earned doctorate. Since each successive level rests upon earlier levels, one cannot hope to improve materially the quality of education in the sciences, let alone the production of highly trained professionals, by concentrating efforts at any one academic level. Even massive effort at the graduate level produces limited results in the absence of improved preparation of students prior to that point. On the other hand, efforts at the early levels of education are ineffectual unless momentum can be sustained thereafter. The education activities of the Foundation are designed at each major level to address those components of the system which exert the most leverage in terms of improving science education, but with varying emphasis. At the graduate level, a major portion of support funds is invested in professional training of future scientists; at the undergraduate level, in the improvement of instructional programs and institutional capability; and at the pre-college level, in

Table 5
Education in Science
Fiscal Year 1970

[Dollars in thousands]

	Number of proposals received	Dollar amount requested	Number of awards made	Funds obligated
Graduate Education in Science:				
Fellowships	10,914[1]	$73,063	3,082[1]	$15,877
Traineeships	279	100,126	368[2]	27,269
Advanced science education program	166	8,476	92	2,393
Undergraduate Education in Science:				
College teacher program	474	13,833	394	4,161
Science curriculum improvement	1,795	36,517	685	9,806
College science improvement program	104	18,610	46	6,829
Undergraduate student program	836	9,300	432	3,817
Pre-College Education in Science:				
Institutes	1,472	60,500	1,049	36,936
Cooperative college school science program	325	14,075	136	4,654
Course content improvement	101	11,504	77	6,507
Student science training program	305	4,873	130	1,931

[1] Individuals involved.
[2] Includes 89 same-year supplementary amendments not included in proposal count.

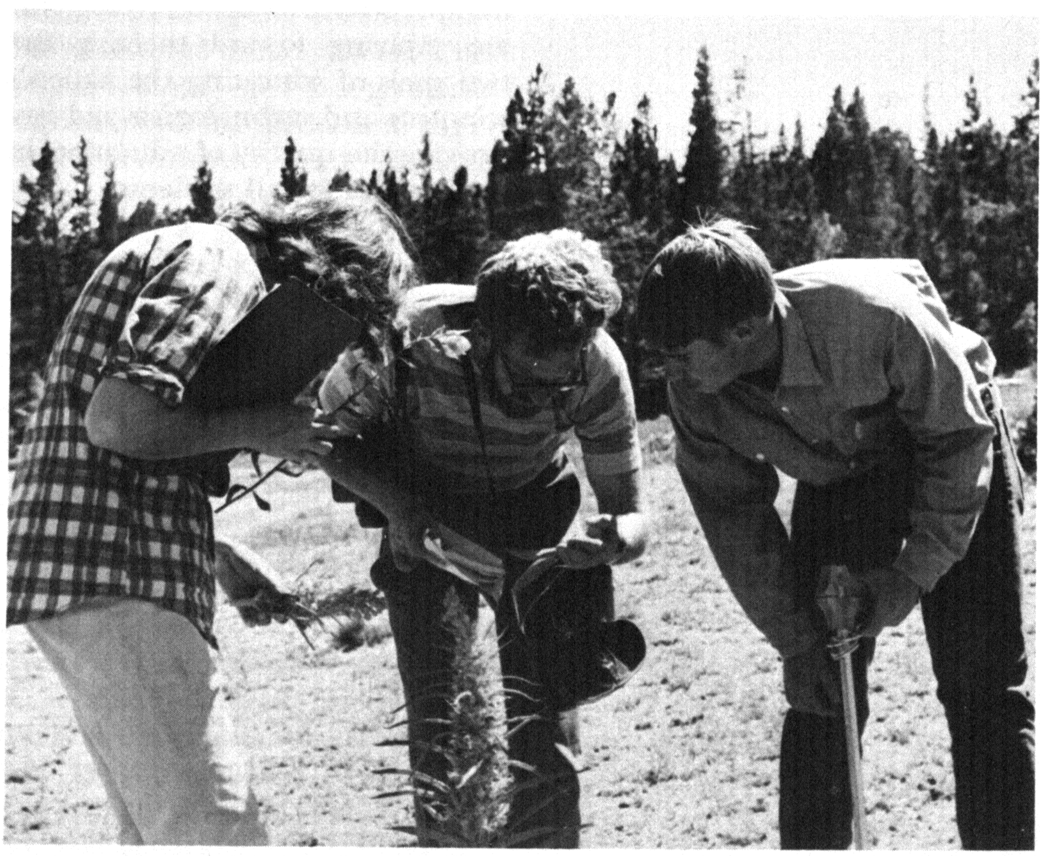
teacher training—but all these elements are represented at each level. Table 5 reflects NSF support for educational activities in fiscal year 1970.

The Quality of Science Education

Early Foundation efforts to improve the quality of science education in schools and colleges emphasized resources and personnel from outside the normal educational system or institution—particularly the improvement of teacher competency and the creation of high-quality instructional programs. Several years ago, it became clear, not unexpectedly, that the use of these external resources would be neither widespread nor—in many instances—effective without financial and professional assistance. Accordingly, some five years ago the Foundation began programs to help with actual implementation, e.g., the College Science Improvement Program at the undergraduate level and the Cooperative College-School Science Program at the pre-college level. Simultaneously, the existing teacher institute programs expanded their efforts to include increased participation by training specialists who could assist their schools in the adoption of new courses and methods. Looking ahead, the Foundation plans to support the generation and growth of capability *within* educational systems and institutions for locally initiated improvement of educational programs, relying on broadly constituted curriculum and advisory groups and some of the resources developed over the last decade.

Assessments and Priorities

While the Foundation's education programs have evolved over the past several years from a limited manpower goal to include a concern with improved science educa-



In a unique project combining several program elements, the Foundation in 1970 supported a research project which included superior high school and undergraduate students working with a college teacher of science to explore the ecology of lands above the timberline. (Photos NSF) tion for all, and from the development of external resources to increasing emphasis on implementation and development of capability for locally generated change, the past year was one of particularly intensive review. A number of factors sparked this evaluation and planning: the recurring need to examine the efficacy of established programs, changes in the demands for and supply of different types of scientific and technological manpower, fiscal retrenchment both at government and local institutional levels, and—overarching all—ever more insistent pressures for reform at all levels of education.

NSF staff and consultant review and planning for educational programs was augmented by a study commissioned by the National Science Board and conducted by the Advisory Committee for Science Education under the leadership of Dr. Joseph B. Platt (President, Harvey Mudd College) and Dr. Herbert S. Greenberg (University of Denver). The study report develops a theme for the next decade: "To educate scientists who will be at home in society and to educate a society that will be at home with science." Recommendations to achieve this aim include:

> Grants to support faculty and graduate students for research in science education equivalent to those for research in science;
>
> Experimentation and innovation in the application of technology to education to develop not only better hardware systems specially designed for educational needs but also an adequate range of high-quality materials suitable for exploration of television and computers as instructional tools; and
>
> Increasing support for science education outside the formal classroom such as museum activities, travel exhibits, films, and television programs.

The report also makes specific recommendations at each level of education. At the graduate level, support is urged for advanced practitioners degree programs; revitalization of the master's degree for those who will be engaged in the teaching and application of existing knowledge rather than creating new knowledge through research; and innovation in interdisciplinary course content. At the undergraduate level, the report recommends improvement of science courses for the non-science major; development for science majors of interdisciplinary problem-oriented science programs; increase and improvement of the science component in the education of prospective teachers; greater emphasis on two-year programs for the training of technical personnel; and some experiments in restructuring the total undergraduate experience. Recommendations for the pre-college level include second-generation course development focused on interdisciplinary, vertically integrated course sequences; production of outlines and suggestions to be adapted by teachers to fit local conditions; increased support for social and behavioral science curricula and teacher training; and support of experimental schools exploring major changes in the school environment.

New Directions

The Committee's recommendations and the staff planning have found expression in specific program activities during fiscal year 1970 designed to meet the current challenges in education. A number of projects supported in the Advanced Science Education Program are experimenting with alternatives to the traditional research Ph.D. programs. These experiments are given impetus by the changes both in manpower needs and in the interests of students oriented more and more toward interdisciplinary problem-solving rather than research in a narrow specialty. A newly established program at the undergraduate level — Student-Originated Studies — will support projects by creative and able students who wish to take a hand in their own education while gaining an understanding of how to analyze science components of a problem and formulate possible approaches toward solutions. An increasing number of projects are concerned with developing new instructional patterns for the undergraduate preparation of prospective technical and teaching professionals. At the pre-college level, fiscal year 1970 was marked by growing coordination between curriculum development and the training of teachers who can implement new curricula. Also, an increasing number of principals, science supervisors, and science education faculty from colleges and universities have received special information and training instruction so that a cadre of supervisory and resource personnel will be able to aid individual classroom teachers.

In addition to its investment in individuals to recognize and develop scientific talent, and in instructional programs and the training of instructional personnel to improve the quality of science education, the Foundation is also concerned with exploring and defining the role of educational technology (computers, television, film, programmed instruction) and with support of basic research that has educational significance. Projects in support of these two aims are funded through several of the education programs, often in conjunction with the Office of Computing Activities or the Division of Social Sciences. The following reports for each education division illustrate in greater detail the direction that the Foundation's science education activities are taking.

GRADUATE EDUCATION IN SCIENCE

The Foundation's concern with graduate education in science is apparent not only in its graduate education programs, but also in the emphasis given it in research and institutional programs. Support is extended to talented individuals for graduate and postdoctoral study through a variety of fellowship and traineeship programs. From 1952 through 1970, the Foundation will have funded about 65,000 awards for 9 or 12 months' study at the graduate level. Research grants to institutions of higher education usually carry a component of support for graduate students—some 6,000 being so supported in fiscal year 1970; special grant programs to support in-depth field work directly pertinent to dissertation projects contribute to the quality of the individual's training; large development grants to institutions—or to departments within institutions—are designed to improve their graduate education programs. Graduate students are also supported through the National Research Centers, the Sea Grant Program, and in various National Research Programs. Through these mechanisms, NSF provides support for nearly one-fourth of all science students holding federally funded awards.

In direct support of graduate education, fellowship programs designed as open national competitions for graduate students identify scientific talent and provide support to develop that talent to its fullest potential. Similar programs serve to further advanced training for postdoctoral and senior postdoctoral scientists and members of the science faculties of colleges. Particularly in the senior postdoctoral and science faculty programs, a major effect is on higher education itself, since fellows from those programs return with new training and insight to their teaching responsibilities. In addition to those programs, traineeship grants permit institutions to make their own selection of recipients for support of graduate studies and develop graduate departments. A program that brings outstanding foreign scientists in leadership roles to U.S. faculty positions for periods of up to one year adds new perspectives and experience to U.S. faculty members and graduate students, and strengthens scientific cooperation and understanding on an international basis. Table 6 shows the number of individuals supported with fiscal year 1970 funds under each of these programs.

Through the Advanced Science Education Program (ASEP), grants are made to institutions for the development of innovative graduate-level course offerings, to experiment with new kinds of educational techniques, and to examine the needs and problems in various disciplines so that graduate education in science can evolve to keep step with the changing needs of individuals and society as a whole. A particular responsibility of ASEP is the funding of Advanced Training Projects which provide educational opportunities for graduate and postdoctoral students and for graduate-level faculty where no training is available through regular university offerings.

Scientific Manpower and Graduate Education

The Selective Service Act had its most severe impact on the NSF Graduate Fellowship Program during 1969–70. Of the 2,500 persons offered fellowships for the year, a total of 101 requested that the awards be deferred because of military obligations. It appears that the Congressional action in December 1969, which made possible the order of call on a lottery basis, may result in a reduction of this impact, since the rate of deferment requests to date has been half that of last year.

Fiscal year 1970 was a period of intense re-examination of the whole manpower question as it relates to graduate education in science. In some areas of science, particularly physics and mathematics, it appeared that the number of Ph.D.'s produced during the last decade had satisfied or even surpassed demand for their services in the usual professions associated with academic careers or industrial research. Conflicting statements as to the seriousness of the situation have appeared, but the supply of traditional Ph.D. manpower seems to be coming into balance with the need. Recent studies have also shown that, since the mid-1960's, there has been a trend toward disinclination on the part of graduate students to enter the science fields, with a resulting decrease in enrollments. The decrease in Federal support for research and graduate study is likely to result in an even sharper decrease in the overall graduate school enrollment beginning in the fall of 1970. The Foundation is planning readjustments in its support of graduate students to take account of these projections and trends while still meeting anticipated needs for the 1970's. With less Federal support for graduate students, an increase in the number of part-time graduate students is anticipated; accordingly, the graduate traineeship program has been adjusted to permit institutions to award part-time traineeships beginning in the fall of 1970.

Another likely result of decreased Federal support is an increase in the number of students who will pursue the master's degree as a terminal degree. Some graduate training will probably be necessary for many scientific and technological professions immediately below the

Table 6
NSF Fellowship and Traineeship Programs
Fiscal Year 1970

	Awards requested by institutions	Individuals involved in applications	Fellowships awarded	Net amount
Graduate traineeships	17,510 ([1]224)		5,301 ([1]224)	$26,240,000
Summer traineeships for graduate teaching assistants	8,737 ([1]211)		938 (207)	1,029,290
Graduate fellowships		8,201	2,212	10,374,817
Postdoctoral fellowships		1,295	109	1,000,000
Senior postdoctoral fellowships		338	50	686,000
Science faculty fellowships		994	209	3,083,889
Senior foreign scientist fellowships		86	61	779,518
Total	26,247	10,914	8,880	43,146,514

[1] Number of institutions involved.

top levels, so that the master's rather than the doctorate degree may well become the target of a large segment of the student population. The Advanced Science Education Program is supporting several projects designed to explore the role of the master's degree. For instance, Georgia State University is developing a master's degree physics program to serve both part-time students from industry and students preparing to become secondary school and junior college teachers.

Improving the Quality of Graduate Education

An important resource to institutions trying to strengthen their graduate programs is the Senior Foreign Scientist Fellowship Program. It brings to institutions in this country foreign scientists whose training, experience, and formal accomplishments enable them to make significant contributions to the education and research programs of the host institutions. The increasing importance of this program for U.S. institutions is indicated by the extent of their participation this year, the greatest since inception of the program in fiscal year 1963: nearly 85 percent of the eligible institutions nominated candidates. The selection process is such that individuals nominated for the fellowships are able to exert in-depth influence within the departments they join, usually for a year, where they are considered members of the senior science faculty. They teach, lead faculty seminars, collaborate with and guide research activities of faculty and graduate students, contribute to professional society meetings in the United States, lecture at nearby institutions, and participate fully in the departmental development programs of the U.S. universities. They also bring to the institutions different views in their fields of science, particularly in smaller departments, and afford educational opportunity and scientific expertise often not available in this country to faculty personnel as well as to students. In addition to being an important resource in upgrading graduate science education in this country, the association between the outstanding foreign scientists and their colleagues in the United States adds a significant increment to the improvement in international understanding and cooperation.

The Senior NATO Fellowships in Science Program (administered but not funded through the Foundation) also provides resources for strengthening graduate education by allowing a limited number of senior staff members of U.S. institutions to spend short terms (usually 1 to 3 months) in other NATO countries to learn new developments in their fields of specialization. In fiscal year 1970, 36 individuals received support for senior NATO fellowships.

In attempting to improve and introduce new directions into graduate education, the Foundation is particularly concerned with the societal problems facing the nation in the next decade. Solutions of these problems will require broadly trained, creative individuals capable of working in interdisciplinary teams. In its fellowship programs at the postdoctoral level, the Foundation has invited applicants whose training and experience are in one field of science to propose plans of study or research in different but related fields. For instance, a person trained in chemistry might wish to tackle problems associated with air or water pollution and, to be effective, might need additional training in atmospheric or oceanic sciences. In another area, a person whose training is in business-cycle economics might now wish to undertake research in urban planning or some other sociological aspects of the inner city.

The training provided through Advanced Training Projects is frequently interdisciplinary in nature and aimed at current problems. Some of the fields of science in which courses, seminars, symposia, or field work were supported this year are: molecular techniques in developmental biology, geographical analysis of U.S. metropolitan areas, behavioral and social science in legal education, earthquake engineering, pest management, planetary atmospheres, and marine paleontology.

In addition to training scientists who can work in multidisciplinary areas, the Foundation is concerned with new interdisciplinary fields presently emerging as scientific disciplines. For example, a grant to the Greater Los Angeles Consortium, made up of liberal arts colleges in California, supported a conference in May 1970 on urban studies. Academicians from approx-

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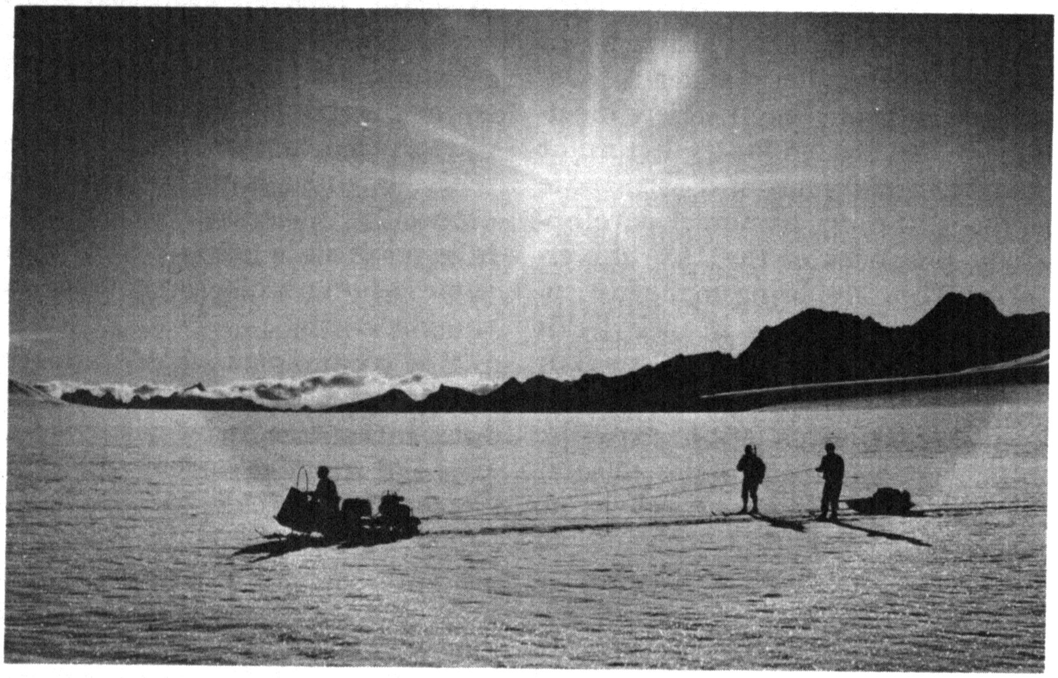
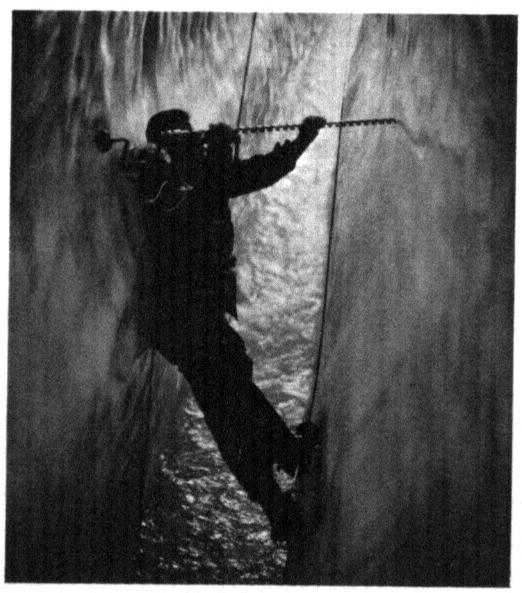




Under the program of Advanced Training Projects, the Foundation provides support for the Juneau Icefield Research Program, a long-term education and training project conducted by Michigan State University. In addition to academic courses in glaciology and related fields, graduate students receive practical training in the techniques of safe operation and survival in a variety of Arctic environments. (Photos Christopher G. Knight (c) National Geographic Society)

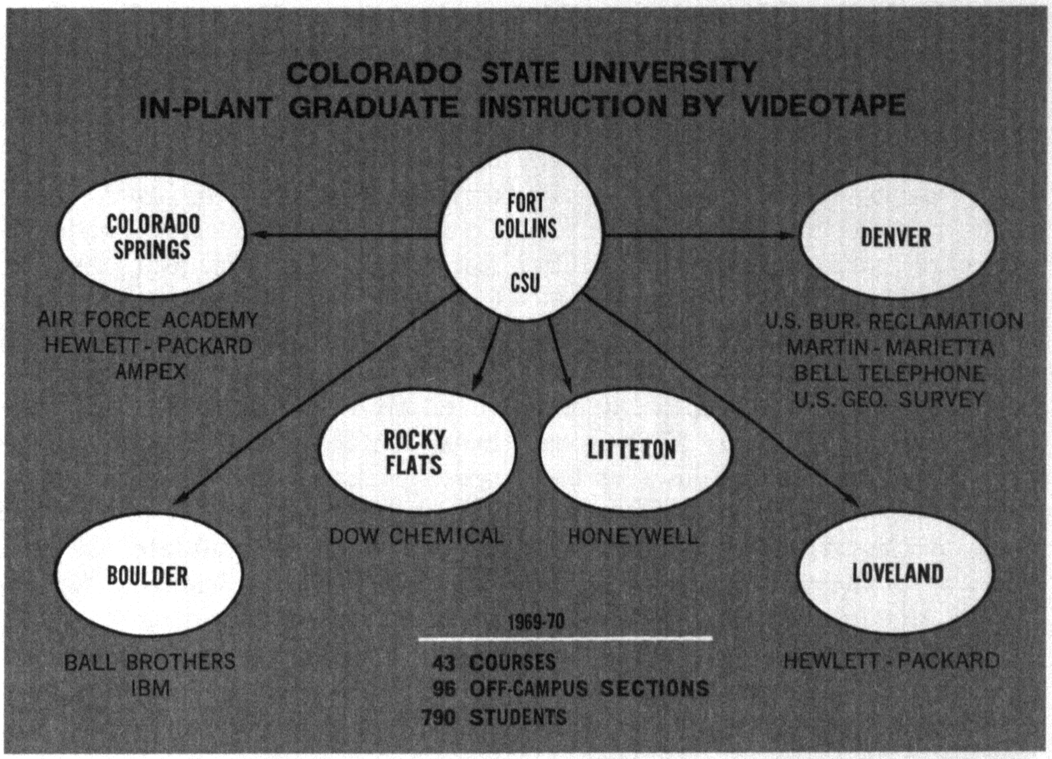
imately 25 colleges and universities in all regions of the United States who had been involved in urban and regional studies met with professional urban specialists for the purpose of evaluating the present state of urban studies as an area of science. Considered were such topics as: Should this be an undergraduate or graduate field of study? What preparation should its instructors receive? What kind of graduates does it seek to produce? Is interest in the field transitory, or will it become a distinctive discipline? A report of the conference is expected to have major impact in developing a degree-granting curriculum.

Alternatives in Graduate Education

A number of experimental projects supported through the Advanced Science Education Program are exploring new approaches to curricula or seeking alternatives to the traditional Ph.D. research degree so as to meet a variety of needs for highly educated science and technology professionals. An example of the kind of experimentation now underway is the recently established "SESAME" (Search for Excellence in Science and Mathematics Education) Ph.D. program at the University of California at Berkley. In this program, a student takes all the course work required for a Ph.D. in a specific discipline and a few courses in education. After passing a qualifying examination in his scientific field, the student undertakes a thesis research project dealing with educational improvement and innovation. The program seeks to encourage work in the area of science education by science faculty members and to train students who will be qualified to teach at the college level. In fiscal year 1970, the Foundation made a modest grant for this program to the university to help with faculty-released time, educational research assistantships, and related expenses.

