

National Science Foundation Annual Report 1975

Dr. Clark

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National Science Foundation

Twenty-Fifth Annual Report for Fiscal Year 1975

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Letter of Transmittal

Washington, D.C.

DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1975 of the National Science Foundation for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,



H. GUYFORD STEVER
Director, National Science Foundation

*The Honorable
The President of the United States*

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Director's Statement

Like the Nation entering its bicentennial year, the National Science Foundation, celebrating its 25th anniversary, found itself more challenged by its future than taken with its past. Though both the Nation and the Foundation can take just pride in their past accomplishments, the events of the year and the problems that clearly lay ahead pressed hard for attention and action. As a Nation there was the feeling that the past, for all its achievements, was but a prologue, that our missions were still far from completed, and that there would be a day more appropriate for celebration when we had overcome some of the major challenges still faced.

Perhaps what engendered this feeling most was a growing recognition of the economic and social aspects of the Nation's—and the world's—problems. Over the past years we have been made acutely aware of our environmental responsibilities; real and projected scarcities of resources and food have alarmed us; and an unsettling energy picture with rising prices and impending shortages has added to and aggravated the already complicated situation. But while there remains a broad feeling—an underlying faith—that through science and technology all these problems are potentially surmountable, there is now the harsh realization that, though they may be closely related, all cannot be solved at once, and we face a series of difficult economic and social choices. Such choices will involve us in strict priority setting, and they will call for making ethical and human value judgments as well as economic decisions. In the course of all this, we may find it at times quite difficult to pursue all our ideals—for as an astute political writer once observed: "Idealism is fine; but as it approaches reality, the cost becomes prohibitive."

Economically speaking, the costs of achieving all that we wish—that the Nation and the world now deem necessary—are indeed rising, and the question of how prohibitive the cost of human progress is, and how we might overcome that prohibition is now a major one before us. Therefore, it may be worthwhile to examine briefly some of the economic theory of the processes taking place and then go on to consider

how advances in science and technology might affect their future course.

What we are witnessing today is an effect somewhat akin to that which, over a century ago, the classical economist David Ricardo predicted would take place. Ricardo, a contemporary of Thomas Malthus, disagreed with Malthus that the factor limiting mankind's growth would be the physical limits of resources, at that time principally land and food. Instead, Ricardo saw the major roadblock to progress as the rising cost of extracting and using resources in order of declining economic quality. According to Ricardian economics then, scarcity would result not through the depletion of finite resources, but because as we sought to move from the more accessible, high grade resources to the more difficult to find, extract, and use, the cost of labor and capital involved in the process would literally price progress out of the market.

We know that during the more than 100 years following Ricardo's theorizing a number of factors—natural and social—came into play which tended to raise doubts as to the validity of his ideas. The age of science and the Industrial Revolution brought advances in man's relation to resources that forestalled scarcity and, in fact, made available to many societies the benefits of a new abundance. Among the factors that seemed to counter Ricardian economics were discoveries that enlarged the stock of resources, methods of developing substitute resources which had, among other things, the effect of enlarging the total resource base, and technological advances that allowed increased productivity and efficiency—that provided more units of output per unit of capital and labor. These and other influences were, in fact, so successful in the era following Ricardo's writings that an effect opposite to that which he predicted seemed to take place.

In their extensive study on this matter conducted in the early 1960's, economists Harold J. Barnett and Chandler Morse showed that in the United States, "contrary to the hypothesis which called for increase in the labor-capital cost of extractive output, the unit cost of extractive output declined." In pointing this out in their

book *Scarcity and Growth—The Economics of Natural Resource Availability*, they wrote:

Our empirical test has not supported the hypothesis—that economic scarcity of natural resources, as measured by the trend of real costs of extractive output, will increase over time in a growing economy. Observing the extractive sector in the United States from 1870 to 1957, we found that the trend in the unit cost of extractive goods as a whole has been down—not up. In the cases of agriculture and minerals, which account for the bulk of the value of extractive output, costs not only declined, but declined more in the latter part of the period—when according to the hypothesis they should have increased sharply.

But the final chapter of this story is yet to be written. For in the dozen years or so since the publication of that Chandler-Morse study other factors have come into play which have caused a resurgence of Ricardian thinking. One of these involves the fact that during all those previous decades of economic progress based on new technologies, many costs, such as those associated with environmental effects and the health and safety of workers, were treated as externalities—in other words, ignored. Now in cases where such external costs must be internalized, the price of certain resources is affected. A similar process is affecting costs in industrial production.

Another factor affecting resource costs has been the move on the part of Third World nations to seek what they consider fairer prices for the commodities they export. The OPEC price increases for oil are, of course, the prime example of this, and have set a precedent which others are trying to follow.