Several projects are trying to introduce greater relevance into graduate training for students who are both scientifically sophisticated and intensely concerned with societal problems. A student-initiated research project at Stanford University will permit graduate students to conduct a study of mass media coverage of environmental problems. The students will first construct an environmental picture of the San Francisco Bay area from available technical information and their own study of specific aspects of pollution. They will then analyze coverage of environmental problems in the newspapers, radio, and television. The two sets of information will be compared to determine the accuracy and scope of media coverage. The researchers plan to conclude the study with a seminar at Stanford University for editorial writers, environmental reporters, station managers, news directors, ecologists, and environmental specialists.

New graduate curricula in technology have received particular emphasis, especially those seeking to increase opportunities for continuing education on a part-time basis for employed individuals—generally industrial scientists and engineers. For instance, a grant to Creighton University will support a joint educational-industrial-governmental symposium to explore how universities can cooperate with industries and other organizations employing research scientists in a specific geographic area. A project at Colorado State University started out in 1967 developing videotapes for graduate instruction in several engineering areas to be taught at in-plant locations. Demand for the courses increased rapidly, so that by 1969–70, some 40 courses in a wide variety of fields were being made available to nearly 800 students at 14 off-campus locations. Moreover, the expanding clientele began to demand new graduate curriculum development. In the area of remote sensing of material resources, off-campus response was so great in 1969–70 that the enrollment exceeded the total interest in the subject at the university in all prior years combined. Hence, the university, with partial support through a 1970 grant, is now developing a major new graduate curriculum on the technology and application of remote sensing through new techniques using sound, light, radio, radar, heat, X-rays, and magnetism to monitor the environment.



UNDERGRADUATE EDUCATION IN SCIENCE

Foundation activity in support of undergraduate education in science must be sensitive to the critical nature of undergraduate education within the educational chain, as well as the diversity of the institutions in which it operates. In its position between the two other major educational "establishments"—pre-college education and graduate education—undergraduate education is the crucial connecting link between the generally uncommitted and the practitioner, for it is at the undergraduate level that serious preparation for a career begins. At the pre-college level the student may decide for or against "science;" at the college level he decides *which science*, if any, and in the 4-year college period must either acquire the knowledge and training that will enable him to pursue a career for which an undergraduate degree constitutes the necessary formal requirement, or build a foundation on which his specialized graduate training will rest.

Undergraduate colleges face a formidable task. They must take students from secondary schools with very good to very poor preparation, and they must recognize the wide variety of career choices possible and offer the necessary preparation. Further, they cannot overlook the fact that modern society requires that there be within the citizenry at least a core of educated nonscientists who understand science and its interactions with society.

The 2,550 undergraduate colleges are far more diverse in nature than either the secondary schools or the graduate schools: 12 percent are parts of major institutions offering graduate education to the Ph.D. level; another 21 percent offer graduate work through the master's degree; for 30 percent of them the baccalaureate is the highest degree granted; and another 37 percent offer something less than the baccalaureate, usually the first two years of undergraduate education. In each of these categories, institutions range in size from enrollments of less than 100 to thousands or tens of thousands. The quality of science education provided varies from totally inadequate to excellent.

Even the best of the undergraduate colleges and universities find it difficult to maintain their positions as high quality institutions—not only because of increasing enrollments and the rate at which new knowledge is being developed but also because of the changing demands imposed by increasing expectations. The orientation of many science students toward courses of study relevant to societal problems is likely to force major changes in science curricula. Advances in science and a rapidly changing technology demand curricula that will permit far greater flexibility in career choices. Scientists are also increasingly recognizing that they can no longer concentrate only on reproducing their own kind—that they must take a hand in giving the great body of students, many of them heading toward nonscience careers, an understanding of what science is, of its impact on society, and of its importance to the nation's future.

During fiscal year 1970, the Foundation assisted with the maintenance and improvement of the quality of undergraduate science education through several programs, some of them of long standing. Over 3,000 faculty members from 4-year and junior colleges participated in programs to enhance or update their knowledge and capabilities through Summer Institutes, Short Courses, or the Research Participation programs operated through College Teacher Programs. Support for the improvement of undergraduate science curriculum was provided through the Science Curriculum Improvement Program, supporting the development of teaching materials adaptable to use by a variety of undergraduate colleges; the Instructional Scientific Equipment Program, providing matching funds for the purchase of instructional equipment for use in science laboratories and demonstration lectures (suspended for fiscal year 1971); and the Pre-Service Teacher Education Program, assisting in the development and modernization of programs to produce adequately prepared teachers of science for the secondary and elementary schools.

The College Science Improvement Program is aimed at improving the overall instructional programs of institutions. Through its three sections, it provides (A) comprehensive support for the improvement of a wide range of instructional activities in individual colleges; (B) support for associations of 4-year colleges to carry on cooperative projects beyond the capabilities of an institution working independently; and (C) support for associations of junior colleges working with a major college or university on problems of curriculum and curriculum articulation. Table 7 records fiscal year 1970 funding of the respective components.

Through the Undergraduate Research Participation Program, over 3,100 students shared in the research and study activities of university scientists, thus gaining intensive exposure to both the satisfactions and frustrations that scientific work can bring. A small but significant number of special projects were funded to encourage development and testing of new ideas, concepts, and techniques in the teaching of undergraduate science.

In its programs to support undergraduate science education, the Foundation, while recognizing the need for maintaining and indeed improving the preparation of those who will be the nation's future scientists, has also turned its attention to new problems and ways to help undergraduate institutions meet their changing responsibilities. In this endeavor, several areas have begun to receive particular emphasis.

The Need for Relevance

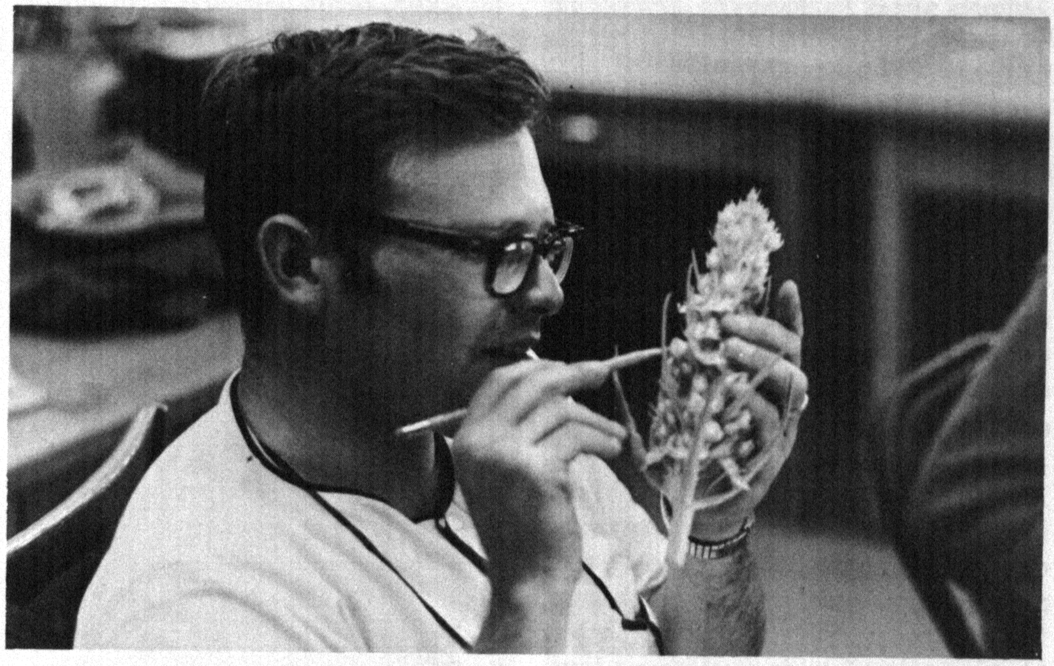
One of the major issues in undergraduate education is the need to face the question of what science has to offer in the solution of problems of intense concern to many undergraduate students, particu-

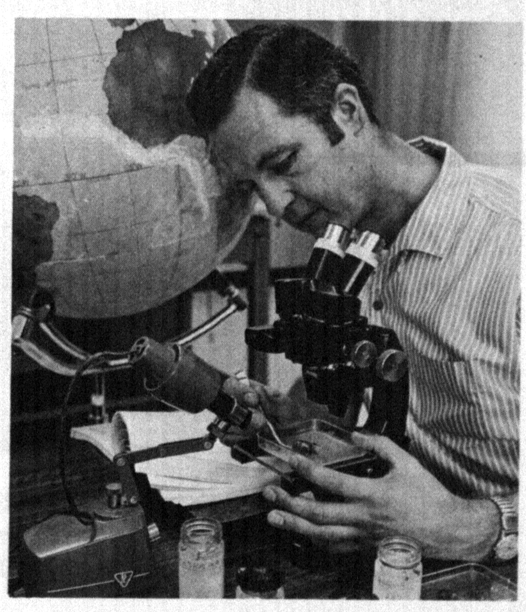
Table 7
College Science Improvement Program

	Requests		Grants	
	Number	Amount	Number	Amount
Individual Institutions	58	$12,812,984	25	$5,235,900
College Associations	20	3,869,344	11	887,500
Junior College Cooperative Projects	26	1,927,400	10	680,800
Evaluation Contract				25,000
Total	104	18,609,728	46	6,829,200

larly the contamination and pollution of the physical, biological, and social environments. Several of the NSF undergraduate programs are encouraging the introduction into curricula of a consideration of the applications of science to a wide variety of these emerging problems.

An increasing number of college teacher programs will respond to the desire of undergraduate teachers for better understanding of the interactions of science and technology with society. For example, a Short Course on "Models of Urban Spatial Structure and Ecology" at Ohio State University is being given in response to the recent convergence of research themes in economics, geography, sociology, and social psychology which focus on the structure and organization of urban space. Problems of metropolitan government, transportation, land use, housing, employment, social conditions, and health all have important spatial dimensions which at present are only partially understood. It is the intent of the Short Course to review critically ongoing research into the spatial structure of cities and to promote the dissemination of urban research findings among a wider group of social scientists and policymakers. Another Short Course on "Engineering and the Technological Society" at Ohio University assists social science teachers in assessing the social consequences of technological development—such phenomena as machines, automation, energy resources, the computer—and encourages them to develop curricula on the role of technology in our society. A Summer Institute on "History of Technology" at the Smithsonian Institution surveys the evolution of technology from antiquity to the early 20th century, with emphasis on the interactions between technology and the physical sciences and on the unsolved problems. Discussion of these problems—requiring no costly equip-

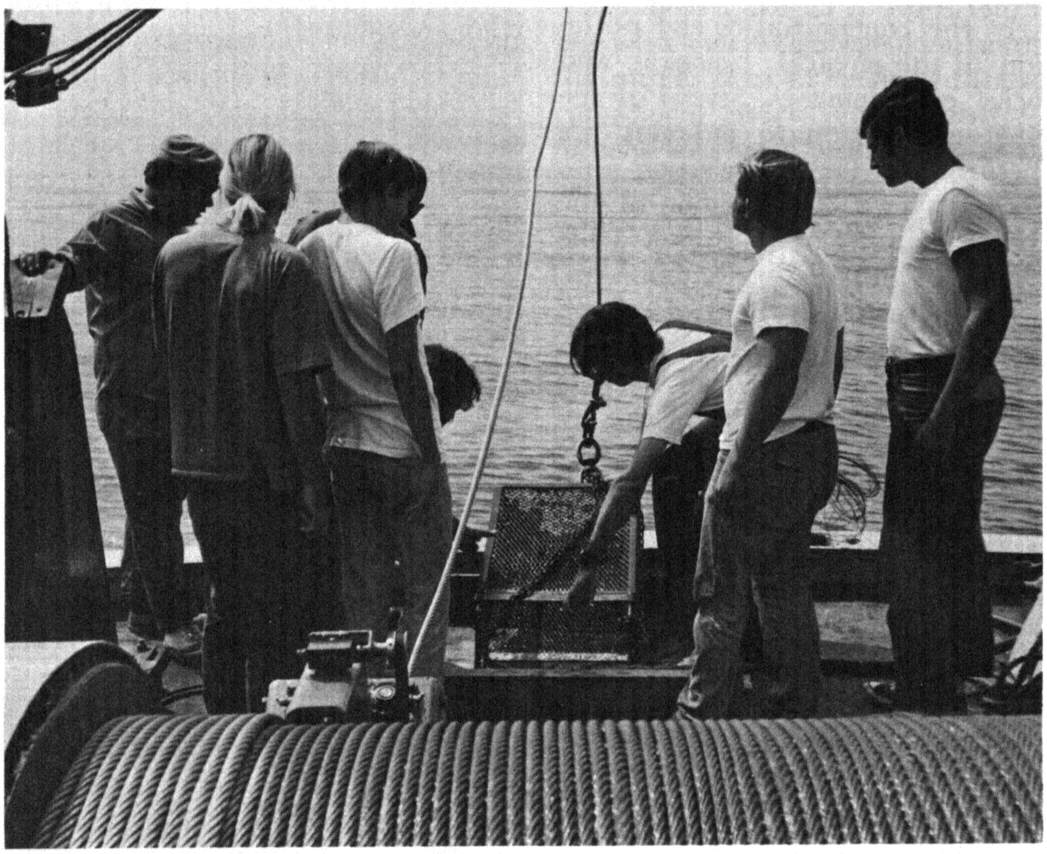




During fiscal year 1970 more than 3,000 college teachers participated in programs to enhance or update their knowledge and capabilities through Summer Institutes, Short Courses, or Research Participation. (Photos University of Miami) ment or personnel—is particularly well suited to exploitation by teachers at smaller colleges. The institute also includes opportunity for original investigations using the notable resources and personnel of the Smithsonian Institution.

At several institutions, support under the College Science Improvement Program has facilitated introduction of more "relevance" into courses and curricula. For example, the Departments of Physics and Biology at Albion College (Michigan) are concerned with revising curricula so that they recognize and attack significant current problems. Former science students and other visiting scientists, including at least one Nobelist, have served as advisors and lecturers while the college faculty are carrying out the curriculum changes. At Sweet Briar College (Virginia), the focal point of the project is the establishment of a center for ecological studies utilizing the college's exceptional campus of 3,400 acres and the surrounding rural and urban communities. Participating in this multidisciplinary activity are the Departments of Biology, Psychology, Economics, Government, Sociology, and, to a lesser extent, Chemistry and Physics.

Several proposals reaching the Undergraduate Special Projects Program indicate that, in faculty-student interactions, students are often the prime moving force. During fiscal year 1970, five grants were made to support student-originated and -managed research or study projects directed toward problems of the physical, biological, and/or social environment. For example, at Heidelberg College, five undergraduate students will conduct a study of pollution of the Sandusky River. The students plan to investigate the extent of agricultural fertilizer runoff and its contribution to the nutrient pollution of the river, the rate at which biodegradable detergents in the river break down as the water



Undergraduate students from several Southern California colleges collect marine samples from the teaching-research vessel *Vantuna,* developed with the aid of a College Science Improvement Program grant. (Photos Occidental College) temperature changes, and oxygen depletion below the towns of Bucyrus and Upper Sandusky. Through the project, the students hope to obtain results useful in local pollution controls, but with applications to more widespread problems; and to arouse interest and gain experience in environmental research. In recognition of the strong student interest in such problems, and to encourage students to express productively their concern for the environment, the Foundation announced (on Earth Day, April 22, 1970) its intention to initiate a new program, Student-Originated Studies (SOS), to provide support for interdisciplinary groups of college and university students prepared to undertake a search for solutions. It is expected that the first grants under SOS will be made in fiscal year 1971, with project activities beginning in the summer of 1971.

The Junior Colleges and Technician Education

Since 1965, when NSF institutes and short courses for college teachers were opened to applications from junior college teachers, the number of participants from junior colleges has risen steadily. In the spring of 1968, at a combined meeting of project directors of all college teacher programs, a full session was devoted to a discussion of the college-parallel programs offered in junior colleges, the project directors being joined by a large number of junior college representatives. That meeting culminated in suggestions for an entirely new cooperative program for junior colleges, directed toward developing better articulation between the programs of the 2-year colleges and the upper-level programs of 4-year colleges and universities. The proposed program, now identified as one component of the College Science Improvement Program, was initiated in the following year and has, since its beginning, provided funds amounting to $2.7 million for support of 41 associations of junior colleges (a total of 467 colleges) in 23 States, each association working in cooperation with a major nearby college or university.

The Foundation recognized, even then, that in concentrating its attention on college-parallel science courses, it was essentially ignoring one of the important fields of activity of many of the junior colleges—that of providing training for students in technical fields. The extent to which the Foundation should become involved in the education of technicians and technologists was at one time a question of major concern. The question as to "whether" was resolved in 1969 with the decision to support several institutes dealing with technician-training subjects. Fiscal year 1970 saw expanding support for technical education, most of it directed toward development of curricula and teaching materials for training of the kinds of technicians now needed to provide adequate backup for scientists and engineers. For example, the Chemical Technician Curriculum Project (ChemTec) has begun development of curriculum materials for a 28- to 30-semester-hour chemistry core for a 2-year college level program in chemical technology. Located at the Lawrence Hall of Science in Berkeley, Calif., the project developed in summer 1970 texts, laboratory experiments, film-loops, and other teaching materials, which are being field tested in 12 pilot schools during academic year 1970–71. The experience accumulated will be used to revise the materials in the summer of 1971 and prepare them for release through conventional commercial channels. So that the training will be consistent with the abilities and interests of the target group of students, the curriculum will emphasize laboratory work and direct "hands-on" experience. The aim is comprehensive coverage of basic chemical subject matter which, through modular organization of the content units, will encourage the inclusion of locally important topics and modifications.

A major study of engineering technology education is being conducted by the American Society for Engineering Education as a guide to later developments and to institutions engaged in the training of technicians and technologists. Included is a broad survey of all technology education — 2-year, 4-year, and graduate programs—together with an assessment of the industrial demand for the personnel output at the various levels of training, and suggested curriculum accreditation standards.

Based on experience with projects thus far supported, and in response to a number of recent studies indicating a continuing shortage of adequately trained technicians and technologists, plans have been developed for introduction, in fiscal year 1971, of a new program specifically oriented toward Technical Education Development.

Pre-Service Teacher Education

The Pre-Service Teacher Education Program has, up to fiscal year 1970, been concerned with the education of prospective elementary and secondary school teachers. During the past year, however, concern about the preparation of teachers at the college level increased considerably—not about their knowledge of the subject matter of science, but about their acquaintance with the teaching-learning process. There is questioning, too, of the preparation for teaching offered in the course of earning the Ph.D., even though many who take this course will eventually become teachers in undergraduate colleges. Fellows and research assistants may have little chance to learn about the rewards of a career as a teacher;

teaching assistants often have a distressing or disappointing experience, as too many are expected to function without benefit of guidance, to the detriment of their undergraduate students. Several conferences held during the year have addressed the problems in current patterns of using teaching assistants. Consideration is being given to providing support in some form that, while meeting the needs of the graduate students acting as assistants, will focus on providing better instruction for the undergraduates.

Problems of Communication with the Academic Community

Because adequate communication between the National Science Foundation and the college and university community is an integral part of developing effective support programs for undergraduate science education, strong efforts have been undertaken to further exchange of information. Mass mailings of lists of projects conducted under the Undergraduate Research Participation Program and the various Programs for College Teachers seem to be effective in apprising prospective participants of available opportunities, judged by the number of applications for participation. On the other hand, preliminary proposals for special projects and curriculum improvement indicate that the academic community is not sufficiently informed about projects and developments already under way. It is in this area—the dissemination of information about ongoing activities or about materials already developed and in many cases available for distribution—that avenues of communication seem ineffective.

Attempts were made during fiscal year 1970 to broaden these avenues in two ways. In February 1970, abandoning the project directors' meetings usually conducted program by program, arrangements were made for a more comprehensive meeting, bringing together for the first time project directors of all NSF undergraduate programs. This group, almost 1,000 in number, spent 3 days in Washington hearing about and discussing topics of current importance in undergraduate science education. Some of the topics covered were: instructional technology, new course patterns, science for nonscience students, student-originated research, graduate teaching assistants, preservice teacher education, and technology education.

The other attempt took NSF staff members out of Washington, closer to the scene of activity in the colleges and universities. For periods of 2 weeks, NSF staff were present in each of three major cities—Atlanta, Boston, and Minneapolis. Colleges in each of the areas were notified well in advance, and appointments were scheduled enabling individual faculty members or, more often, groups of faculty members, from area schools to discuss Foundation-related matters with NSF staff members on duty during the period. The response was greater than expected; during each 2-week period the staff were visited by, on the average, some 200 faculty members representing 40 colleges. Plans are now being developed to extend the operation to seven other areas during academic year 1970–71.

PRE-COLLEGE EDUCATION IN SCIENCE

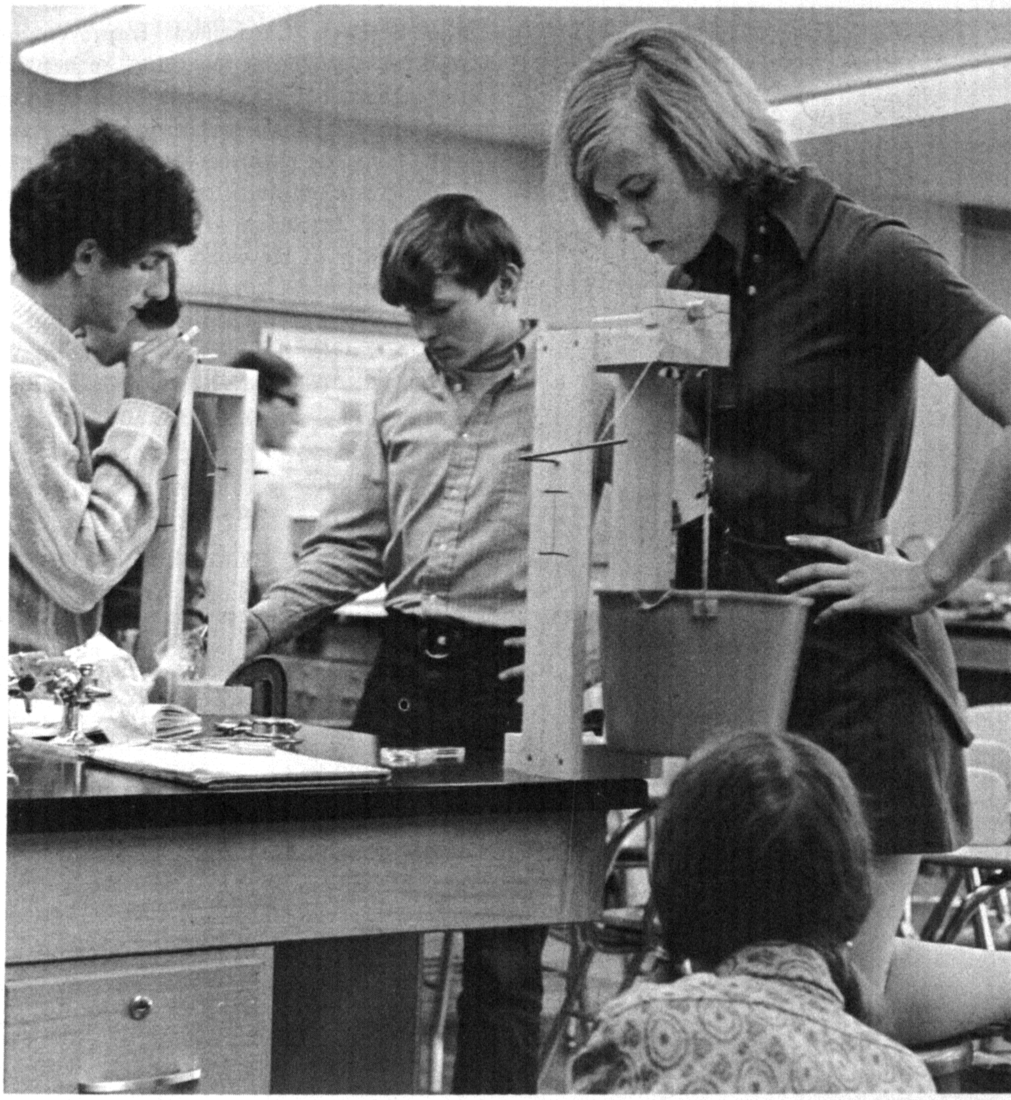
Through the Division of Pre-College Education in Science, the Foundation administers programs for the development of scientific talent, the supplementary training of teachers, and the improvement of school science programs for all students. By far the largest portion of funds available for this level, nearly 75 percent in fiscal year 1970, is devoted to in-service training for secondary school teachers and supervisors through the various institute programs. These programs cover all the scientific disciplines and include a broad range of activities from short briefing conferences on new teaching materials to intensive studies during the academic year and/or adjacent summers. Nearly 50,000 individual teachers and science supervisors will participate in institute programs during the summers and academic year of 1970–71.

In addition, about 6,300 elementary and secondary school teachers will receive in-service training through Cooperative College-School Science (CCSS) projects. The primary objective of CCSS is the effective introduction of new teaching materials and methods in a school system or related group of schools through a plan developed jointly with a university whose staff then helps with implementation.

Course Content Improvement projects are concerned with developing better instructional materials for science education from kindergarten through the 12th grade, ranging from single-topic pamphlets to multimedia courses, from equipment for students to resource materials for teachers. Included also are Resource Personnel Workshops to train leaders who will then initiate local in-service programs for the effective use of new curriculum materials.

The Student Science Training Program for developing scientific talent is a relatively small component of pre-college activities, accounting in fiscal year 1970 for 3.7 percent of the total budget to support training for some 5,500 students. These special study opportunities in science and mathematics for high school juniors of outstanding ability not only further their science interests, but help them in career decisions which usually begin to crystallize at this level.

The way in which the various pre-college programs interact is il-



Students investigate gravitational potential energy in Physical Science II class. This course is intended for the middle segment of the high school population but can serve as a preparation for more specialized courses in science. (Photo Educational Development Center)

lustrated by several examples of the kind of approach made to problem areas that represent priorities for fiscal year 1970 and the coming years.

Second Generation Curriculum Efforts

During the past decade, Foundation support has been predominantly focused on strengthening the quality of instruction in the schools as they now function. The new courses developed and the programs for teacher training have emphasized up-to-date content and student experimentation and inquiry, but they were designed to fit established curriculum guidelines. The disciplinary structure of subject matter characteristic of the senior high school was maintained, with the middle school (7th through 9th grades) representing a transition stage to the basic disciplines of chemistry, biology, and physics. Mathematics is unique in the sciences in having a separate disciplinary niche throughout all levels of instruction.

With Foundation support, curriculum materials have been developed in mathematics and the natural sciences which can now be sequenced to provide a variety of curricula from kindergarten through high school, and a substantial start has been made in assisting schools in their implementation. The present stage of development can be regarded as a first generation effort. Two basic problems must now be confronted:

—Should there be a next round of curriculum effort, and, if so, what should be its directions?

—How can the Foundation help improve the learning environment in the schoolroom? This includes not only problems of teaching competence and implementation of better curricula but also support of new ways to better utilize time and space.

In the consideration of these problems, new objectives have been identified and activities initiated or planned.

Scientific Literacy vs. Scientific Manpower

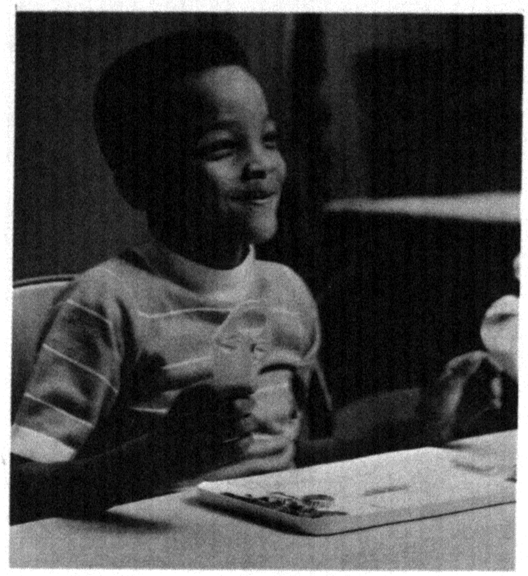
The first efforts supported in curriculum development in the early sixties were aimed at developing materials for the students who generally enroll in high school science courses, ranging from 80 percent in biology to 25 percent in physics. Some critics argue that these courses are too rigorous and sophisticated for nonscience students. For the junior high school and earlier, where all students take science courses, the materials have been specifically designed to fit the requirements of all students insofar as that can be done. It is now clear that a second generation of materials is required which provides more options and is geared to the needs of students not necessarily intending a scientific career. At the same time, efforts will continue to support development of some materials for scientifically gifted students when such needs are documented. For example, in fiscal year 1970 a grant was awarded to Columbia

University for an integrated mathematics sequence in grades 10–12. This is deliberately designed to serve high-ability students who are likely to become mathematicians. Over the last several years, however, support of materials for talented students has amounted to less than 10 percent of total pre-college course improvement, a proportion likely to be maintained for the present.

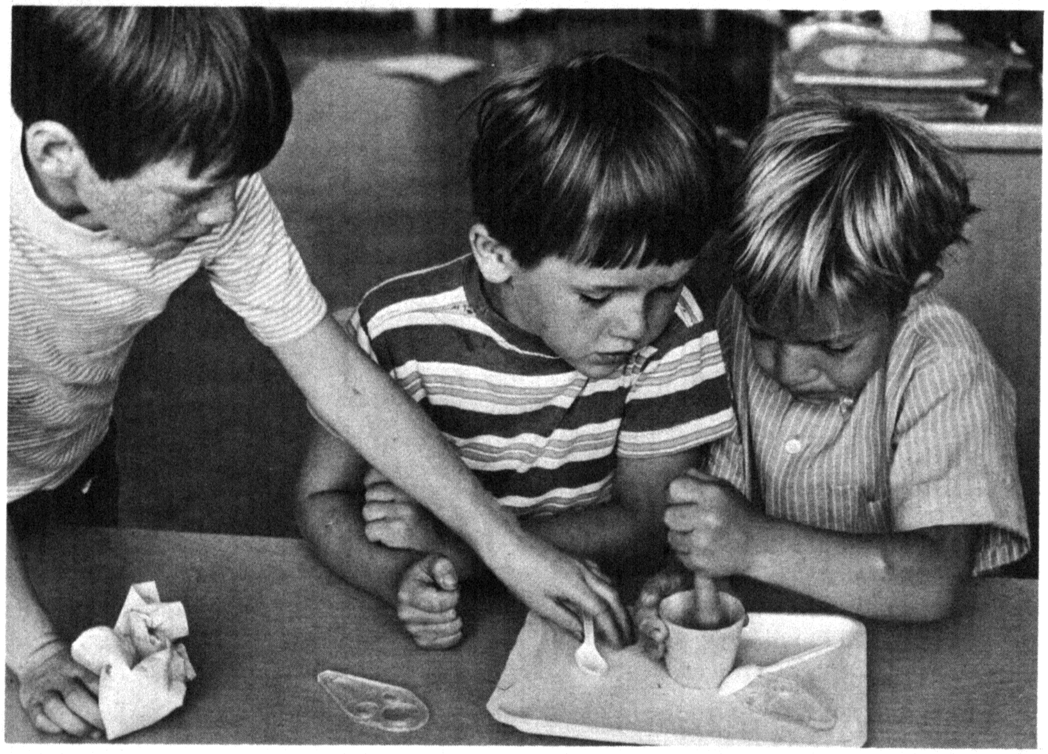
Interdisciplinary Courses

A substantial investment has been made in the development of interdisciplinary courses for the junior high school level. An example of one of these will illustrate how curriculum development proceeds, and what subsequent steps are necessary to implement the new courses.

The Earth Science Curriculum Project (ESCP) was initiated in the summer of 1964 through a grant to the American Geological Institute. At that time, spurred by the nation's space exploration program and by increasing concern with the physical environment, rapid growth in earth science instruction took place in junior high school, but it was severely hampered by a dearth of good instructional material. Hence, earth scientists and educators planned, developed, and tested curriculum materials for a modern, interdisciplinary course. The textbook, *Investigating the Earth,* published in 1967 by Houghton Mifflin, is intended for use in the 8th or 9th grade, and covers the disciplines of astronomy, meteorology, oceanography, geophysics, geology and geography. The materials also include a laboratory manual, teacher's guide, field study guides, laboratory equipment and experiments. Current concerns of the study group are teacher training, both in-service and pre-service, implementation, and evaluation related to the use of the materials.



The Science Curriculum Improvement Study is developing ungraded, sequential physical and life science programs for the elementary school—programs which in essence turn the classroom into a laboratory. A child's elementary school years are a period of transition as he continues the exploration of the world he began in infancy. Extensive laboratory experiences at this time will enable him to relate scientific concept to the real world in a meaningful way. (Photos University of California, Berkeley)



Assistance to schools in the effective use of the materials has been provided through teacher training institutes, cooperative college-school science projects, and resource personnel workshops which provide training for teachers who then become leaders for in-service training projects in their own areas.

An illustration of the implementation of ESCP materials is exemplified in the State of Missouri. A resource personnel workshop held at the University of Maryland in the summer of 1968 trained teams from all sections of the country in the use of ESCP materials. The teams consisted of a college or university scientist, a school administrator, and a classroom teacher-leader. The team from Missouri organized a "second generation" leadership conference supported by the Foundation in the summer of 1969 which was designed to prepare teams from eight Missouri colleges and universities for a State-wide in-service ESCP training program. This was followed by an In-Service Institute project, starting with a 1-week preliminary session involving the participants from the eight separate in-service institutes scheduled to begin locally in September 1969. The result of these activities is described by John Hooser, Missouri State Science Supervisor and a member of the initial Missouri team.

> "Prior to the earth science project, only a few schools offered earth science. The State Department of Education did not offer certification in earth science. Since this project, there are 126 school districts, 231 teachers, 761 sections, and 21,000 students involved in earth science in Missouri. The State Department of Education has certified requirements for earth science. The first year of funding has made it possible to involve 110 to 115 teachers with eight colleges in this State-wide earth science project. This is approximately half of the teachers presently teaching earth science in the State. The teachers enrolled in this program will fulfill about half of the required hours of certification."

Grants have been awarded in fiscal year 1970 for the continuation of the in-service program in the eight colleges. Grants for ESCP teacher training and implementation activities awarded in fiscal year 1970 throughout the country include 18 summer institutes and conferences, 54 in-service institutes, and 11 cooperative college-school science projects. These projects will provide a variety of training opportunities in the use of ESCP materials for over 2,000 junior high school teachers. It is estimated that over a third of the million students now taking earth science in the secondary schools of the country are using ESCP materials.

Finally, to round out the set of activities ultimately required for curriculum and teaching reform, the ESCP has this year received an NSF grant through the Division of Undergraduate Education in Science for a teacher education project in which the ESCP will assist and coordinate a consortium of colleges across the country in the establishment of undergraduate curricula for prospective earth science teachers geared to current materials and techniques. Included as participants in the project will be Boston College, Southern Illinois University, Minot (North Dakota) State College, California State College at Fullerton, the State University of New York College at Oswego, Western Connecticut State College, and Colorado State College.

Social Sciences Curriculum Materials

The social sciences represent a major curriculum area in which development of suitable materials has lagged rather far behind that for mathematics and the natural sciences, with large gaps over the whole kindergarten to 12th grade range. Because there is no discernible consensus as to what an integrated sequence might be, the Foundation has supported the development of specific high school courses in geography and sociology, and of supplementary materials in sociology and anthropology for use in social studies courses. An interdisciplinary effort was initiated this year, led by Dr. Irvin De Vore of Harvard, to create a behavioral science course for the intermediate level on the general theme, *Exploring Human Nature.*

At the elementary level, an innovative 5th grade course neared completion in fiscal year 1970. This course, *Man—A Course of Study,* is based on three questions framed by Jerome S. Bruner, the principal developer: "What is human about human beings? How did they get that way? How can they be made more so?" The first half of the course concentrates on the life cycles and behaviors of salmon, herring gulls, and baboons. These studies lead students to assess the significance of generational overlap and parental care, innate and learned behavior, group structure and communication, and their relevance to the varying life styles of animal species, including the human species. The second half of the course is an intensive study of man in society—as culture-building, ethical creatures, toolmakers and dreamers. The Netsilik Eskimos of the Canadian Artic are studied in depth, because their society is small and technologically simple, yet universal in the problems it faces. Course materials rely heavily on research sources and present subject matter through a variety of media, including films, filmstrips, records, posters, and booklets.

This project posed an unusual distribution problem. Although the teachers and children involved in the trial phase of the development were enthusiastic about the course, commercial book publishers and film distributors were unwilling to contract for publication because of the variety of materials to be handled and the unconventional subject matter. Support therefore was made available to the sponsor, on the basis of a revolving fund award, to conduct a quasi-commercial publication and distribution operation to demonstrate the general public acceptance and the commercial feasibility of distributing the materials. The success of this venture is attested to by the fact that a publication contract has recently been executed with Curriculum Development Associates. Further implementation is being aided through the development of resource teams in teacher training institutions and through cooperative college-school science projects.

Teacher Participation in Course Development

One criticism of curriculum materials developed by nationally constituted groups of scientists and educators, and distributed through commercial channels, is that this procedure deprives local teachers of the opportunity to contribute their own creative efforts and develop their own ideas. As one approach to the problem, a grant was made this year to Indiana University for a project directed by Robert A. Hanvey to develop materials for supplementary units in cultural anthropology for secondary school social studies courses. These units will treat the topics of *Biological and Social Differentiation of Man* and *Science, Technology and Change,* each occupying from two to four weeks of class time. The final materials, instead of commercial textbooks, will be "unfinished" outlines, syllabi, and resource materials that may be fleshed out and refined to suit the teacher's specific needs and taste. Opportunities can then be provided through institutes or other means for individual teachers to complete adaptations for their own classes. To serve this kind of approach, the Summer Institute Program is encouraging prospective directors to submit proposals for special institutes in all disciplines that will permit teachers, with leadership from university scholars, to develop their own curriculum ideas which they do not have the time or resources to pursue during the teaching year.

Supervisory and Resource Personnel

There are two major problems in the introduction of new courses and methods into school curricula. One of these is the dissemination of information to administrators and supervisors sufficient to enable them to reach decisions on curriculum adoption. To try to meet this problem, the Foundation has begun support of short courses for administrators and science supervisors to acquaint them with new materials that are available. During the summer of 1970 the Foundation is supporting nine conferences for secondary school principals designed to provide information on curriculum developments. Also, the Association of Secondary School Principals cooperated this year in arranging informational workshops which were conducted during the annual meeting of the association. In addition, conferences for State science supervisors and State mathematics supervisors have been supported for the past 3 years. These conferences are concerned with current science education activities and problems; for example, this year's theme of the science conference was environmental education in the secondary school curriculum.

A second aspect of the implementation problem is the training of supervisors, subject-matter specialists, and resource personnel in the content and methods of new courses so that they can serve effectively as leaders in teacher training and implementation. Two avenues of support have been provided through pre-college programs. One of these is the Academic Year Institutes Program. Last year, the first academic year institute designed expressly for experienced, practicing supervisors was held at the University of Maryland, under the leadership of David Lockard. The applicant response to this innovation was so encouraging that a second such project is to be conducted by Ohio State University this year. Other academic year institutes stress intern training for science and mathematics supervisors-to-be, the placement of project graduates, and rigorous discipline orientation for subject-matter specialists in specific areas needing this kind of expertise.

The Resource Personnel Workshops approach the same problem in a different way by developing leaders in colleges and schools with sufficient in-depth understanding of one or more new curricula to initiate teacher training activities in their own schools and colleges reflecting the content and spirit of the new materials. This program, initiated as an experiment in 1967 with six grants, has expanded this year to 27 projects at a cost of over $1 million with provision for approximately 1,800 participants. The need for leadership training has been particularly acute at the elementary level since there is no existing cadre of experts for the interdisciplinary courses at this level analogous to college physicists, chemists, or biologists in the case of new high school courses in those disciplines. Demand for the elementary school materials is increasing as they become widely available, but familiarity with them has tended to be restricted to those science educators and teachers who had participated in their development.

Hence, the workshops are filling a real void in developing the resources necessary for implementing improved curricula.

One example of the "multiplier effect" of the workshop projects has been cited earlier in the Missouri implementation of ESCP materials. Another instance is the leadership development project in *Science—A Process Approach,* the American Association for the Advancement of Science elementary science curriculum, at Pennsylvania State University. The initial grant was made in 1968; follow-up studies in May 1969 (85 percent of those trained responded) revealed that the participants had trained 2,050 teachers, who in turn instructed almost 56,000 children in 1969–70. Moreover, those participants who are members of college faculties have already incorporated about 200 hours of instruction from the in-service course into their pre-service course for approximately 550 college students preparing to teach.

Experimental School Activities

To help each student learn at his own pace and to the extent of his own abilities, schools need to modify their rigid concepts of how to organize time and facilities, particularly at the elementary level. This is a difficult problem area for the Foundation which has historically been concerned with the support of science and mathematics education activities only. And yet, the problem is so critical and its scope so broad that joint funding with other agencies deserves consideration to support integrated educational efforts, with the Foundation responsible for the science and mathematics components. In this connection, Max Beberman at the University of Illinois received support this year for an intensive study of the suitability for U.S. elementary schools of the English "Integrated Day" approach. The main objective of the project is to establish at an experimental public school a working model of a total educational program which takes into account individual differences through using broad themes as vehicles for integrating the various traditional school subjects. The children work on projects, both individually and in groups. Emphasis is to be placed on interrelations between mathematics and science, the use of laboratory equipment and experimentation, and the invention of teaching procedures and student practices which develop the ability to reason.

Experiments of this kind appear to have great educational effectiveness in England, and offer promise for U.S. schools. It is therefore of prime importance to investigate the exportability of this kind of school experience to the American scene. The Foundation expects to extend this type of support to other experiments for reorganizing the structure of educational processes.

Program Evaluation

With rapid changes in the current climate of education, the present time is a critical one for reconsideration of NSF programs in pre-college education. The educational structure and its modes of operation for which the established NSF educational programs were conceived seem to be undergoing irresistible pressures for reform. Earlier evaluations are now for the most part obsolete and often inadequate to provide guidance for planning purposes. Hence, the Foundation intends to place increased emphasis on evaluation. Initial steps were taken in fiscal year 1970 to evaluate the impact of the Academic Year Institutes Program with distribution of a questionnaire to all participants in this program since its inception in 1956. From the returns, the staff will derive information on how influential this program has been in effecting changes in secondary schools to date, and whether the investment in time and money for the teacher participants has paid off and will be likely to pay off in the near future.

Data are also being collected from a sample population of science and social science teachers. This study, undertaken by contract with Vitro Corporation, will establish a baseline of teacher characteristics of the present era, so that past and future comparisons will be possible. Student participants in the pre-college programs are also being followed up in a contract with the American Council on Education. Of particular interest is a comparison of the influence of the Student Science Training Program on the current generation of high school and college students as compared with those of a decade ago, since comparable data were collected in 1960.

Beyond the appraisal of the effects of individual programs, the Foundation is now exploring ways of studying the total impact of pre-college programs through observation and data collection of change in science education in individual classrooms and school systems.

PUBLIC UNDERSTANDING OF SCIENCE

The overall objective of this program is public education with respect to science and technology, so that citizens may function more effectively in a technological society. This involves communicating not only the "facts" of science but also some appreciation of the relationship of science to other forms of scholarly investigation and some understanding of the scientific and technological aspects of societal problems. In fiscal year 1970 the Foundation made 15 awards, amounting to $212,488, for public understanding of science projects. The mechanisms employed included conferences, summer courses, an exhibit, design of a film series, curriculum development for an adult education program, and a State-wide information program on the scientific aspects of environmental pollution.

A recent issue of *Impact of Science on Society* discusses the problems of bringing about a public understanding of science. In one article Miguel Angel Asturias, 1967 winner of the Nobel prize for Literature, states: "In our day science and literature seem so far removed, so widely separated from one another that a poet or writer like myself looks with timid respect on everything relating to science, scarcely daring to inquire into, to glance at, the awesome discoveries of the scientists. There are those who speak, not unjustifiably, of a veritable schism in what is called Western culture, a schism which, at its most extreme, leads not a few men of letters and artists to ignore and despise the scientists and the technicians . . . ."

The problem is enormous and is compounded of a lack of knowledge of the humanistic origins of science, a confusion between science and technology, and a concern with the misuse of technology. What is worse—a misunderstanding of science and technology (and the difference between the two) is shared by the uneducated at all ages, by educated adults, and by many of our brightest youth.

The support of two seminars on the Impact of Science and Technology on Society for women community leaders and undergraduate women students represents an approach to the less scientifically oriented of our two sexes. These are to be carried out (one in September 1970 and one in January 1971) by the Oak Ridge Associated Universities, which in the past conducted similar programs for humanities professors and practicing clergymen.

Joint support of a Dialogue on the Identity and Dignity of Man with the National Endowment for the Humanities was an attempt to focus scientific knowledge and humanistic wisdom on such problems as Control of Population and Regulation of Behavior, Extension of Life Through Organ Replacement, and the Improvement of Life Through Genetic Manipulation. The dialogue was conducted at Boston University in conjunction with the annual meeting of the American Association for the Advancement of Science.

A Summer Session on the Quality of Life, supported by a grant to the Institute on Man and Science, helped a group of scientists, educators, doctors, lawyers, publishers, politicians, clergy, housewives, and students to explore the interactions of science, technology, and human values as they converge on environmental concerns. Predictions concerning the environmental state of the world in the near future were examined from the standpoint of solid experimental evidence, and participants sought solutions to real case problems such as the decision on where, if anywhere, in a given State to build nuclear reactors for increased electrical power.

Institutional Programs

Foundation programs for improving and sustaining science in institutions of higher education began to undergo substantial reorientation in fiscal year 1970. A major change in the basis for computing Institutional Grants for Science greatly increased the number of institutions eligible to receive these flexible funds. Two separate programs designed to develop science in doctoral-level universities were replaced by a single Science Development program. And the oldest of the Foundation's institutional programs —Graduate Science Facilities—was discontinued as a discrete grant-making activity and became contributory to the new emphases planned for institutional development. Most of the changes in organization and function came late in the year, however, and their results will provide the content of future annual reports.

NSF obligations under the institutional programs discussed below appear in table 8.

SCIENCE DEVELOPMENT

For several years the Foundation has been making a large and sustained effort to increase the number of universities capable of conducting distinguished programs of education and research in the sciences. The widely known University Science Development (USD) activity, initiated in March 1964, aimed to help very good universities to become excellent. USD has normally provided funds to improve several science departments in an institution. A related program, Departmental Science Development (DSD), begun in fiscal year 1967, has focused on a single department or area of science within a university. In both programs the Foundation's intention has been to assist universities in the achievement of their long-range science goals, and the grants have been predicated on substantial commitments of the institutions' own resources to the execution of their development plans. The 3-year grants under the DSD program have not been renewable for the same department, but the USD program has usually offered the prospect of 2 years of supplementary support if the initial grant resulted in the anticipated progress.

In fiscal year 1970 the Foundation obligated $15.9 million through the University Science Development program. Supplementary awards to the University of Colorado, the University of Georgia, Louisiana State University at Baton Rouge, the University of Oregon, and the University of Rochester accounted for $10.3 million; 3-year grants to Brandeis University, Northwestern

Table 8
Obligations for Fiscal Years 1968, 1969, and 1970
(Millions of dollars)

Program	Fiscal year 1968		Fiscal year 1969		Fiscal year 1970	
	Number of awards	Amount	Number of awards	Amount	Number of awards	Amount
Science Development:						
University Science Development	9	$29.6	9	$23.1	9	$15.9
Departmental Science Development	29	12.0	15	8.6	18	10.6
Graduate Science Facilities	50	17.8	14	6.0	15	4.0
Institutional Grants for Science	497	14.2	(1)	(1)	634	14.5
Total	585	73.6	38	37.7	676	45.0

[1] A change in the timing of awards from June 1969 to fall 1969 resulted in no obligations in fiscal year 1969.

UNIVERSITY SCIENCE DEVELOPMENT GRANTS
FISCAL YEARS 1965-1970

* Three-Year Special Science Development Grant Resulting from USD Proposal

o One-Year Planning Grant

University, and the State University of New York at Stony Brook, and a 1-year grant for curriculum development and planning to the University of Connecticut, accounted for the remainder of the obligations. The Foundation has awarded \$168.7 million through the USD program since its beginning. Thirty-one institutions have received large, multidisciplinary awards, and of this group 11 have thus far qualified for supplementary grants. Counting the supplements, the average NSF development support for the 31 institutions already amounts to \$5 million. Eleven other institutions have received special awards based on parts of their science development proposals. These special grants are somewhat less comprehensive and are smaller in amount, although one amounted to \$2 million and three others to more than \$1 million.

Through the Departmental Science Development program the Foundation obligated \$10.6 million in 18 awards in fiscal year 1970. Since the program began in fiscal year 1967, 59 grants amounting to \$33.1 million have been made to 54 institutions in 32 States. (Five universities have received two awards.) The grants have averaged \$560,000.

In both programs public universities have received more funds than private institutions—62 percent of the total in the USD program and 65 percent in DSD.

The DSD program has especially emphasized the improvement of the quality of faculty and graduate students as the principal means of institutional development. Nearly two-thirds (65 percent) of the DSD funds have been allocated for manpower. The comparable figure for the USD program is 40 percent. One important difference between the two programs is that only small amounts of DSD grants have been for renovation of facilities, whereas nearly one-fourth of the funds of the USD grants has been for construction or renewal of science buildings. Both programs have allocated a substantial share of their funds for the purchase of equipment and supplies and some funds for library resources, computer costs, and travel.

By field of science, slightly over half of the USD program funds was for physical sciences and about one-sixth for life sciences. Engineering accounted for 12 percent, mathematics for 11, the social sciences for 6, and environmental sciences for 3. A considerably larger share of DSD program funds has been awarded for the social sciences—13 percent in all years and 22 percent in fiscal year 1970.

The Foundation has expected institutions receiving development grants to make contributions of their own funds to their improvement. Thus, the institutional commitment under the DSD program amounts to nearly one-half of the estimated total development cost; the \$33.1 million in DSD grants amounts to only 17 percent of the total; the remainder (about one-third) of the development costs is expected to come from other sources. Similarly, under the more expensive development activities aided by USD grants, institutions have committed themselves to make contributions greater than the Foundation. Thus far, most institutions in the USD program have contributed from their own resources at least as much as they had initially projected, and sometimes considerably more. Experience under this program, which is greater than under the newer DSD program, indicates that universities can construct realistic plans which set important and attainable goals; that the NSF grants have stimulated improvement not only in the departments supported but often in other parts of the institution; and that the achievement of an institution's primary goals justifies supplementary NSF investment in support of its further planned development.

One of the chief hopes for the USD program was that it would eventuate in the emergence of very high quality universities in areas of the country having none or too few such centers. A similar goal to strengthen resources for advanced scientific education and research in as many regions and population centers of the nation as possible animated the DSD program. The accompanying maps show how this purpose has thus far been attained through the development programs. Underlying this policy of geographic distribution has been the desire to further the national goal of equality of opportunity for higher education and to help achieve equitable distribution of the beneficial effects of strong educational and research centers.

The separate University and Departmental Development programs were incorporated in a new Science Development program near the close of fiscal year 1970. Besides making departmental grants, this reshaped institutional development program will provide continuing opportunities for supplementary grants, as well as other forms of developmental support, to the institutions that have already received awards through the USD program. The program will also expand institutional development activities of the Foundation in new directions by seeking to stimulate the development of institutional capabilities in the social sciences and interdisciplinary areas so that the recipient universities can effectively participate in the solution of important problems confronting society. The nation's foremost universities, which have formerly been discouraged from applying for NSF development funds, will be eligible for support under some of the new categories of institutional development. Also, in attempting to develop centers or institutes focusing on national problems, the Foundation will foster concerted efforts of a variety of institutions, nonacademic as well as educational.

(A related development program—College Science Improvement—is discussed in the chapter on Education in the Sciences.)

GRADUATE SCIENCE FACILITIES

Graduate Science Facilities, the first of the Foundation's institutional programs, completed its 11th year in fiscal year 1970. Aimed at sustaining the strength of graduate-level science departments, the program provided funds for the renovation and construction of academic facilities for research and research training. In fiscal year 1970 the Foundation obligated through the program $4 million to 15 institutions. The average grant was $267,178, substantially below the average of $446,000 in fiscal year 1969. As noted above, the Foundation has decided to discontinue, for a year at least, Graduate Science Facilities as a separate program and to use its resources in the reoriented science development activity.

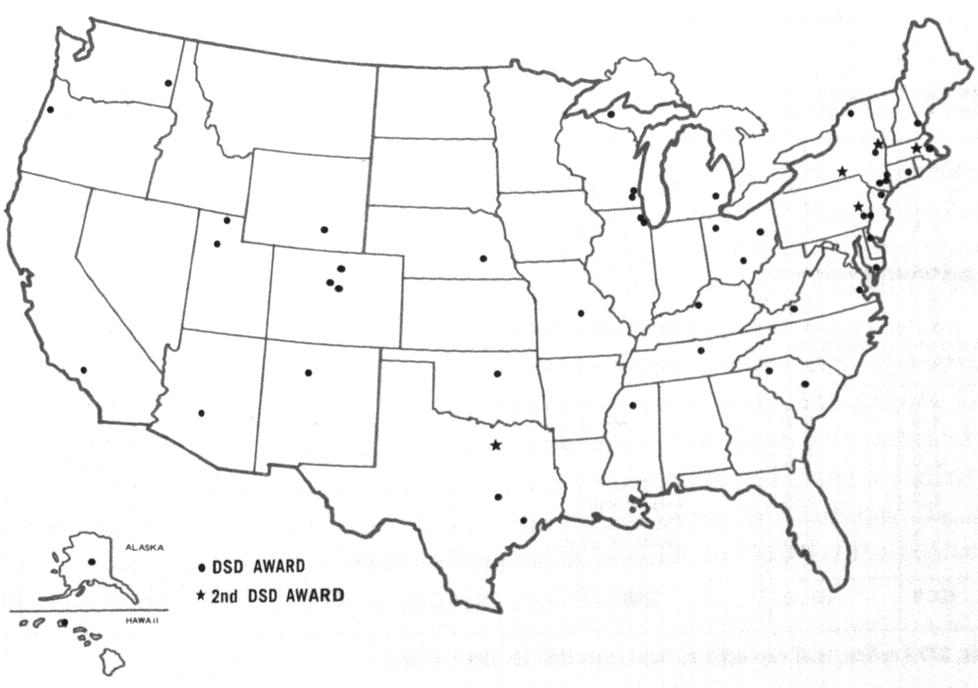
During the 11 years since its inception, the Graduate Science Facilities program provided $186 million to 179 different institutions of higher education. The recipient institutions were required at least to match the NSF funds. They usually overmatched. The actual facilities constructed with NSF support have cost about half a billion dollars and accommodate approximately 40,000 academic personnel in research and graduate education. The 10 million net square feet of space they use is comparable in size to the entire academic facilities of Michigan State University (East Lansing) and the University of Maryland (College Park) combined.

INSTITUTIONAL GRANTS FOR SCIENCE

Through its program of Institutional Grants for Science the Foundation provides funds for the general support of science in U.S. colleges and universities. Campus officials determine how the grants will be used, and this discretionary nature of the funds makes them uniquely adaptable to local circumstances.

In fiscal year 1970 the Foundation made an important change in the program. In earlier years the grants had been computed by applying a graduated arithmetical formula to the amount of NSF research

DEPARTMENTAL SCIENCE DEVELOPMENT GRANTS
FISCAL YEARS 1967-1970



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Dreyfus Chemistry Building at Massachusetts Institute of Technology. (Photo MIT)

and research-training support received by an institution. The fiscal 1970 awards were computed on a much wider Federal base—the research obligations to colleges and universities of the Departments of Agriculture; Commerce; Defense; Health, Education, and Welfare (exclusive of the Public Health Service); Housing and Urban Development; Interior; Transportation; the Atomic Energy Commission; the National Aeronautics and Space Administration; the National Science Foundation; and the Office of Economic Opportunity. (The Public Health Service awards were excluded to prevent overlap with similar formula-grant programs of the National Institutes of Health.) In addition to these Federal research obligations (for fiscal 1968) the Foundation continued to include in the computation base awards made through the NSF programs of Undergraduate Research Participation and Research Participation for College Teachers.

The extension to a broad Federal base resulted in the eligibility of many institutions that had not participated in the program before. The largest number of Institutional Grants in any earlier year had been 517; in fiscal 1970 grants totaling $14.5 million were made to 634 institutions. The formula continued to provide 100 percent of the first $10,000 of an institution's base figure, but the subsequent percentages were much smaller than in earlier years. The largest grant ($138,967) amounted to less than one-fifth of one percent of the amount on which it was based. Some institutions that had participated in the program before benefited from the shift to a broader Federal base, but most did not. The average grant dropped from $28,410 to $22,894, and the median grant from $13,256 to $10,800. Eighty institutions that had received fiscal year 1968 grants suffered reductions of 30 percent.

Since the beginning of the pro-

Table 9
Uses of Institutional Grant Funds
Fiscal Years 1962–69

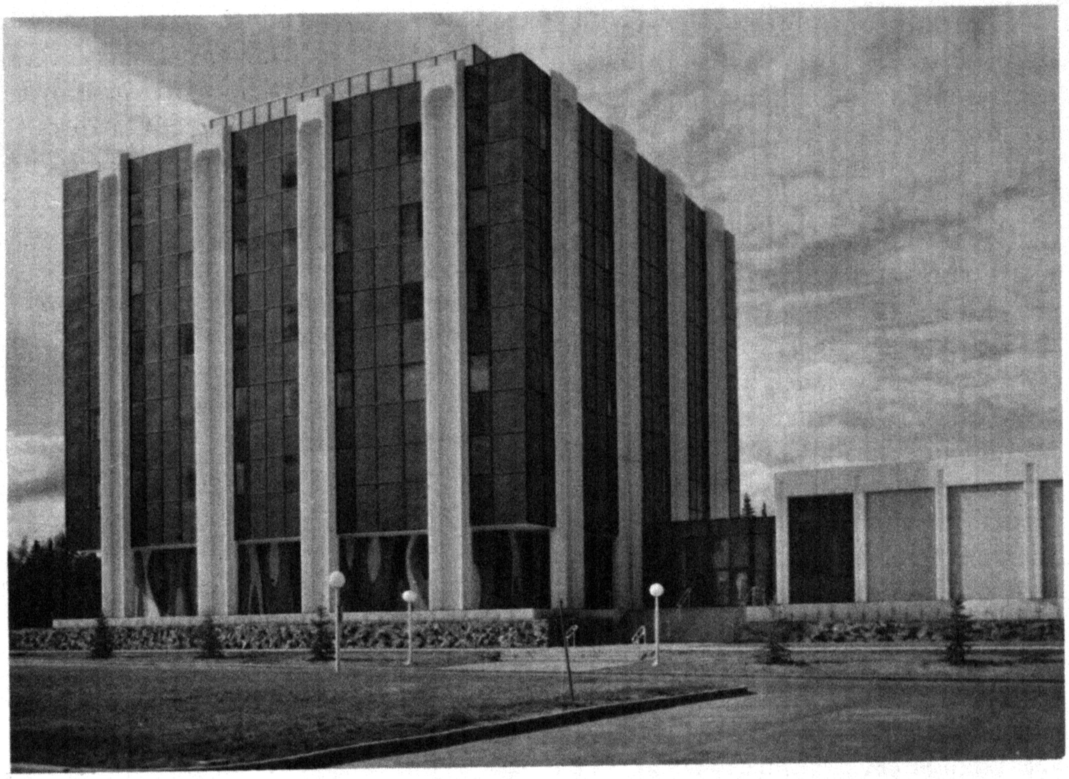
[Millions of dollars]

A. Type of use:	Amount spent [1]	Percent of total expenditures
Equipment and supplies	$34.8	50.6
General	32.0	46.5
Libraries	2.8	4.1
Facilities	11.2	16.3
General	8.1	11.7
Computers	3.2	4.6
Personnel	19.3	28.1
Faculty salaries	9.0	13.1
Graduate assistants	3.9	5.6
Other student stipends	1.9	2.7
Visiting lecturers	1.1	1.6
Technicians' salaries	1.8	2.6
Other	1.7	2.5
Travel	1.7	2.5
All other	1.7	2.5
Total	68.9	100.0

B. Field of science:	Amount spent [1]	Percent of total expenditures
Physical sciences	$24.6	35.7
Astronomy	1.0	1.5
Chemistry	12.5	18.2
Physics	10.1	14.7
Other	0.9	1.3
Mathematical sciences	3.4	5.0
Environmental sciences	5.5	8.0
Atmospheric sciences	0.8	1.1
Earth sciences	3.9	5.6
Oceanography	1.0	1.4
Engineering	8.6	12.5
Life sciences	14.7	21.4
Psychology	2.7	3.9
Social sciences	4.2	6.1
All other (inter- and multidisciplinary)	5.2	7.5
Total	68.9	100.0

[1] From awards made fiscal years 1961–68. Total amount of awards, $79.4 million; total expenditures fiscal years 1962–69, $68.9 million.

NOTE: Totals do not add because of rounding.



C. T. Elvey Building, The Geophysical Institute, University of Alaska. (Photo University of Alaska)

gram in fiscal year 1961, the Foundation has made Institutional Grants amounting to $94 million to 820 colleges and universities. Many of these institutions have participated in the program every year.

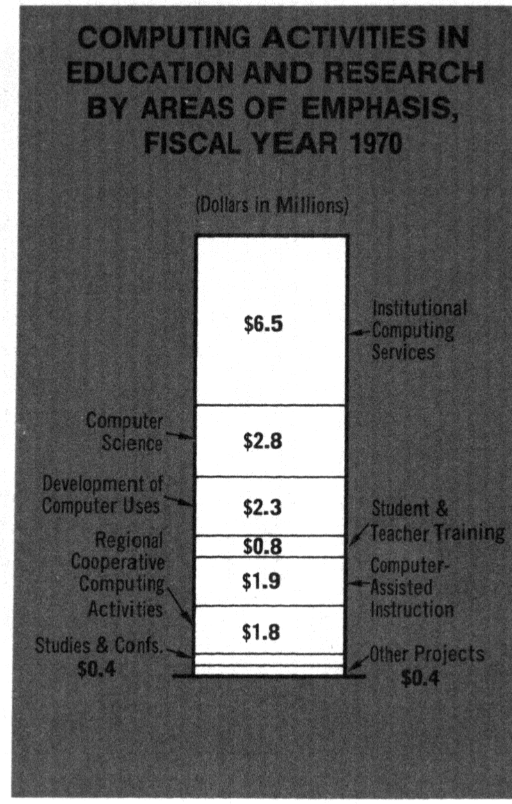
As table 9 shows, about half of the funds has been spent for equipment and supplies; about one-sixth for construction, renovation, and computer costs; over one-fourth for personnel; and small amounts for travel and other uses. By field of science, more than one-third of the funds has been allocated to the physical sciences and more than one-fifth to the life sciences. The social sciences and psychology if combined accounted for one-tenth of the total expenditures.

Although the grants are not large, their flexibility makes them unusually useful for such purposes as the following: ensuring a backup for commitments and freedom from normal budgetary constraints; making available small research grants for new faculty members; providing means of keeping graduate students on campus during the summer and of speeding up the earning of degrees; encouraging undergraduate research and interest in scientific careers; facilitating the employment of new faculty members; bolstering neglected departments or areas and maintaining balance; breaking down traditional barriers between departments and colleges; fostering the development of central services used by several departments; and exploring new means of instruction and new fields of research. Local control and ready availability of the funds have permitted institutional officials to respond quickly to unanticipated needs and opportunities. In such ways the grants have helped to maintain the strength of academic science during a period of growing financial constraints and have helped to uphold institutional autonomy.

Computing Activities in Education and Research

Computers and related methodologies exert a pervasive influence on research and educational efforts in many disciplines, and particularly in interdisciplinary projects. Hence, various programs throughout the Foundation are involved with computer-related activities, but the Office of Computing Activities is the primary focus for support and coordination of such projects. Since this office was established in 1967, it has developed a variety of programs to promote research, to foster educational innovations, to explore training techniques, to assist the improvement of academic resources, and to promote institutional cooperation in the area of computing.

The figure below shows the distribution of fiscal year 1970 funds by major program categories, and table 10 gives the history of awards. Areas of emphasis during the year are illustrated through a sample of projects supported.



EDUCATION, RESEARCH, AND TRAINING

The technologically advanced computing industry is built on a rather narrow research base, so academic work in computer science helps broaden this base while training future specialists. One of the principal features of current research is the attempt to bring structure and definition to computer science through providing the experimental evidence and theoretical understanding which will permit guided development. Other thrusts involve studies of the implications of new technology for hardware and software and efforts to extend the utility of computers.

Investigations of theoretical foundations of computing are being supported at various universities throughout the country. A grant to the University of California at Los

Table 10

Computing Activities in Education and Research
Awards by Program Categories, Fiscal Years 1968, 1969, and 1970

[Millions of dollars]

Section	1968		1969		1970	
	Number	Obligations	Number	Obligations	Number	Obligations
Education, research and training	64	$6.1	116	$5.9	89	$6.0
Institutional computing services	42	10.6	23	6.5	23	6.5
Special projects	67	5.3	55	4.6	75	4.5
Total	173	22.0	194	17.0	187	17.0

Angeles will enable experiments with computer systems to determine parameters which can be measured as sensitive indicators of systems performance. Also, the development of very complex integrated circuits with components a few thousandths of an inch in size points to new hardware and software possibilities. A project at the University of Texas is concerned with micro-programming, in which the operations of the computer are built up in a flexible way from very simple, fundamental, logical instructions. Other grants, to Rice University and to the Universities of Iowa and Michigan, support research in the application of repetitive arrays of basic logical elements to theoretical aspects of system design.

The use of computers to restructure the teaching of subjects in many disciplines and to develop interdisciplinary, problem-oriented curricula is in the ascendancy. At Dartmouth, the Departments of Sociology and Political Science are developing data bases and an inquiry system which permit students to investigate, through a computer link, various relationships among data elements. In a short time, a student can develop good intuitive understanding of the relative significance of data elements, how to formulate questions to study relations, and how to pursue an evolving direction of investigation based on earlier results. This Project IMPRESS is jointly supported by NSF, the Alfred P. Sloan Foundation, and the Carnegie Corporation.

At the University of Michigan, computer simulations of living systems such as animal populations will serve as the basis for a course in natural resource management. A student will sample important parameters of the simulated populations, analyze data, formulate management programs, and evaluate the effects of his decisions. Through simulations of increasing sophistication, the student can be exposed to the complexities of real situations, challenged to make decisions based on the incomplete data available, and confronted with the long-term consequence of his actions —all at a computer terminal.

A project at Tulane University presents a unique opportunity to foster the utilization of surplus Minuteman I general-purpose digital computers. One hundred of these $234,000 systems have already been declared surplus, and it is expected that over a thousand will be available in the next few years. These computers have significant potential for educational use, but considerable hardware interfacing with external devices is required. This project will develop tested hardware interface designs which will be available to others, and will explore various computational and control applications of this machine.

INSTITUTIONAL COMPUTING SERVICES

The dynamic growth rate of academic computing and an accompanying increase in sophistication of computer applications in education and research is reflected in the number, substance, and quality of the proposals received in fiscal year 1970. Over 90 proposals were considered for improvement of computing facilities, a greater number than for any other year in the history of the program. Awards were made to 22 institutions for a total Foundation commitment of $6.5 million. Grants ranged in size from $5,000 awarded to Western Michigan University for improvement of its computer printing facilities to a $1 million grant made to the University of California at Los Angeles as partial support of a major new computer system to meet significant new

A camera is mounted on the graphics display terminal, connected to the UCLA computer, for permanent recording purposes. (Photo University of California, Los Angeles) and innovative computing requirements of the institution. Three awards are described in detail to illustrate program activity and its role in institutional development.

The University of Tennessee at Knoxville, with more than 22,000 undergraduate and 4,500 graduate students, had a medium-size second generation computer as the primary facility to service exploding computing demands. In addition to growing research computing requirements, a new degree program in Computer Science emerged in late 1969 to add to the already heavy demands on an overtaxed system. A substantial upgrading with planned future expansion was needed. To help accomplish this, a Foundation grant of $500,000 was awarded to support a program with a 3-year budget of $3.5 million. A large third generation computer has been installed, with memory expansions scheduled at regular intervals, along with periodic additions of remote terminals and on-line peripheral devices. A new building is scheduled for completion in the third year to house the central computer and staff. The result of this program is a modern facility with a planned growth consistent with the developing computer demands of a major institution.

North Carolina A&T State University illustrates a situation where a change in academic curricula and research activity has caused the small but satisfactory computer facility of 5 years ago to be completely inadequate today. Recent accreditation of the School of Engineering, now offering degrees in architectural, electrical, and mechanical engineering, an increased emphasis in Computer Science activity in a growing mathematics department, and increased research activity in physics and social sciences made the establishment of a major computing facility a high priority objective of the university.

Students at North Carolina A&T State University load magnetic tapes on a Control Data tape drive. A Foundation grant will assist in significant expansion of computing facilities at this growing institution. (Photo North Carolina A&T State University)

A large-scale computer with batch and time-sharing capabilities will be installed in the fall of 1970, with new space to be available as permanent quarters for the new Computer Science Center in the spring of 1971. The staff size will be increased from two to 21 in a program with a 3-year operational budget exceeding $1 million. An NSF grant of $175,000 will assist this significant expansion, with two private foundations providing another $280,000.

Bucknell University acquired a small IBM 1620 computer in 1961, and by 1968 there was an obvious need for improved facilities to support a broad class of computer-related activities. These activities extend beyond the university to smaller institutions in the vicinity as a consequence of the keen sense of community leadership which exists at Bucknell. Following a long period of careful planning, a third generation computer system was selected capable of providing a variety of local and remote computing services. The equipment acquisition was closely coupled with a strong emphasis on the strengthening of faculty and senior professional staff to encourage further developments of educational and research computing applications. A Foundation grant of $395,000, representing approximately 25 percent of the estimated 3-year project costs, was made to assist Bucknell University in the program. The regional significance of a strong computing center extends beyond the educational institution itself, and this led the Appalachian Regional Commission to provide funds to improve the equipment configuration.

SPECIAL PROJECTS

Regional Cooperative Computing Activities

In fiscal years 1968 and 1969, the Foundation explored the merit of various computer-based cooperative arrangements, principally at the college level. Typically, each regional activity was centered about a major university which provided computer services and technical assistance to help a cluster of nearby institutions introduce computing to faculties and students, thereby developing a potential for further educational innovation. Altogether, 15 regional activities were established including 12 major universities, 116 participating colleges, 11 junior colleges, and 27 secondary schools located in 21 States.

In July 1969, a regional project directors' meeting was held at Oregon State University in Corvallis to study successes and failures and to assemble a reservoir of useful data for others. A *First Report on An Exploratory Program of Regional Cooperative Computing Activities,* available from the Office of Computing Activities, includes descriptions of the participating institutions, hardware and software systems utilized in the various projects, some cost figures, and indications of the educational impact of computer use.

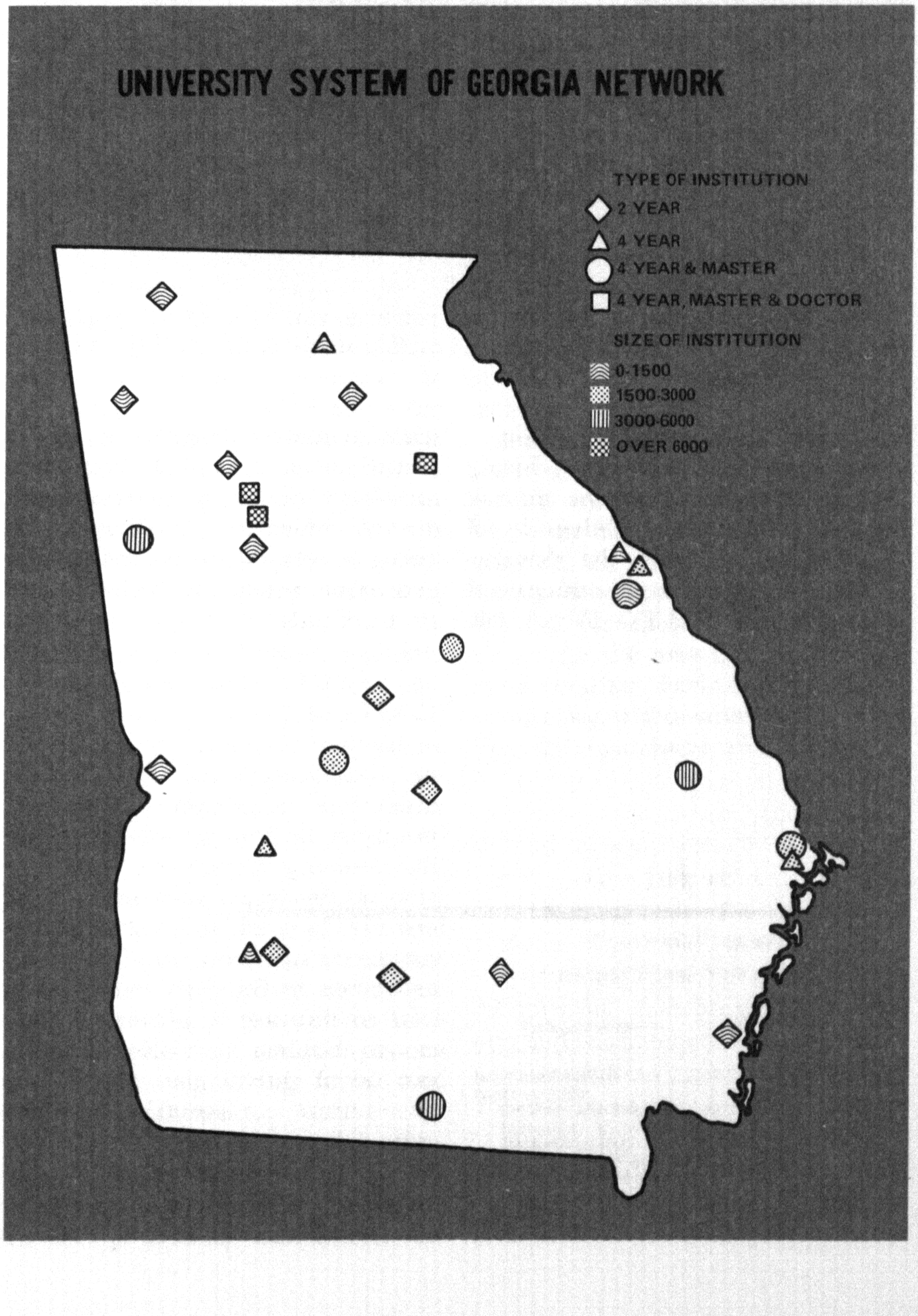
In fiscal year 1970, 47 additional grants totaling approximately $1.8 million were awarded involving 15 major universities and 79 participating colleges in 24 States. Three new regional activities were established, two of which are unique in that they provide models for State-wide cooperative computing activities, one in North Carolina and one in Georgia. (See figure.)

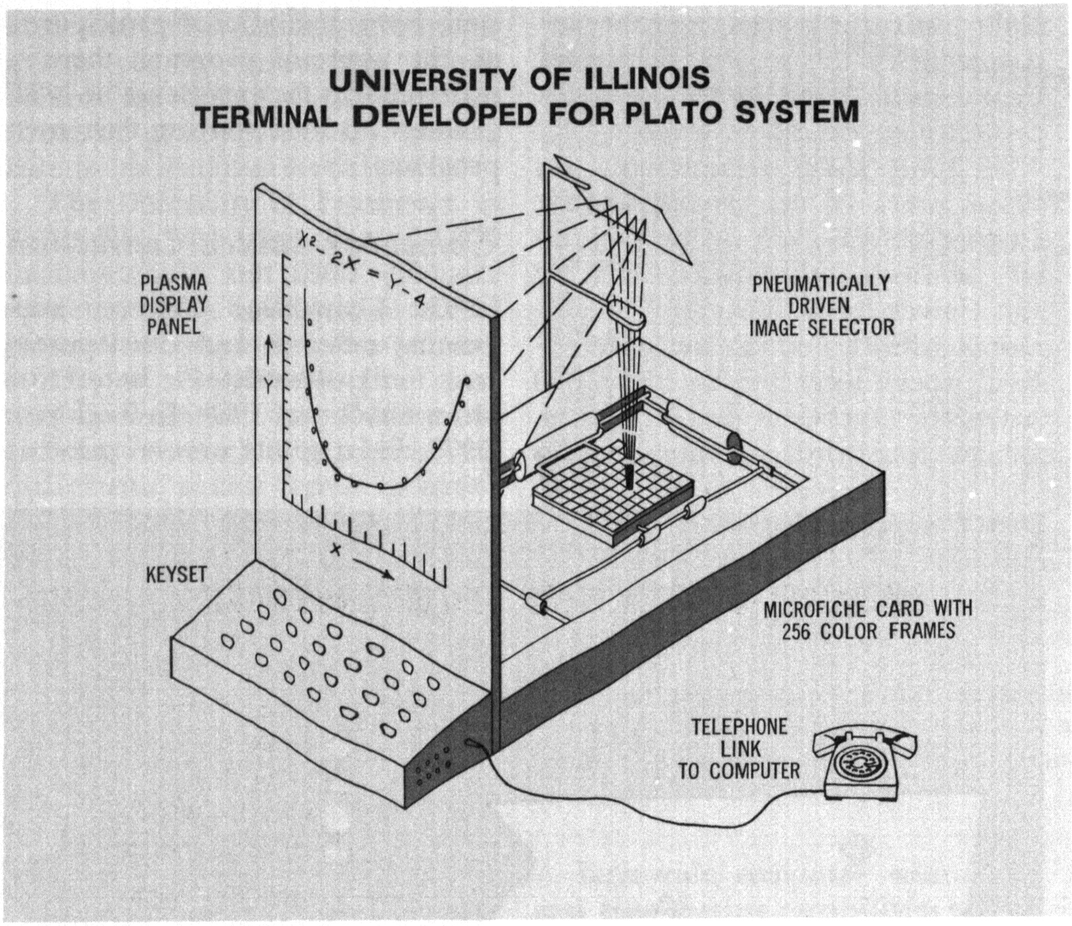
In Georgia, 19 grants totaling $519,300 enabled the University System of Georgia to extend by telephone lines the computing resources of the Georgia Institute of Technology and the University of Georgia to other institutions throughout the State. One grant for $233,200 to the University System of Georgia provided partial support of its central staff of curricular experts and computer specialists. Two grants of $66,000 each were made to the University of Georgia and the Georgia Institute of Technology, and 16 grants were made to participating institutions ranging in size from $1,500 to $14,000. Twenty-eight institutions are currently participating in the project. State and institutional contributions to this project now exceed $1,675,000.

In June 1970, a conference on "Computers in the Undergraduate Curricula" was held at the University of Iowa, sponsored jointly by the University of Iowa and the National Science Foundation. Seventy-five papers were presented to 800 attendees representing 48 States. About one-third of these papers were from institutional participants of the regional program, thereby transmitting the experience of NSF grantees to those starting their own programs.

Computer-Assisted Instruction

The Foundation has been supporting research and development in computer-assisted instruction since fiscal year 1968. In fiscal year 1970, eight grants were awarded in





the total amount of $1.9 million.

Of particular interest among these awards is one in the amount of $430,000 to the University of Illinois to accelerate the development of a prototype educational system called PLATO IV. A full-scale system is designed to service simultaneously 4,000 student-terminals based on a novel plasma-display device invented at Illinois and being developed commercially. The prototype system will include up to 10 terminals.

Sea Grant Programs

The National Science Foundation Sea Grant Program supports activities in research, education and training, and advisory services for development of the nation's marine resources. In fiscal year 1970, the Foundation awarded approximately $9 million for these purposes as shown in the table below.

One of the principal objectives of the National Sea Grant College and Program Act of 1966 is the creation of a strong base of institutions dedicated to development of marine resources comparable to the Land Grant College efforts in the field of agriculture. In its third year of operation, the Foundation's National Sea Grant Program has continued active development of the National Sea Grant network of institutions with the addition of the University of Southern California, bringing the total of major universities now in the program to nine.

The other eight institutions which received initial support in fiscal years 1968 and 1969 are: Oregon State University, the University of Rhode Island, the University of Washington, Texas A&M University, the University of Hawaii, the University of Wisconsin, the University of Miami, and the University of Michigan.

The nine institutions are engaged in comprehensive Sea Grant programs involving research in all fields important to marine conservation, management, and development, including law, economics, and other social sciences as well as engineering and the natural sciences. All institutions have major educational programs at both the graduate and undergraduate level, and all engage in programs designed to communicate the results of research to such users as fishermen, seafood processors, ocean engineering firms, and State governments.

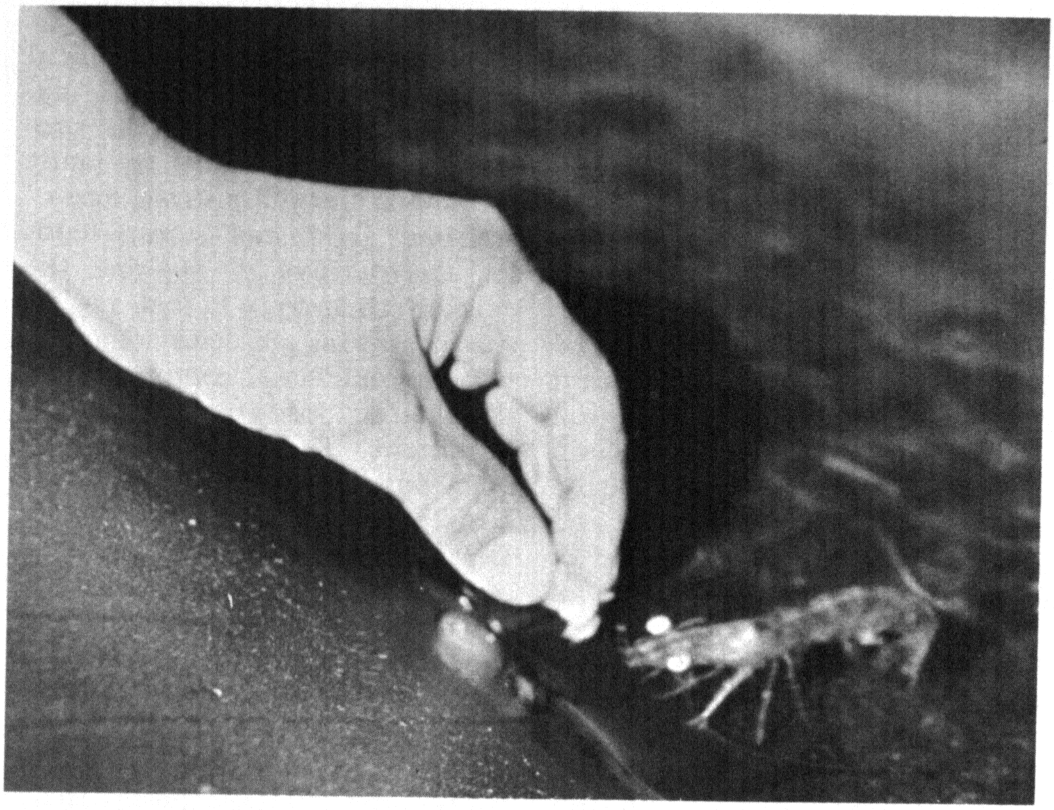
In addition to the major institutions, the Sea Grant Program has initiated comprehensive activities in several smaller institutions for the purpose of developing major marine competence in geographical areas where no broadly based marine research and education programs now exist. Grants are made to universities with a strong core of activities in limited marine fields for the purpose of applying the existing competence to local and regional marine problems while developing additional competence for the future. Such grants, known as "Coherent Project Grants," were made in 1968 to Louisiana State University and the University of Delaware. In 1969, the University of California at Santa Barbara, Humboldt State College, Calif., and the Virginia Institute of Marine Sciences were added. In fiscal year 1970, major coherent project grants were made to the University of Alaska and the Massachusetts Institute of Technology. These grants, in company with the institutional grants, form the base of the rapidly growing Sea Grant family of institutions.

Activities funded in previous years, under institutional, coherent project, and general project grants, began to show positive results of value to the national marine effort during fiscal year 1970.

Sea Grant efforts to develop techniques for the mass culture of high-value marine food organisms are continuing with a number of problems in aquaculture already solved.

Table 11
National Science Foundation
Sea Grant Program
Awards Fiscal Year 1970

Category of grant	Number	Amount
Institutional support	7	$5,675,400
Project support:		
Coherent area projects	3	797,400
Educational projects	7	561,512
Research projects	17	1,776,144
Study and planning projects	2	33,700
Advisory services projects	2	130,000
Total	38	8,974,156



Notable advances have been made in the development of techniques for mass culture of marine food organisms, including the successful raising of shrimp from egg to adult. (Photo University of Miami)

Tanks and artificial ponds are used by scientists at Oregon State University in a project designed to introduce exotic species of salmon into Oregon waters. (Photo Oregon State University)

One of these is the raising of shrimp from egg to adult, accomplished at the University of Miami. Substantial progress in the introduction of exotic species of salmon into Oregon waters was made during the year by fisheries scientists at Oregon State University. Louisiana State University scientists determined the salinity and temperature tolerances necessary for the culture of pompano.

Disease of fish and shellfish will be an increasing problem as aquaculture on a large scale is attempted. Scientists at Texas A&M University identified what could be a serious problem for commercial shrimp growers when it was noted that shrimp being used for nutritional experiments developed a high mortality. The Texas A&M Sea Grant team determined the cause to be a pathogenic bacterium, *Vibrio parahemolyticus.* This organism could be especially lethal in closed ponds where young shrimp are raised. While the bacterium also could cause food poisoning in America (as it does in Japan), this is unlikely because little seafood is eaten raw in this country; cooking destroys the disease organism.

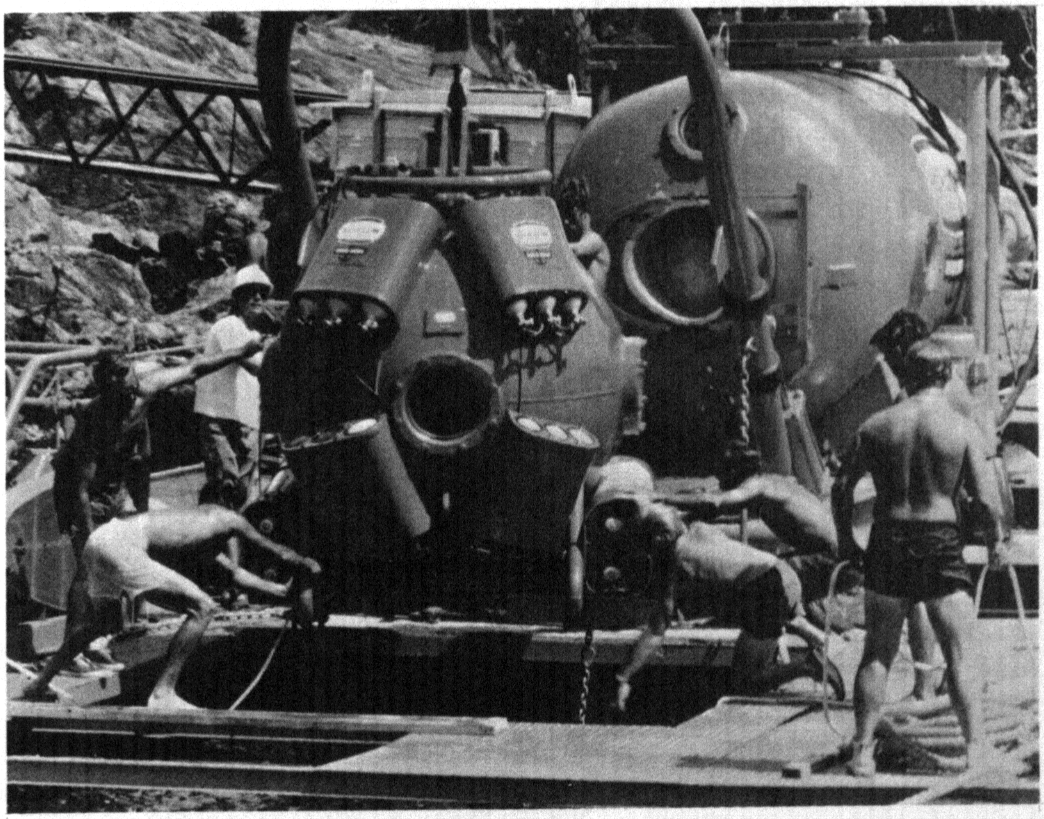
Scientists at the Lamont-Doherty Geological Observatory of Columbia University successfully installed the first stage of a system that will not only provide nutrients for aquaculture, but should also produce fresh water and electric power through the raising of deep, cold seawater from near the ocean bottom. A mile-long pipeline was laid from the shore of St. Croix, in the Virgin Islands, into deep water where the temperature is only 41 degrees, and far more nutrient-laden than the warm surface waters. As the project continues, the cold water will be used in large condensors to remove fresh water from the warm trade winds by condensation. The cold water will also contribute to production of electric power by use of a steam generator powered by the temperature difference between the surface and bottom waters. Finally, the bottom water will be fed into a lagoon where its nutrients will support the start of a food chain that will end with commercially valuable marine organisms.

On the neighboring Virgin Island of St. John, Project Tektite II, a continuation of the man-in-the-sea program under Department of the Interior leadership, received major support from Sea Grantees. For the first time, student divers were given prime responsibility for logistic and diver safety support in a major operation. The divers were senior students from Highline Community College, Midway, Wash., trained and supported under the University of Washington institutional Sea Grant program. Cape Fear Technical Institute operated its own training vessel, *Advance II*, and the NSF vessel, *Undaunted*, in support of the operation. The Cape Fear Technical Institute at Wilmington, N.C., was responsible for coordinating and supporting a program of scientific oceanographic and meteorological research conducted in conjunction with the underwater scientific program, with over 400 persons and more than two dozen universities, industries, and Government agencies taking part. The University of Delaware Sea Grant program supplied the girl engineer, Margaret Lucas, to the first all-female aquanaut team. The Texas biomedical Institute at Galveston, under a Sea Grant project, conducted both medical support and a training program for diving doctors as part of Tektite. Southern Maine Vocational Technical Institute at South Portland, Me., provided both technician trainees and faculty members to the Tektite operations.

In advisory service operations, a significant forward step was the organization of the Pacific Coast Advisory Service. Centered at Oregon State University, the service involves institutions and agencies in California, Oregon, Washington, British Columbia, and Alaska. Cooperating with the Sea Grant program are the Bureau of Commercial Fisheries, the Environmental Science Services Administration, and a number of State agencies. The program is planned to improve information and extension services to marine activities throughout the Pacific coast.

During the year, other grants produced a broad spectrum of research and education activities, including the following:

- Scientists at Texas A&M University measured the effects of waves and currents on submerged pipelines and listed the data in a regular Sea Grant publication available to industry as a basis for improving pipeline operations.
- The cooperative work-study ocean engineering program at Florida Atlantic University resulted in 27 industry requests for the first 11 graduates. Fourteen graduates of the comparable bachelor-degree course at Mississippi State University/Gulf Coast Technical Institute were employed after graduation in June.
- Engineers at Stevens Institute of Technology developed a computer program for analysis of offshore floating platforms. By application of this technique, they expect to improve by 10 percent the design of offshore oil derricks for resistance to all elements of sea damage. This should eventually decrease insurance costs to industry and reduce platform loss.
- Sea Grantees at the University of Washington have successfully completed the first stage in de-



Student divers from Highline Community College, trained under the University of Washington Sea Grant program, provided logistic and diver safety support service in connection with Tektite II man-in-the-sea program. (Photo University of Washington) velopment of a system to locate biological targets in the sea more effectively through acoustic techniques—a project to help fishermen cut down the long periods spent hunting for fish.

- The University of Rhode Island has made extensive strides in developing a computerized lobster management model for optimizing the environment for lobster rearing.
- Sea Grantees at the University of Wisconsin have received a grant from oil companies to be used for unspecified research occurring as an outgrowth of the minerals research carried out under the Sea Grant program.
- The University of Maine Law School has identified and categorized the laws, regulations, and court decisions of Maine pertaining to recovery of living and mineral resources of State waters.
- Sea Grant food scientists and marine extension agents at Oregon State University brought shrimp and crab processors together for the first time, and conducted a program that has increased both the sanitation and efficiency of the entire Oregon shrimp and crab processing industry.
- The University of Hawaii uncovered deep shrimp resources about 1,500 feet under the sea. The shrimp may occur in commercially exploitable quantities. Tests indicate that, with heavy hauling gear, fishermen might catch as much as 1,000 pounds of shrimp per working day. Experiments at the University of Hawaii in growth rates of an octopus with commercial potential indicate that this is an extremely promising organism for aquaculture because of its rapid growth, good energy conversion, and high retail price.
- Scientists at the University of Rhode Island succeeded in raising Atlantic salmon from an average weight of 1½ ounces to a size of nearly 12 ounces in 6 months under relatively poor growing conditions. With improved environmental controls, it should be possible to effect an even greater growth rate. Progress is also being made in the raising of other so-called luxury fish, including chinook salmon from Alaska, rainbow trout, bluefish, and striped bass.

The Sea Grant Program is primarily geared to long-term results, and these "quick returns" represent a tiny fraction of the potential.

Science Information

Science information, as an integral part of the research and development process, must be easily accessible to scientists and engineers if science and technology are to make progress in improvement of the quality of man's physical and social environment. The Foundation's science information programs are directed toward ensuring that adequate information systems and services are available to the scientist and engineer. The long-term goal of the Foundation's Office of Science Information Service and its programs is to close the gap between the information needs of scientists now being served and those needs which must be met in the future as science and technology progress.

In pursuit of this goal the following major objectives have been set:

1. Investment in information system development for physics, chemistry, and other areas of science;

2. Aid to major universities to develop mechanisms which effectively serve research and education with present and new information products and services, including machine-readable tapes which are produced by professional societies, government agencies, and commercial organizations;

3. Short-term support to ongoing information activities, including translations, which are not yet self-sustaining;

4. Continued support of research and advanced development on science information problems; and

5. Fostering of cooperation, coordination and standardization among the various components of the present science communications complex which will lead to national and international networks of information services.

In fiscal year 1970, the Foundation awarded 104 grants and contracts and obligated $11.4 million for science information activities.

INFORMATION SYSTEMS DEVELOPMENT

The information systems development program was initiated in response to the needs of scientists and engineers for modernized information systems. The costs of developing modern computerized systems while simultaneously supporting exsisting services exceeds the financial resources of the scientific community. Therefore, to insure an adequate flow of information in the future, the Foundation has undertaken to provide support for the development of modernized systems.

Discipline-Oriented Science Information Activities

Support is being provided for the development of discipline-oriented science information systems in nine disciplines.

Chemical Information System.—Fiscal year 1970 marked the end of 5 years of intensive development of an information system for chemistry. By the end of June 1970, the American Chemical Society (ACS) had exceeded the 5-year objectives as stated in the Office of Science and Technology planning document issued in October 1965. Some of the major achievements during fiscal year 1970 were:

1. The American Chemical Society has concluded agreements with the West German Chemical Society and the Chemical Society of London for the processing of the primary publications of their respective countries for direct input into Chemical Abstracts Service (CAS) computer system. Similar agreements are being discussed with two other countries.

2. Agreements have been concluded with organizations in seven foreign countries for the utilization

of the computer tapes produced by the CAS system.

3. In the United States, the computer tapes are being used by commercial, industrial, and not-for-profit organizations as well as universities and Government agencies to provide scientists with a variety of services.

4. The Chemical Registry System now contains nearly 1.5 million substances with more than 1.75 million names and 3 million references.

5. The conversion of the file for CAS's Eighth Collective Index (1967 to 1971) to machine-readable form continued and the funding provided in fiscal year 1970 should be sufficient to complete this project.

The use of the CAS system has emphasized the need for better cooperation between the major abstracting and indexing services in order to avoid excessive duplication. Accordingly, CAS, Biological Abstracts, and Engineering Index, Inc. have undertaken a joint study to determine the areas of overlapping coverage and, if possible, to develop a plan to reduce the duplication of effort and effect operating economies.

National Information System for Physics.—The American Institute of Physics (AIP) continued its creation of a computerized file of the primary physics literature. The file contains the following items for each journal article: (1) bibliographic information—journal, volume, page, article title, author, and author's location; (2) abstract of article; (3) indexing information; and (4) citations of the article to other literature. About half of the world's primary physics literature is being entered into the file.

Four different services are either available or in the process of being made available. They consist of a magnetic tape service which covers the monthly additions to the file, a current awareness journal entitled *Current Physics Titles,* a series of bibliographies in special areas of physics, and the production of indexes to the various AIP journals.

The computer tapes produced by AIP are being used in a number of pilot operations which provide feedback information which will be used to improve the efficiency of the system.

Other Disciplines.—In the engineering sciences, indexes to electrical and electronics literature for both manual and automated usage have been developed. The American Psychological Association has defined a program of system development. The five remaining disciplines—linguistics, environmental sciences, life sciences, mathematics, and social sciences—are either in the process of defining their programs or in the preliminary study stage.

University-Centered Information Systems

The immediate objectives of support for university-centered information systems are threefold: (1) to meet the information requirements of academic scientists and the students they are training; (2) to establish "retail" campus-based terminals to accept the "wholesale" machine-readable tapes from the society-based, discipline-oriented systems, as well as the mission and problem-oriented products from Federal and private sources; and (3) to support the development of major nodes for the emerging national science information system.

During fiscal year 1970, the Foundation supported the development of discipline-oriented information service centers at six universities. Three of the centers—University of Georgia, University of Pittsburgh, and the Illinois Institute of Technology Research Institute—were originally established to develop systems to provide service for the tapes produced by CAS, but have now expanded their operations to cover tapes from commercial and mission-oriented systems. These centers together with other centers using tapes from Chemical Abtracts Service (CAS) and from other tape processors have formed the Association of Scientific Information Dissemination Centers (ASIDIC). A similar organization of distribution centers has been formed in Europe and is known as the European Association of Scientific Information Dissemination Centers (EUSIDIC). Both organizations include commercial and industrial organizations in addition to universities and other not-for-profit organizations.

Two other centers—University of Arizona and University of Washington—are concerned with the development of systems for the acquisition, processing, and distribution of interdisciplinary or subdisciplinary information. The University of Arizona is developing an Arid Lands Information System and is exploring the feasibility of establishing a worldwide arid lands information network with other institutions in the United States which are processing similar material and with institutions in Israel and Australia. The University of Washington continued to work on the development of a computerized data bank of the information in the U.N. Treaty Series and is investigating the extension of the system to cover maritime laws of interest to the Sea Grant project at the University of Washington.

OPERATIONAL SUPPORT FOR SERVICES AND PUBLICATIONS

The Foundation continued its support of existing information systems and services at an operational level, and extended its temporary support for the operation of developing systems in the major scientific disciplines. Altogether, support was provided for the operation of systems in six disciplines—psychology, engineering, geology, physics, mathematics, and atmospheric sciences. In addition support was provided for eight specialized bibliographies and indexing services.

The Foundation's support of publications was rigorously reduced. Only three monographs were supported as opposed to 22 in the previous year. Only one journal, one conference proceedings, and one critical review received support. Support was continued for the translation of 20 current primary journals by U.S. professional societies.

The science information activities conducted under the Agricultural Trade Development and Assistance Act of 1954 (Public Law–480) with eight foreign contractors resulted in the translation and republication in English of foreign primary journals, patents and monographs from Russian, East European, Japanese, and other languages; the preparation of abstracts; the compilation of annotated bibliographies, and the preparation of guides to foreign scientific institutions and information services. The combined activities of the Public Law–480 projects and the society-sponsored translation journals provided the scientific community with approximately 100,000 pages of foreign scientific and technological literature.

RESEARCH AND DEVELOPMENT

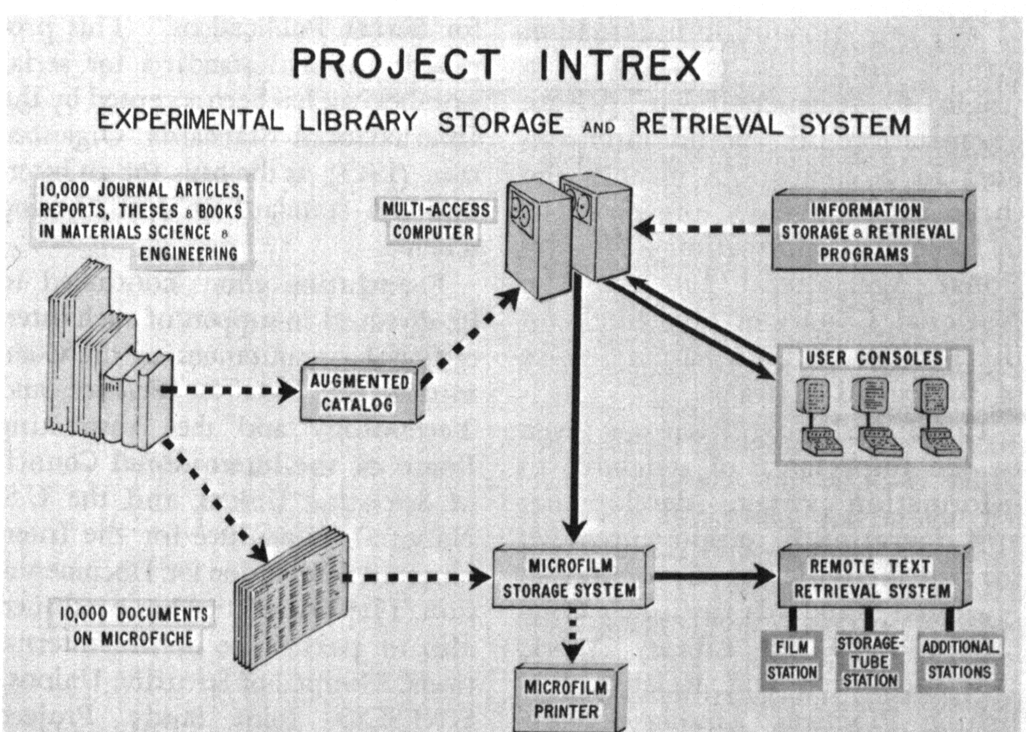
Support was provided for projects undertaken by individual research workers, research conducted by investigators associated with science information research centers, and the development of prototype experimental systems.

Cornell University has been doing research on procedures for the automation of indexing, classification, and construction of retrieval tools for indexers. These procedures and their effectiveness are being tested by comparison of manual and automatic processing of textual material.

Project INTREX at the Massachusetts Institute of Technology (MIT) has been studying the utilization of digital computers, communication systems and microphotography to enhance the effectiveness of the library as an information transfer center. During the past year, the remodeling of the Engineering Library at MIT provided INTREX with an opportunity to compare the conventional library services with the new information transfer techniques. INTREX terminals are being intermingled with bookstacks and study carrels in a variety of arrangements to determine the preferences of the users.

The Alfred P. Sloan School of Management at MIT has been studying how scientific and technical information passes from one person to another in industrial organizations. It was found that in any organization a few key people called "technological gatekeepers" are relied upon to provide information to other people. These key people read the professional literature and maintain close liaison with the experts in their fields. The extension of the "gatekeeper" concept to information transfer on an international scale is now being studied.

The Science Information Research Center at the Georgia Institute of Technology demonstrated its newly developed audiographic learning system at the 1970 International System Meeting, Las Vegas, Nev. The system provides access via telephone to a modular body of indexed, graphically supported, narrative presentations for a student controlled study. The existing facility is capable of supporting several telephone-connected student stations and providing each with random accessibility to learning ma-



(Photo MIT)

terials or scientific information stored on computer-controlled tape recorders.

The Ohio State University Science Information Research Center reported that work on molecular cybernetics has led to the hypothesis that DNA stores programs or algorithms rather than "blueprint" or descriptive information. This suggests that the bridge between molecular and developmental biology is to be sought along lines similar to those developed for pattern recognition. Substantial progress has also been made on the theory of how people process information.

PLANNING, COORDINATION, AND COOPERATION

The Office of Science Information Service continued to support studies and organizational activities and to provide assistance of a planning, coordinative, and cooperative nature to enhance science communication at the national and international levels.

During the year attention was given by the Committee on Scientific and Technical Communication (SATCOM) to the problem of determining the most appropriate planning and coordinating mechanism for the science communication complex. A SATCOM Task Group on the Economics of Primary Publication also prepared a study report on the present situation of primary journals, recent trends and problems, and a perspective for general national policies.

INTREX augmented catalog console at MIT. (Photo MIT)

The Committee on Biological Sciences Information (COBSI), under sponsorship of the National Academy of Sciences-National Research Council, issued a report on *Information Handling in the Life Sciences*. The report concludes that the U.S. information system for the biological sciences, in the absence of any one monolithic information service, cannot be provided by a single Governmental or private organization but should inter-connect in a compatible manner the three existing major organizations in biological information—The National Agricultural Library, The National Library of Medicine, and the Biosciences Information Service of Biological Abstracts.

Continued recognition was given to the importance of standards to information system development and operation by support provided for the activities of the American National Standards Institute's Committee Z-39 on Library Work, Documentation and Related Publishing Practices. Among accomplishments of Z-39 during the year is a "Standard Identification Number for Serial Publications." This proposed national standard for serial numbering has been accepted by the International Standards Organization (ISO) as the basis for an international standard serial numbering scheme.

Foundation efforts continued to be directed in support of such international organizations as the Committee on Data for Science and Technology and the Abstracting Board of the International Council of Scientific Unions, and the U.S. National Committee for the International Federation for Documentation. The Foundation has continued also to participate in the International Council of Scientific Unions/UNESCO Joint Study Project, UNISIST, on a worldwide science information system.

International Science Activities

Many of the research and science education activities supported by the Foundation have international significance. In addition to such major multinational projects as the International Biological Program, the Arctic and Antarctic research programs, among others, international aspects are also reflected in fellowship programs, support for attendance at scientific meetings, exchange of science information, and the translation into English of scientific literature published in foreign countries. These programs are discussed elsewhere in this report, and the activities summarized below represent only those programs administered by the Office of International Programs.

COOPERATIVE SCIENCE PROGRAMS

The Foundation's cooperative science programs include support for research projects, seminars, meetings, exchanges of scientists, and other scientific activities. The objective of these programs is to strengthen science in the United States. During fiscal year 1970, the Foundation acted as the lead agency for six bilateral cooperative science agreements (Australia, Republic of China, India, Italy, Japan and Romania). In addition, the Foundation supports the U.S.–U.S.S.R./Eastern European Exchange Program through the National Academy of Sciences. During the fiscal year, the Foundation and the National Center for Scientific Research (CNRS) of France made arrangements for a scientific exchange program. Highlights of these programs are presented below.

United States-Australia Agreement for Scientific and Technical Cooperation

No Foundation funds were awarded for projects under this agreement in fiscal year 1970. Most of the activity concerned plans for possible collaborative research projects in fiscal year 1971 and beyond. Some of the topics being discussed are scientific ballooning, drug abuse, biomedical research projects, photosynthesis, weather modification, and forest/brush fires.

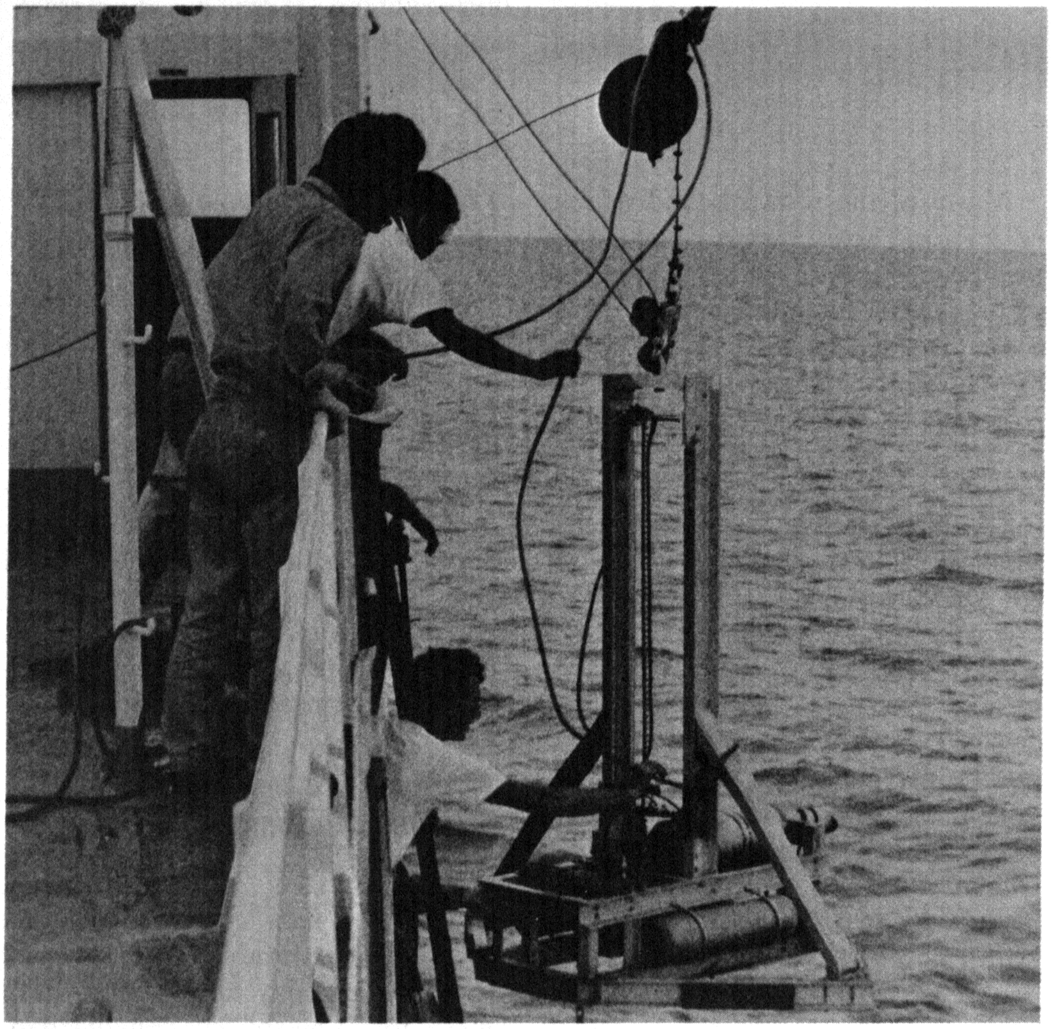
United States-Republic of China (Taiwan) Cooperative Program

During fiscal year 1970, the Foundation provided travel support to U.S. scientists for 25 short-term visits to Taiwan for consultation, teaching, and research. A grant was awarded to the University of California to study the "Ecology of *Fusarium* Species in Taiwan with Special Reference to the *Gibberella* stage of *F. moniliforme* on Rice."

Foundation funding in this program amounted to $105,140; funds from other sources equalled $51,000. Total funds: $156,140.

United States-India Exchange of Scientists and Engineers

During fiscal year 1970 12 scientists from India visited the United States under this program. Fields of interest included engineering (soil mechanics and foundation engineering; integrated circuits; fire safety; desalination techniques; textile technology), paleontology; solid state physics, chemistry, and science information. Each of the visits consisted of a study tour of selected



American and Japanese scientists on the Research Vessel *Seifu Maru* lower a Brunogradmeter into the Philippine Sea for measurement of terrestrial heat flow through the shallow ocean bottom.

academic, industrial, and governmental laboratories and participation in conferences. Eleven American scientists participated in the program in 1970. Fields of interest included physics; engineering (aerodynamics, materials research, fuel research, foundation engineering); operations research; biomedicine (hematology, pharmacology); and mathematics.

United States-Italy Cooperative Program in Science

The Foundation provided $35,000 for the continuation of cooperative research under this program in fiscal year 1970. There are presently 27 active research projects as follows: physics, 10; biology, 5; agricultural sciences, 5; chemistry, 5; geological sciences, 1; and engineering, 1. An example of collaborative research is the study of proton channeling through gold crystals by American and Italian physicists. The Proton Channeling Spectrometer, located at the University of Bologna, is constructed partly with U.S. and partly with Italian funds.

United States-Japan Cooperative Science Program

The Foundation awarded grants to 13 U.S. scientists during fiscal year 1970 to visit and conduct research in Japan. Twenty-two seminars were held—12 in the United States and 10 in Japan—in which 224 American and 226 Japanese scientists participated. The Foundation funded seven new research grants in chemistry, engineering, biology, geology, and meteorology. Two ongoing projects were extended with additional funds.

An example of a cooperative research project is one being conducted by the Lamont-Doherty Geological Observatory and the Maisuru Marine Observatory. The objective of the project is to study the tectonic development of the Pacific Ocean floor by geothermal and geomagnetic investigations, with particular emphasis on the Philippine Sea basin. American scientists joined Japanese scientists on the Research Vessel *Seifu Maru* to make a geophysical survey in the seas around the Ryukyu Island Arc. The American scientists worked at the Earthquake Research Institute, University of Tokyo, on the results of the U.S.-Japan field work. A Japanese scientist joined American researchers on the Research Vessel *R. D. Conrad* for geothermal and geomagnetic studies in the seas around the Aleutian Islands. The Japanese scientists then visited the Lamont-Doherty Geological Observatory to work on the results of this trip and to plan future cooperative research.

Total NSF funds awarded under this program during fiscal year 1970 amounted to $421,315; other U.S. funding sources provided $164,937, for a total of $586,252 in U.S. funds.

United States-Romania Cooperative Science Program

During fiscal year 1970, the Foundation accepted the nomination of seven Romanian scientists for 48 man-months of study and travel in the United States. Two

U.S. scientists have visited Romania under the terms of this program. The Romanian National Council for Scientific Research has submitted applications for an additional 40 candidates for visits in fiscal year 1971. The Foundation obligated $35,000 under this program in fiscal year 1970.

United States-U.S.S.R./East European Exchange Program

These exchanges of scholars are conducted between the U.S. National Academy of Sciences (with Foundation funds) and the Academies of the Union of Soviet Socialist Republics, Poland, Yugoslavia, Romania, and Czechoslovakia. In fiscal year 1970, eight American scientists went to the U.S.S.R. for 1-month lecture and survey visits, and another 28 made research visits totaling 106 months. U.S. interest was divided evenly among biological, chemical, physical, and mathematical sciences; least interest was shown in engineering and the social sciences. Eleven Russian scientists made 1-month visits, and 25 spent a total of 92 months conducting research in the United States. Their emphasis was overwhelmingly on the physical, chemical, and engineering sciences.

In January 1970, a new Inter-Academy Exchange Agreement (National Academy of Sciences-Academy of Sciences of the U.S.S.R.) for 1970–71 was negotiated in Washington. The agreement continues the level of subsidized individual visits at 90 man-months per annum. A provision for joint research projects involving United States and Russian scientists was included for the first time. The U.S. National Academy of Sciences has submitted a proposal to the Academy of Sciences of the U.S.S.R. on behalf of an American zoologist who wishes to conduct a joint field trip to Siberia with a Russian colleague.

United States-France Exchange of Scientists Program

An additional bilateral agreement is expected to be implemented in the near future. During fiscal year 1970, representatives of the Foundation and the French Centre National de la Recherche Scientifique (CNRS) developed the terms for an exchange of scientists for study and research in the respective countries. Eligible individuals will be citizens or nationals of the United States and France who will have earned a doctoral degree or its equivalent normally not more than 5 years prior to the commencement of the exchange visit. The period of the visit will be normally between 5 and 15 months. The Exchange Agreement will be signed early in fiscal year 1971.

DEVELOPMENT ASSISTANCE PROGRAMS

In fiscal year 1970 the Foundation continued to manage two programs on behalf of the Agency for International Development (AID): (1) Science Education Improvement Program in India, and (2) Technical Cooperation and Evaluation Program—Worldwide Program.

Science Education Improvement Program in India

The collaborative program for the improvement of science education in India is defined by a contract between the United States and India. Funding is provided by the Agency for International Development and the Indian Ministry of Education. It is implemented jointly by the Foundation and the (Indian) National Council for Science Education. There are three main efforts: (1) the training of personnel through summer institutes, workshops, seminars, and short courses; (2) the development of new teaching materials including syllabi, textbooks, examinations, laboratory equipment, handbooks, and journals; and (3) the development of institutions which can sustain the improvement effort.

The jointly sponsored Summer Institute Program became a fully Indian institution in 1970, as this was the final year in which U.S. consultants are to be supplied to the Indian directors of the summer projects.

Technical Cooperation and Evaluation Program—Worldwide Program

With funds provided by AID's Technical Assistance Bureau, the Foundation in 1970 supported three continuing projects of worldwide scope and initiated a fourth:

1. Study of Low Cost Science Teaching Equipment, conducted at the Science Teaching Center of the University of Maryland, to gather information and materials from all parts of the world on science teaching equipment of low cost and easy manufacture from locally available materials;

2. Activities of the Biological Sciences Curriculum Study (BSCS) headquarters in support of adaptation of BSCS materials by local groups in AID countries;

3. Study by the International Education Committee of the Conference Board of Mathematical Sciences of the demand for and supply of U.S. mathematics educators for service in international projects, especially those in the developing nations;

4. Planning and monitoring an evaluation of BSCS adaptation activities in AID countries.

PLANNING AND DEVELOPING INTERNATIONAL PROGRAMS

The Foundation provides support for U.S. scientists and scientific organizations in their effort to organize, plan, and develop international scientific programs and activities.

U.S. National Committees for International Nongovernmental Scientific Organizations

Foundation funds supported the activities of the committees and staffs established by the National Academy of Sciences to represent the interests of the U.S. scientific community in the affairs and programs of the international scientific unions of which the Academy is the U.S. National Member.

Science Program and Policy Development

During fiscal year 1970, the Foundation awarded grants which provided partial funding to the American Academy of Arts and Sciences for the support of a U.S. Joint Committee for the International Center for Insect Physiology and Ecology (ICIPE). The joint committee participates in the planning and development of ICIPE (in Nairobi, Kenya) which will be administered by an international consortium of academies of sciences.

Table 12

U.S.S.R. and East European Exchange of Scientists Programs, Number and Duration of Individual Visits Initiated, Fiscal Year 1970

	Number	Length of time (in man-months)		Number	Length of time in the United States (in man-months)
U.S. Scientists to:			Foreign scientists from:		
Czechoslovakia	12	49	Czechoslovakia	7	38
Poland	12	33	Poland	8	52
Romania	16	26	Romania	10	45
Yugoslavia	4	12	Yugoslavia	5	13
U.S.S.R.	36	114	U.S.S.R.	36	103
Total	80	234	Total	66	251

Planning and Policy Studies

Through its science resources and policy studies, the Foundation identifies and analyzes important science policy issues; provides an adequate data and methodology base for sound decisionmaking; and develops science planning and policy study capabilities at various institutions in the United States. The information developed through these activities is used in assessing alternatives, in establishing priorities, and in arriving at recommendations concerning the national science effort. The results of these study activities serve not only the requirements of the National Science Foundation, in its concern with the scientific enterprise, but also serve other Federal agencies, Congressional groups, and non-Federal organizations.

SCIENCE POLICY ISSUES

The study of science policy issues is an essential component of any overview of the science picture in the United States. Insight is needed into the interrelationships between the scientific enterprise and the society it serves; the requirements of the various areas of science and engineering must be understood; and assessments of the impact of changes in the scientific resource base and the impact of current and potential changes due to scientific and technological advances must be available for guidance.

With limited resources to draw on, one of the critical and continuing problems facing science administrators is the question of establishing priorities for the competing areas of science. Through its support of the activities and special studies of the Committee on Science and Public Policy (COSPUP) of the National Academy of Sciences and the counterpart Committee on Public Engineering Policy (COPEP) of the National Academy of Engineering, the Foundation has been obtaining information concerning the current status and projected needs of the major areas of science as an aid to the determination of scientific priorities. Two COSPUP studies initiated at the end of fiscal year 1969 with Foundation support were fully underway in fiscal year 1970. One study concerned the status and needs of astronomy (both ground and space based), the other concerned the picture for physics. These studies represent the first efforts of COSPUP to update previous reviews of scientific disciplines. The new reviews are aimed at establishing not only the current and foreseeable needs and problems of these two disciplines but also at determining their relevance to other areas of science and technology and to society in general. The reviews will also concentrate on the establishment of priorities within these broad fields. Additional updating efforts, for other disciplines, are currently being planned in order to assure that information available keeps pace with rapidly changing scientific and technological developments.

Over the past year, support of the Committee on Public Engineering Policy continued. The committee addressed itself largely to the question of engineering as it relates to social utility. One activity culminated in the publication of a report, *Priorities in Applied Research,* which recommended that applied research be undertaken in the following major areas: the biosphere, techniques for applied social research, materials research, construction, and transportation.

Another important issue upon which attention was focused during the year concerned the effect of changes in Federal funding patterns on academic institutions in the United States. Federal obligations to universities and colleges totaled

$3.5 billion in academic year 1968–69, representing only a 2 percent rise over the previous year and the second consecutive year in which the growth rate was limited to this level. In contrast, the annual growth rate during the 1963–67 period was 24 percent.[1] Firm data have not been available on the effects of the changed funding pattern and the Foundation, with the encouragement of the Office of Science and Technology, initiated a survey to determine quantitatively the actual impact on academic institutions. The first phase of the study was conducted in fiscal year 1969 in about one hundred universities and some seven hundred graduate departments within these universities. Since the results of this survey indicated that 1968–69 constituted the first year of a major transitionary period, a second phase of this study was initiated in 1970 to provide a comparison over more than one time period. Results will be published in fiscal year 1971.

Also studied during this past year was the question of possible future imbalances between the pool of available Ph.D.'s in science and engineering and requirements for their utilization, a topic of particular importance when viewed within the context of a rapidly changing national situation. The National Science Foundation undertook to analyze and project the future relationship between the supply and utilization of science and engineering doctorates. The results of this analysis were made public in a report, *Science and Engineering Doctorate Supply and Utilization, 1968–80*. This and subsequent analyses seem to indicate that, by 1980, 320–350,000 science and engineering doctorates (compared with about 150,000 in 1968) might be available. However, present job markets for doctorates are not nearly as favorable as they have been in past years, though it is not clear in the current fluid situation whether the major present problem is a mismatch between opportunities and aspirations or actually an oversupply of Ph.D.'s. Thus, the 1980 pool of doctorates will depend on the extent to which the present situation will affect graduate school enrollments and thus the future rate of Ph.D. production. With regard to utilization, several projections were made on the basis of varying assumptions. The projected relationship between supply and utilization figures indicates that by 1980, the supply and utilization of science and engineering doctorates is likely to be in equilibrium. However, it would also appear that significant numbers of Ph.D.'s are likely to be engaged in activities which are markedly different from the primary ones practiced by most present doctorates. Examples of these different activities include non-R&D functions in industry and government as well as teaching in 2- and 4-year colleges. Recent evidence shows that the shift is already beginning. Implications of this analysis are that Ph.D. education should offer a variety of different programs including training most suitable for these new activities. It thus appears necessary for universities to examine their graduate programs and to develop new and different curricula for Ph.D.'s who do not intend to enter research careers.

[1] National Science Foundation, *Federal Support to Universities and Colleges and Selected Nonprofit Institutions, Fiscal Year 1969* (NSF 70–27) Washington, D.C. 20402: Supt. of Documents, U.S. Government Printing Office, 1970.

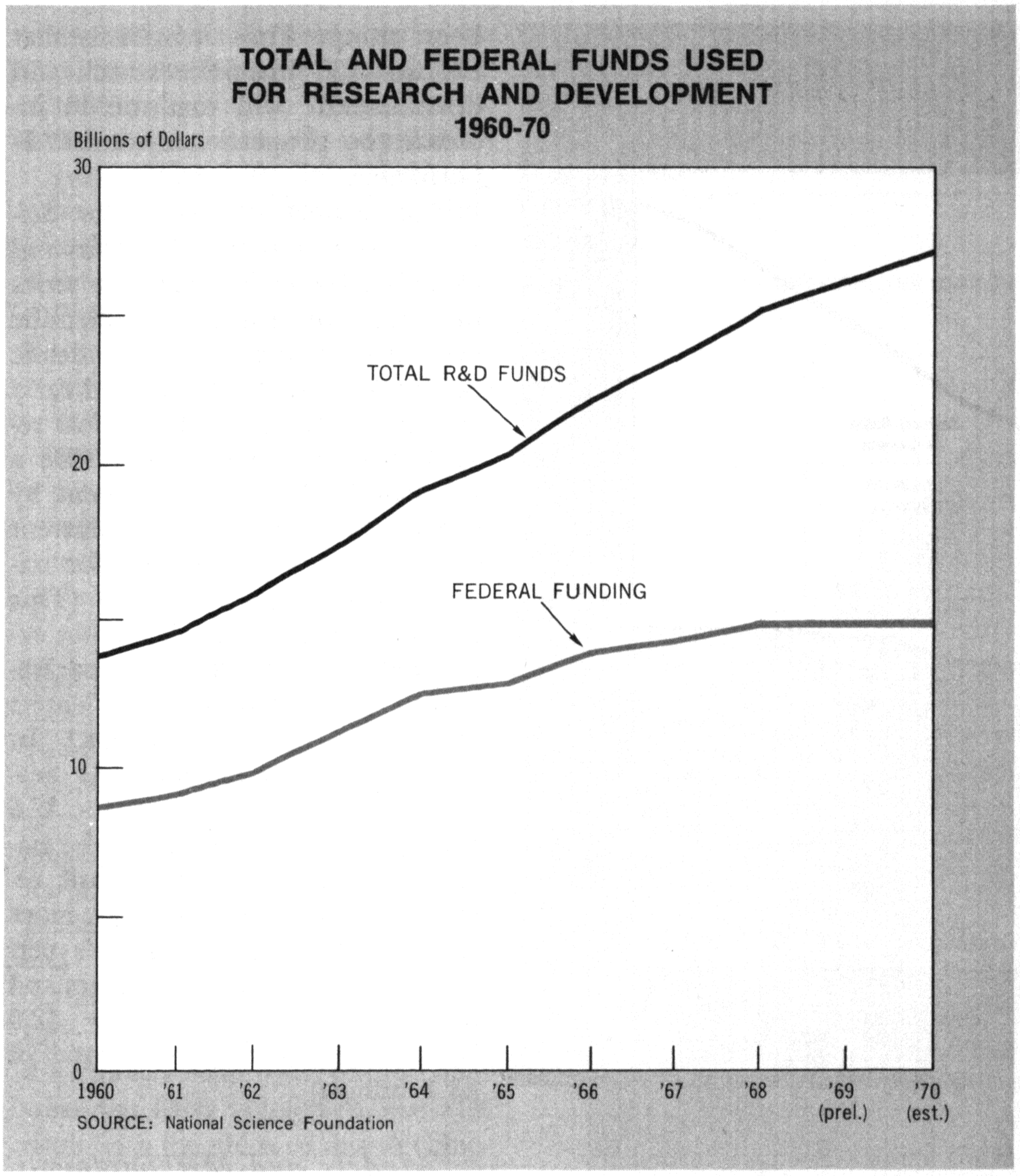
DEVELOPMENT OF BASIC TOOLS FOR SCIENCE PLANNING AND POLICYMAKING

The development of an adequate data and methodology base for the making of science policy decisions is carried out by the Foundation through a broad range of study activities. Included are studies for the collection and analysis of data concerning the nation's scientific resources; the development of concepts and projection and modeling techniques relating to these resources; and the correlation and synthesis of information from many sources on the flow of resources to scientific and technical activities. The more important results of these efforts are highlighted below.

The National Scene

A comprehensive review of total national expenditures for research and development over the period 1953 to 1970 was published in fiscal year 1970 in the NSF report, *National Patterns of R&D Resources.* The data in this publication were obtained through the periodic NSF surveys of all sectors of the economy. They revealed that in 1970 national R&D expenditures, from both Federal and non-Federal sources, reached an estimated record level of $27 billion. This amount is $1 billion higher than the estimated 1969 level and nearly $7 billion more than in 1965. However, the average annual rate of growth during the 1965–70 period was only 5.9 percent compared with a 9.4 percent average for 1958–65. Furthermore, this growth rate over the last 2-year period, 1968–70, has declined to a 3.6 percent level. The major reason for the decline has been a leveling off of R&D support by the Federal Government. Federal expenditures for R&D between 1958 and 1965 grew by 12.3 percent annually but increased by an annual average of only 3.4 percent between 1965 and 1970 and showed no increase at all in the period between 1968–70, remaining constant at about the $15 billion level. (See chart.)

The report on national R&D ex-



penditures also presented information on the full-time equivalent (FTE) number, and sectoral distribution, of scientists and engineers engaged in research and development. During 1968, an estimated 565,000 FTE scientists and engineers were engaged in research and development. Although this was nearly two and one-half times the number employed in R&D activities in 1954, the rate of increase of R&D scientists and engineers has been declining in recent years. Between 1954 and 1961, the annual average rate of growth of R&D scientists and engineers was 8.7 percent. This growth rate fell to 4.1 percent between 1961 and 1968.

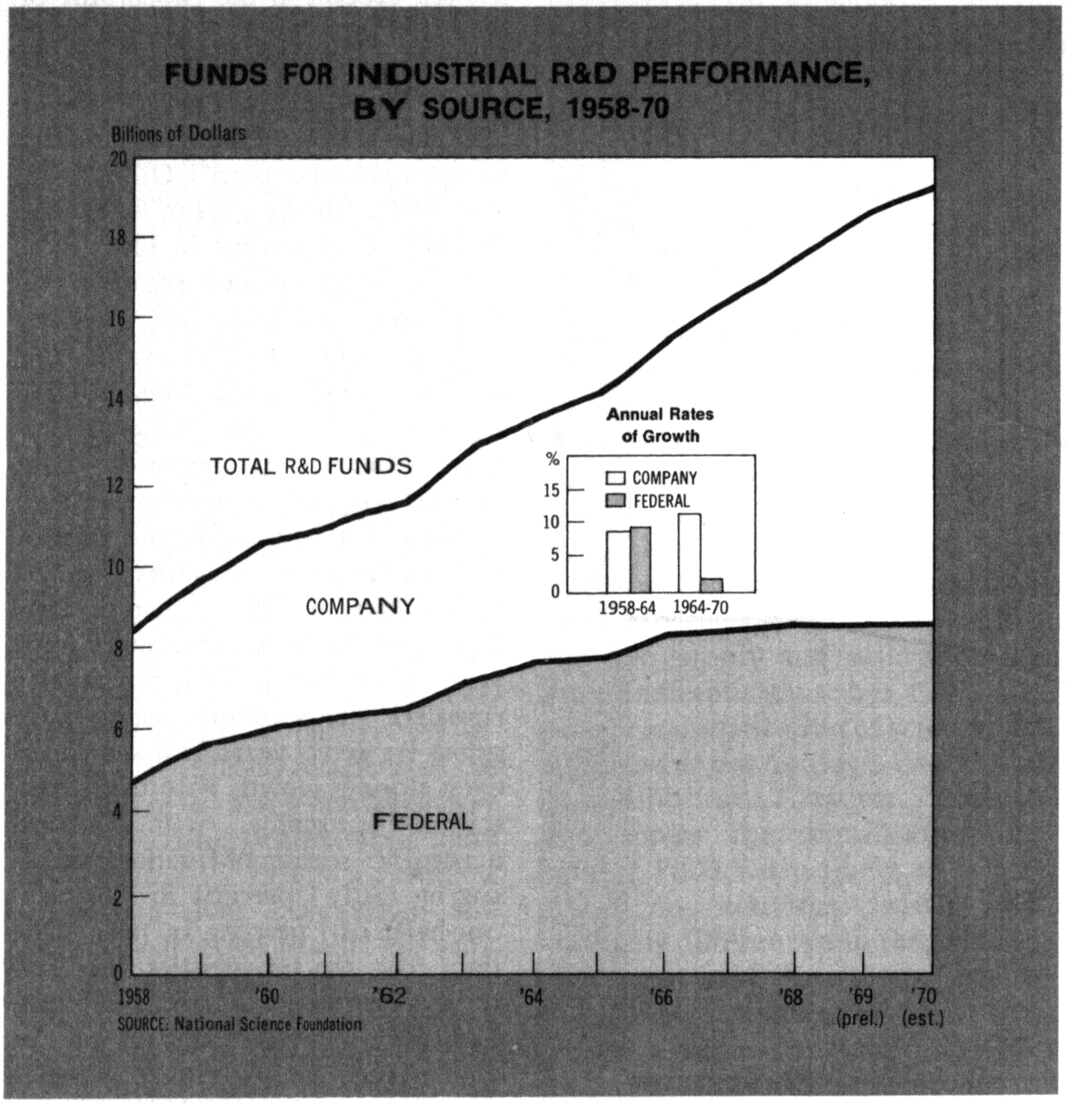
Federal R&D Support

Federal obligations for research and development—as distinct from R&D expenditures discussed above—totaled $15.6 billion in fiscal year 1969 and were expected to total approximately the same amount in both fiscal years 1970 and 1971. (See volume XIX, *Federal Funds for Research, Development, and Other Scientific Activities.* NSF 69–31.) This represents a decline in support from the 1967 R&D obligation total of $16.5 billion—the year of the highest dollar funding of Federal R&D programs. The report on Federal funding also indicates that there has been a significant increase during the last decade in the proportion of federally sponsored R&D activities devoted to areas other than military, space, and atomic energy efforts. The share of total Federal funding in agencies other than DOD, NASA, and AEC has risen from 9 percent in 1960 to 18 percent in 1970.

In its second annual report to the President and Congress, entitled *Federal Support to Universities and Colleges and Selected Nonprofit Institutions, 1969,* the National Science Foundation reported that Federal support to universities and colleges for both academic science and nonscience activities totaled $3.5 billion in 1969, a gain of only 2 percent for the second consecutive year. (See chart.) This report also revealed that academic science programs in recent years have shown an even slower growth rate than nonscience programs, with Federal academic science obligations growing by only 1 percent in 1968 and one-half of 1 percent in 1969. The data for the universities and colleges appearing in this study are gathered under the auspices of the Committee on Academic Science and Engineering (CASE) of the Federal Council for Science and Technology.

In addition to the report to the President and Congress which presents detail for individual institutions, CASE is collecting data on individual federally sponsored university projects covering both funding and manpower associated with the projects. A publication covering this project reporting is expected during fiscal year 1971.

At the request of the Federal Council for Science and Technology, the National Science Foundation compiled a *Directory of Federal R&D Installations.* This directory, the first of its kind, was prepared and released for public use in 1970 and provides a comprehensive general reference to R&D



establishments owned and directly controlled by the Federal Government. More than 700 installations are listed in the directory with information provided concerning their location, size, functions, activities, and capabilities. It is anticipated that the directory will be an important mechanism for making more widely known the Federal installations capable of dealing with significant research and technological problems, and that it will also further interagency use of Federal R&D resources.

Non-Federal R&D Support

In contrast to the Federal R&D funding picture, industry has been increasing its financial contribution to R&D at an increasing rate of growth as reported in the NSF publication *Research and Development in Industry, 1968*. In 1968 industrial firms supported 51 percent of their R&D performance with their own funds compared with a decade earlier when companies funded only two-fifths of their R&D activities. In total, industry spent $8.9 billion in 1968 on company-financed research and development, and the Federal Government funded an additional $8.6 billion of industrial research and development. Indications are that the amount of Federal support for industrial research and development has been leveling off since 1968, while the amount of company support has been rising. Thus, it is likely that industrially financed research and development will continue to increase as a proportion of total R&D performance. (See chart.)

The report *Resources for Scientific Activities at Universities and Colleges, 1969,* the latest in a series providing information on scientific activities in the nation's academic institutions, will be published early in fiscal year 1971. This report reveals that in academic year 1968 a total of $7.0 billion was spent by universities and colleges (in current and capital expenditures) for science research and instruction. (This figure does not include funds expended by Federally Financed Research and Development Centers located at these institutions.) In 1968, R&D expenditures at academic institutions amounted to $2.6 billion, only 10 percent of the national total. In terms of basic research dollars spent, however, more than one-half of the nation's performance took place in colleges and universities (approximately $2.0 billion out of a national total of $3.7 billion).

Models and Methodology

In addition to having current, accurate data for planning and policy purposes, it is important to have available suitable models which can assist in putting the data to use. The development and testing of models and methodologies for use in science planning is still in its early stages and the Foundation has continued to encourage and support new exploratory efforts.

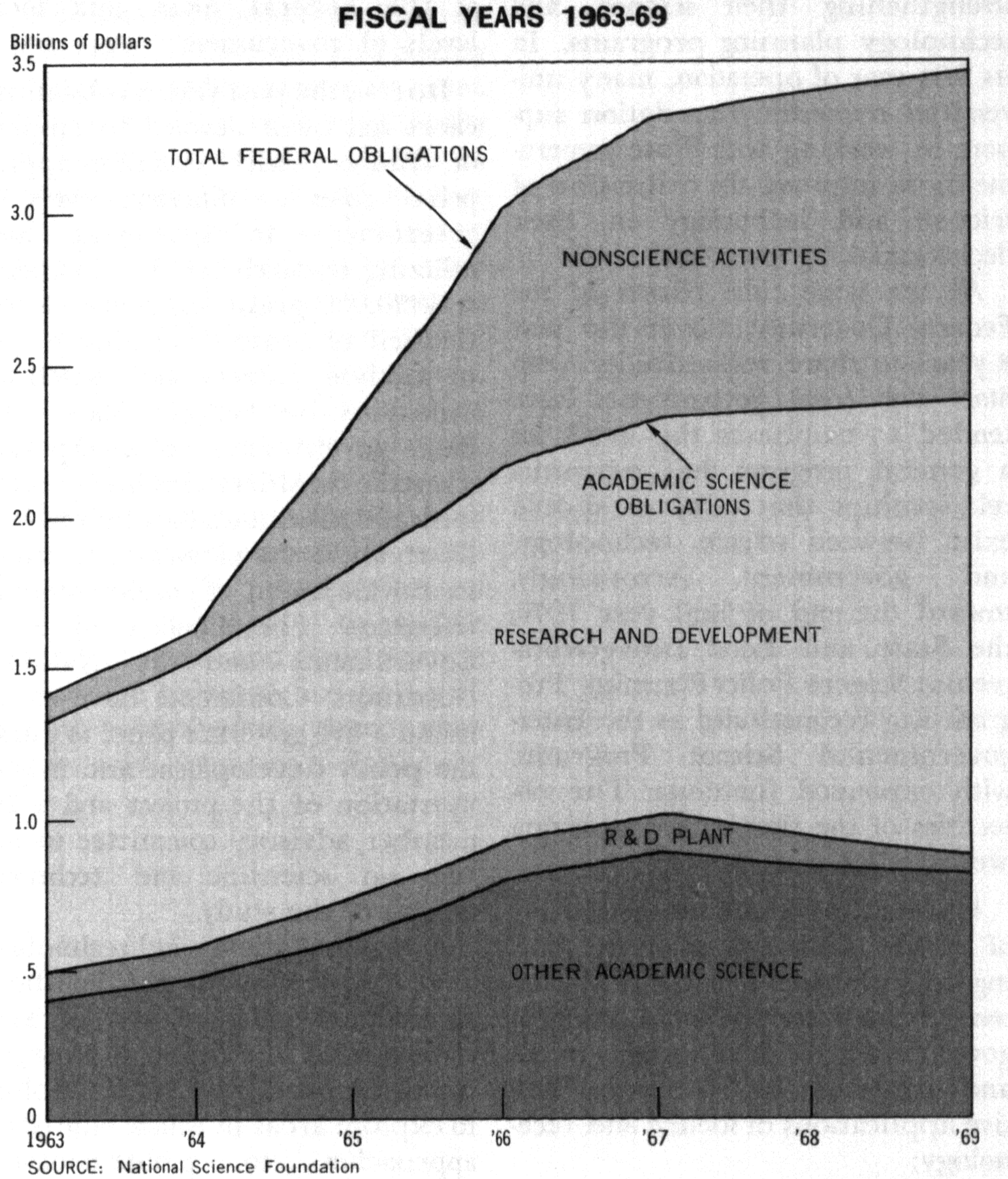
In 1969–70 the Institute for the Future completed a study designed to improve long-range forecasting techniques. New techniques were developed, tested, and applied prospectively and retrospectively to areas of economics, political science, and technology. Specific cases chosen for analysis included:

- the diffusion of hybrid corn in the midwestern United States in the 1930's;
- the dependence of population growth on family planning, health care, mortality, production, etc.;
- the Indian economic Five-Year Plan of 1956;
- future developments in low temperature physics and cryogenics and their interrelationship with certain social changes;
- the social, political, and economic impact of introducing certain technologies into developing countries.

Although the study primarily dealt with the development of methodological techniques, the advice of experts was used to develop the technical framework for consideration of the problem. For example, in the low temperature physics project, physicists were asked to predict the most likely scientific and technological developments occurring over various periods of time. Questions asked of a multidisciplinary team covered not only what was likely to happen, but also dealt with the effects of one development on others. This technique produced matrices which indicate whether one development is likely to increase or decrease another's likelihood. The results strongly indicate that this cross impact method has great potential in a comprehensive approach to forecasting.

NSF has also been contributing to a nationwide effort among academic institutions to design, develop, and implement information systems for their individual use. Conducted by the Western Interstate Commission for Higher Education (WICHIE), the effort involves the development of resource allocation, cost, funding, student flow, and other planning models. In fiscal year 1969 a state-of-the-art seminar was held by WICHIE, supported by the Foundation and the U.S. Office of Education, regarding developments in management information systems and planning models. In fiscal year 1970, again joining with the Office of Education, NSF helped support a WICHIE seminar on the "outputs" of higher education. The conference brought together leaders in higher education research to discuss the identification and quantification of the products of higher education.

FEDERAL OBLIGATIONS TO UNIVERSITIES AND COLLEGES, BY TYPE OF PROGRAM, FISCAL YEARS 1963-69



SOURCE: National Science Foundation

DEVELOPMENT OF SCIENCE PLANNING AND POLICY CAPABILITY

Intergovernmental Science Programs

Fiscal year 1970 saw a significant expansion and reorientation of an NSF activity formerly known as the State and Local Government Science Policy Planning Program. This program was originated in fiscal year 1969 as an experimental effort to assist State governments in strengthening their science and technology planning programs. In its first year of operation, many universities requested Foundation support in working with State governments to improve the utilization of science and technology in their decisionmaking processes.

At the same time, efforts of the Federal Government over the past 8 years to share responsibility with State and local governments have tended to emphasize the need for a general program that examines relationships that exist, or should exist, between science, technology, and government. Accordingly, toward the end of fiscal year 1970, the State and Local Intergovernmental Science Policy Planning Program was reconstituted as the Intergovernmental Science Programs, with expanded functions. The objectives of the reorganized program are as follows:

1. To advance the understanding of public issues and problems having scientific and technological content at the State and local levels of government, and to assess needs and opportunities for more effective applications of science and technology;

2. To demonstrate innovative science and technology planning and decisionmaking processes related to State, local, and regional problems;

3. To stimulate selected State and local government experimentation, on a pilot basis, with science and technology systems in the context of their own needs and resources;

4. To encourage adoption of new systems which show promise for enhancing State and local ability to incorporate science and technology into public programs;

5. To improve communication between persons and groups concerned with science and technology at the Federal, State, and local levels of government.

During the past year, a substantial effort has been devoted to support of studies which examine appropriate roles of different levels of government in sponsoring and utilizing research and development. A $320,000 grant was given to the Council of State Governments (1) to analyze current and potential endeavors by Federal, State, and local governments to incorporate scientific considerations into governmental decisions and operations and (2) to assess the national machinery for development of problem-solving resources. The Council of State Governments and the National Governors' Conference have established a five governor panel to guide the policy development and implementation of the project and a 20-member advisory committee to advise on scientific and technical aspects of the study.

A regional science and technology award was given to the Southern Interstate Nuclear Board in association with the States of Georgia, North Carolina, and South Carolina to explore areas in which multistate approaches to problem-solving might be desirable either because of economics of scale or in areas where problems transcend State boundaries. This study, in addition to an earlier study supported at the University of Tennessee, will also examine how individual States might improve their program and policy relationships with the Federal Government.

Another grant was made to the California State Assembly to examine how scientific and technological considerations can be incorporated into the legislative process. In addition, several smaller grants were made to examine different areas of State science and technology policy relating to environmental quality (Louisiana), technological forecasting (Montana), development of new mechanisms for relating academic research outputs to government decisionmaking (Virginia), and Federal-State-local support and utilization of research and development in regulating air pollution (Pennsylvania). A grant to use a new technique of simulation to study Federal-State decisionmaking in regard to allocating governmental resources for science and technology was made to the Institute for the Future.

To improve communication between governmental leaders and the scientific community, a series of four regional (Southern, Eastern, Western, and Midwestern) and one national conference on Science, Technology and State Government were supported in conjunction with other Federal agencies and State organizations.

A survey of scientific and technological advice available to local governments was supported under a joint grant to the New York State Department of Education and the International City Managers Association. This will provide information at the local level to supplement information at the State level that will be obtained under nine State case studies of the science advisory mechanisms to State government supported under earlier NSF grants.

University Science Planning and Policy Program

The University Science Planning and Policy Program is designed to assist in the development of the resources and capabilities of academic institutions for training and research related to science planning and policy activities. The program was established in recognition of a critical need for a better understanding of the many complex science policy issues and the lack of adequately trained manpower to deal with these problems.

Institutions currently receiving grants under this program include Harvard University, Massachusetts Institute of Technology, University of Virginia, State University of New York at Albany, Cornell University, the University of Indiana, Stanford University, and the University of California at Berkeley.

These grants help to support teaching, research, and special seminars on such science policy problems as: the use of science in international affairs; scientific and technical manpower; environmental management; technology and the city; nuclear energy, the law and international affairs; the effects of new educational technology; legal and moral implications of modern biology and medicine; the effects of technology on economic growth; and the organization of large-scale technological projects.

The Cornell University Program on Science, Technology and Society has, during the first year of its grant, been successful in involving faculty and students from many disciplines, including the sciences and humanities, in new courses and seminars jointly sponsored with other units of the university, in such areas as Biology and Society, International Flows of Science and Technology, Social Implications of Technology, Law and Environmental Control, and Technology Assessment.

Under recent grants, Harvard will develop a series of case studies which demonstrate the application of analytical techniques to public policy problems; and Stanford will analyze the technical and policy alternatives involved in telecommunications and computer technology.

Appendix A

National Science Board, NSF Staff, Advisory Committees and Panels

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ATHELSTAN F. SPILHAUS, Post Office Box 887, Palm Beach, Fla.

H. GUYFORD STEVER, President, Carnegie-Mellon University, Pittsburgh, Pa.

RICHARD H. SULLIVAN, Assistant to the President, Carnegie Corporation of New York, New York, N.Y.

Terms Expire May 10, 1974

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Terms Expire May 10, 1976

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LLOYD M. COOKE, Director of Urban Affairs, Union Carbide Corp., New York, N.Y.

ROBERT H. DICKE, Cyrus Fogg Brackett Professor of Physics, Department of Physics, Princeton University, Princeton, N.J.

DAVID M. GATES, Director, Missouri Botanical Garden, St. Louis, Mo.

*ROGER W. HEYNS (Vice Chairman, National Science Board), Chancellor, University of California at Berkeley, Berkeley, Calif.

FRANK PRESS, Chairman, Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Mass.

F. P. THIEME, President, University of Colorado, Boulder, Colo.

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Acting Division Director, A. P. Crary

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Appendix B

Organizational Changes and Appointments

Dr. William D. McElroy was appointed by the President for a 6-year term as Director of the National Science Foundation. Dr. McElroy, formerly of Johns Hopkins University, was confirmed by the Senate on July 11 and took the oath of office as Director on July 14, 1969.

On October 24, 1969, Dr. McElroy announced a major reorganization of the Foundation. This reorganization implemented the provisions and philosophy of the recently amended NSF Act and provided a framework for developing new approaches to the management of Foundation activities. The first key appointment Dr. McElroy made in his tenure was that of Mr. Bernard Sisco as Assistant Director for Administration. Mr. Sisco was formerly the Deputy Assistant Director for Administration at DHEW.

The President, in June 1970, appointed the four new Assistant Directors authorized in the NSF Act:

Assistant Director for Research—Dr. Edward C. Creutz of Rancho Santa Fe, Calif., Vice President in Charge of Research and Development for Gulf General Atomic in San Diego.

Assistant Director for Education—Dr. Lloyd G. Humphreys of White Heath, Ill., Professor of Psychology at the University of Illinois.

Assistant Director for Institutional Programs—Dr. Louis Levin of Bethesda, Md., Executive Associate Director of the National Science Foundation.

Assistant Director for National and International Programs—Dr. Thomas B. Owen of Seattle, Wash., a rear admiral in the Navy, formerly Chief of Naval Research.

Office of the Director

The position of Deputy Director, another Presidentially appointed post, was not filled during fiscal year 1970. Dr. Louis Levin acted in the capacity of Deputy Director until his appointment as Assistant Director for Institutional Programs. On August 13, 1970, President Nixon announced his intention to nominate Dr. Raymond L. Bisplinghoff, Dean of the School of Engineering of the Massachusetts Institute of Technology, for the position of Deputy Director.

Five changes occurred affecting the Director's Staff Assistants. Mr. Daniel Hunt, Jr., Special Assistant, assumed the new position in NSF of Head, Office of National Centers and Facilities Operations. Dr. Robert W. Johnston, Executive Assistant, left to become Vice Chancellor for Research at Washington University. Three new Special Assistants to the Director were appointed: Mr. David E. Ryer, formerly Director of Planning at Tulane University; Dr. Lawton M. Hartman, former Special Assistant to the NSF Planning Director, and Dr. Douglas L. Brooks who was President of Traveler's Research Corporation.

Executive Council

The Director established the new Executive Council on May 4, 1970. The Council consists of the Director as Chairman, the Deputy Director, the five Assistant Directors, the General Counsel, and the Director of the Office of Government and Public Programs. It serves as the key advisory body to the Director on significant planning, policy, and problem areas. Dr. Brooks serves as the Executive Secretary.

Assistant Director for Research

The new Office of Interdisciplinary Research was established in October 1969. This addition to the Research directorate is a new departure activity for the Foundation and is designed to focus upon the contributions that science can bring in solving societal problems.

Assistant Director for Education

In streamlining the Education organization, the Planning and Evaluation Unit was discontinued as was the section structure in the Division of Pre-College Education in Science.

Assistant Director for National and International Programs

This new directorate was established in the October reorganization. It consists of two offices formerly in Research: Office of Sea Grant Programs and Office of Antarctic Programs (the title was changed to Polar Programs to reflect the addition of responsibility for Arctic as well as Antarctic Programs); three formerly independent offices: Office of International Programs, Office of Computing Activities, and Office of Science Information Service; and three newly established offices: Office of National Centers and Facilities Operations, Office for International Decade of Ocean Exploration, and Office of Intergovernmental Science Programs.

Assistant Director for Institutional Programs

In March 1970, Institutional Programs reorganized five sections into two divisions: Division of Institutional Development and Division of Institutional Resources.

Assistant Director for Administration

In October 1969, the Offices of Administrative Manager, Comptroller, and Data Management Systems were organized into this new directorate. The Program Review Office was added in January 1970. Subsequently, many of the activities of the Office of Planning and Policy Studies were added to create the new Office of Budget, Programming, and Analysis.

Office of Economic, Manpower, and Special Studies

In May 1970, the Planning Organization was redesignated as the Office of Economic, Manpower, and Special Studies.

Personnel Staff Changes

In addition to the appointments mentioned above the following key personnel staff changes were announced during the year.

E. W. Barrett, Data Management Systems Officer.

Arley T. Bever, Head, Office of Budget, Programming, and Analysis.

Henry Birnbaum, Head, NSF Tokyo.

William Bolton, Jr., Head, Grants and Contracts Office.

Robert B. Boyden, Audit Officer.

Douglas L. Brooks, Executive Secretary of the Executive Council.

J. Merton England, Executive Assistant to the Deputy Assistant Director for Institutional Programs.

Charles E. Falk, Head, Office of Economic, Manpower, and Special Studies.

Thomas D. Fontaine, Deputy Assistant Director for Education.

Kenneth B. Foster, Financial Management Officer.

Jerome H. Fregeau, Executive Assistant to the Deputy Assistant Director for Research.

M. Frank Hersman, Head, Office of Intergovernmental Science Programs.

T. E. Jenkins, Deputy Assistant Director for Administration.

Lewis P. Jones, Program Review Officer.

Thomas O. Jones, Deputy Assistant Director for National and International Programs.

Keith R. Kelson, Executive Assistant to the Deputy Assistant Director for Education.

J. L. McHugh, Head, Office for the International Decade of Ocean Exploration.

Howard E. Page, Deputy Assistant Director for Institutional Programs.

John R. Pasta, Head, Office of Computing Activities.

Harry J. Piccariello, Head, Plans and Analysis Office.

Albert H. Rosenthal, Public Understanding of Science Officer.

Joel A. Snow, Head, Office of Interdisciplinary Research.

Edward P. Todd, Deputy Assistant Director for Research.

Resignations

Robert W. Johnston, Executive Assistant to the Director, left the Foundation to assume the position of Vice Chancellor for Research at Washington University in St. Louis.

Sidney D. Reed, Jr., Head of the Office of Planning and Policy Studies, left the Foundation to accept a position with private industry.

H. E. Riley, Head of the Office of Economic and Manpower Studies retired after 32 years of Federal service.

Randal M. Robertson, Associate Director for Research retired after 24 years of Federal service.

Aaron Rosenthal, Comptroller, retired from the Foundation and joined the staff of the National Academy of Sciences.

In total, 978 full-time personnel were employed by the National Science Foundation at the end of fiscal year 1970 as compared to 953 in fiscal year 1969.

Changes in the National Science Board

During fiscal year 1970, the following changes took place in the membership of the National Science Board.

The following members of the Board were reappointed for 6-year terms: Dr. H. E. Carter, Vice Chancellor for Academic Affairs, Urbana-Champaign Campus, University of Illinois; Dr. Roger W. Heyns, Chancellor, University of California at Berkeley; and Dr. F. P. Thieme, President, University of Colorado.

New appointments for 6-year terms were as follows: Dr. Robert A. Charpie, President, Cabot Corp., Boston, Mass.; Dr. Lloyd M. Cooke, Director of Urban Affairs, Union Carbide Corp., Chicago, Ill.; Dr. Robert H. Dicke, Cyrus Fogg Brackett Professor of Physics and Chairman, Department of Physics, Princeton University; Dr. David M. Gates, Professor of Botany, Washington University and Director, Missouri Botanical Garden; and Dr. Frank Press, Professor of Geophysics and Chairman, Department of Geology and Geophysics, Massachusetts Institute of Technology.

Dr. H. Guyford Stever, President, Carnegie-Mellon University, was appointed to fill the vacancy created by the resignation from the Board by the Honorable Clifford M. Hardin, Secretary of Agriculture. Dr. Stever will serve until May 10, 1972.

At the Twentieth Annual Meeting of the National Science Board, May 22, 1970, Dr. H. E. Carter was elected Chairman and Dr. Roger W. Heyns was elected Vice Chairman, both for 2-year terms.

Appendix C

Financial Report For Fiscal Year 1970

Salaries and Expenses Appropriation

Receipts		
Fiscal year 1970 appropriation	$438,000,000	
Unobligated balance carried forward from fiscal year 1969	23,117,160	
Reimbursement from non-Federal source	125,598	
Fiscal year 1970 total availability		$461,242,758
Net obligations		
Scientific research project support:		
Atmospheric sciences	7,922,289	
Earth sciences	7,849,449	
Oceanography	8,912,186	
Biological sciences	40,874,930	
Physics	28,179,892	
Chemistry	17,397,261	
Astronomy	5,799,955	
Mathematics	12,663,766	
Social sciences	15,415,603	
Engineering	16,700,430	
Subtotal, scientific research project support		161,715,761
Specialized research facilities and equipment:		
Specialized biological facilities and equipment	917,946	
Environmental sciences research facilities:		
University atmospheric research facilities	199,187	
Physical sciences research facilities:		
Chemistry research instruments	1,697,074	
University astronomy research facilities	189,800	
University physics research facilities	2,499,262	
Engineering research facilities	599,932	
Earth sciences research facilities and equipment	103,400	
Specialized social sciences research facilities	297,810	
Subtotal, specialized research facilities and equipment		6,504,411
National and special research programs:		
Antarctic research programs	7,407,014	
Weather modification program	2,633,646	
Ocean sediment coring program	6,548,383	
International biological program	3,998,700	
Global atmospheric research program	1,494,600	
Interdisciplinary research relevant to problems of our society	5,984,099	
Engineering systems	3,297,238	
Oceanographic ship operations and facilities	7,600,483	
Subtotal, national and special research programs		38,964,163
National research centers:		
National Radio Astronomy Observatory	5,800,000	
Kitt Peak National Observatory	6,425,000	
Cerro Tololo Inter-American Observatory	1,900,000	
National Center for Atmospheric Research	11,536,800	
Arecibo Observatory	1,550,000	
Subtotal, national research centers		27,211,800
National sea grant program		8,974,156
Computing activities in education and research		16,918,585
Science information activities		11,433,279
International cooperative scientific activities		1,712,426
Intergovernmental science program		460,960
Institutional support for science:		
Institutional grants for science	14,514,832	
Science development	30,186,565	
Subtotal, institutional support for science		44,701,397

	Net obligations	
Science education support:		
Student development:		
Science education for students	$1,930,865	
Undergraduate education for students	3,817,318	
Graduate fellowships and traineeships	37,644,107	
Other fellowships—postdoctoral	1,689,000	
Advanced science education program	788,610	
Subtotal	45,869,904	
Instructional personnel development:		
Institutes	36,935,931	
College teacher program	4,160,497	
Science faculty fellowships	3,033,889	
Advanced science education programs	783,228	
Subtotal	44,913,545	
Instructional program development:		
Course content improvement	$6,506,980	
Cooperative college school program	4,654,421	
Science curriculum improvement	9,805,506	
College science improvement program	6,829,200	
Senior foreign scientist fellowships	779,518	
Advanced science education program	820,791	
Subtotal	29,396,416	
Subtotal, science education support		$120,179,865
Planning and policy studies		2,165,356
Program development and management		19,675,785
Total obligations, NSF salaries and expenses appropriation		460,617,944
Unobligated balance carried forward to fiscal year 1971		624,814
Total		461,242,758

Special foreign currency	
Receipts	
Fiscal year 1970 appropriation	2,000,000
Obligations	
Total obligations for fiscal year 1970	2,000,000

Trust Fund

Receipts	
Unobligated balance brought forward from fiscal year 1969	8,075
Donations from private sources	2,249
Total availability	10,324
Obligations	
Total obligations for fiscal year 1970	4,675
Unobligated balance carried forward to fiscal year 1971	5,649
Total obligations	10,324

Appendix D

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 four patents by the U.S. Patent Office covering inventions arising out of Foundation-supported activities on each of which the U.S. Government has received a nonexclusive, irrevocable, nontransferrable, royalty-free, worldwide license:

Patent No. 3,460,150 entitled "High Gain Frequency Independent Antenna" was issued on August 5, 1969, on an invention made by Kenneth K. Mei during the course of research supported by a grant to the University of California. This invention relates to means for propagating and receiving electromagnetic energy, particularly waves of relatively short length and particularly under circustances wherein considerable directivity of the antenna is desired and in which a high gain is requisite.

Patent No. 3,461,591 entitled "Underwater Sampling Apparatus" was issued on August 19, 1969, on an invention made by Daniel M. Brown and John A. McGowan during the course of research supported by a grant to the University of California. This invention relates to underwater sampling apparatus being more particularly directed to nets adapted to being towed under water and automatically to be opened and closed at predetermined instants of time to collect desired samples of plankton and the like.

Patent No. 3,465,500 entitled "Method and Apparatus for Separation of Components from Gaseous Streams" was issued on September 9, 1969, on an invention made by John B. Fenn during the course of research supported by a grant to Princeton University. This invention relates to a method and apparatus for separating the components of a gaseous mixture containing heavier and lighter species.

Patent No. 3,469,118 entitled "High Voltage Generator" was issued on September 23, 1969, on an invention made by Raymond G. Herb and James A. Ferry during the course of research supported by a grant to the University of Wisconsin. This invention relates to high-voltage generators of the electrostatic type.

Appendix E

Publications of the National Science Foundation Fiscal Year 1970

1 R&D in the Aircraft and Missiles Industry, 1957–68 (NSF 69–15).
2 Scientific Activities of Nonprofit Institutions, 1966 (NSF 69–16).
3 Successful Industrial Innovations (NSF 69–17).
4 Tenth Annual Weather Modification Report (NSF 69–18).
5 Continuing Education for R&D Careers (NSF 69–20).
6 Engineering Research Initiation Grants (NSF 69–22).
7 Grants for Scientific Research (NSF 69–23).
8 Science Facilities Bibliography (NSF 69–24).
9 Improving the Dissemination of Scientific Information (NSF 69–25).
10 Scientific and Technical Personnel in the Federal Government (NSF 69–26).
11 Grants for Graduate Science Facilities (NSF 69–27).
12 Research and Development in Industry, 1967 (NSF 69–28).
13 National Patterns of R&D Resources, 1953–70 (NSF 69–30).
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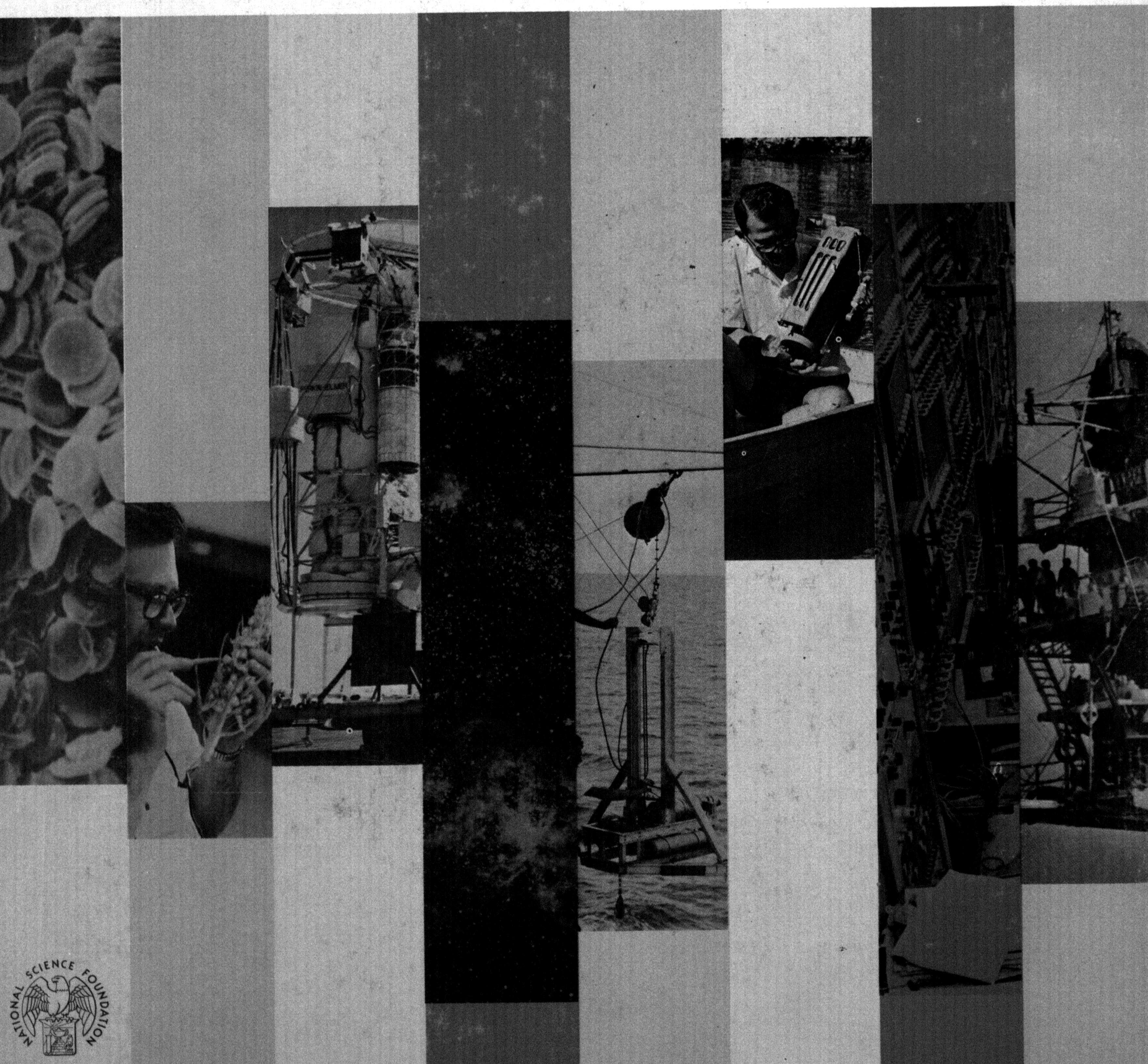

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