While these factors have been responsible for rising resource costs, there are a number of others responsible for increased costs in general throughout our industrial system. One of these is the fact that the improvement in our energy efficiency has leveled off, as has the rate of increase in industrial productivity. At the same time as this has been happening, exponential population growth combined with growing social expectations has put enormous pressures on our system to produce increasing amounts of goods and services, the cost of labor and capital has risen rapidly, and most recently there has been a rising and largely unmet demand for new

capital—capital needed both to replace obsolete equipment and develop new technologies. In fact, fears have been expressed that between now and 1985 we may experience a shortfall of domestic investment capital as great as \$650 billion.

Therefore, though the past century has been one of remarkable scientific and technological progress, and a period that for the most part seemed to counteract the Ricardian effect, we find today that we have no reason to be complacent. In fact, there is considerable evidence that despite our entrance into the age of space, nuclear energy, and the computer, we have been living to a large extent on previous technological successes. Peter Drucker, for example, claims that "The 50 years that came to an end with World War I produced most of the inventions that underlie our modern industrial civilization." And he lists a number of these—from the synthetic dyes (and with them the organic-chemical industry) to the Siemen's electric generator, the inventions of Edison, and the processes that spawned the steel and aluminum industries. These, and the inventions in the automotive and aircraft fields, Drucker points out, are still responsible for the largest part of our industrial output today.

What does all this mean? Taken all together it could indicate that we may be on a plateau of human innovation, and once again if we want to prove Ricardo and others wrong, we must, through a new burst of scientific, technological, and social advances, start to ascend to a much higher plane.

But clearly such advances must now involve far more than the development of technologies to reduce cost, raise productivity, and improve efficiency. We have added new dimensions to human needs that involve more than overcoming the scarcity of natural resources—although for some two-thirds of humanity obtaining enough of those resources to support a decent living remains a serious problem.

While economic growth has been basic to human development, the importance of integrating it with those environmental and social improvements which would enhance our total well-being is now being recognized and emphasized. It is for this reason that the focus is on achieving a higher quality of life—one which includes, among other things, a healthier natural environment, better urban conditions, and the reduction of social strife. It is the fulfillment of this desire, to combine quantitative and

qualitative advances and to make them available to the largest number of people, that represents the great challenge of our times.

Is the transference of such an ideal into reality prohibitive? Can we as a Nation find the resources—both physical and human—to achieve it? And if so, can we combine them to produce results that are economically, environmentally, and ethically acceptable?

Some believe that science and technology, for all their achievements of the past, cannot match the demands placed on them by today's growth—by the pressures of people and the limits of resources. Others feel that great strides in science and technology notwithstanding, our society still lacks the social and political maturity to meet our aims. Certainly the qualitative issues are more complex than the quantitative, involving diverse value choices. This is particularly true in a democratic society and in a large country where there are a variety of different and often conflicting interests, and often where an improvement in the quality of life in one region is at the expense of the same in another.

In their study on scarcity referred to above, economists Barnett and Morse agreed that the search for quality imposed the more complex problem. As they put it:

Modern societies may be less able to counteract adverse qualitative change, or take advantage of opportunities to improve the quality of life, than they are to circumvent increases in the economic scarcity of resources. Political and other social decisionmaking processes are available, but their operations are more cumbersome and less assured than technical and market processes. The problems of qualitative evaluation are more difficult, especially where they require joint evaluation of consequences for large numbers of people; they are a social rather than a private value problem.

The recognition of this, and of the entire matter of the relationship between the quantitative aspects of science and technology and the more qualitative areas is beginning to have an effect on the focus and direction of scientific activity. So is the matter of the ethical and human value implications of science and technology. In addition to the questions of why, what, and how, the science and engineering communities are now

being involved in those value-laden questions—for whom, and to what end. The partnership between science and society is growing closer. To be more successful, it must take on both the intimacy and openness of a good marriage.

Much of this has been reflected in the year's activities in science and in the programs and policies of the National Science Foundation. During the year, in addition to its usual communication with the Congress, the Foundation found itself engaged in a dialogue with some committees and individual members of the Congress on a number of subjects that showed a heightened sensitivity to the process of science support. The Foundation responded to questions raised concerning its methods of evaluating research proposals and to criticisms of some of the programs it supported. The nature and extent of Congressional oversight of such methods and programs was discussed in great detail. It is most likely that this dialogue will continue, and that its principal outcome will be a Congress more aware of the difficulties and problems involved in science support and a Foundation more aware of and responsive to Congressional concerns over how and to what ends it delivers such support.

Broadly, the Foundation's policies and programs were responsive to the new needs of the Nation—to its environmental, energy, and economic concerns. In the pages that follow in this Annual Report you will see evidence of that response.

In its support of basic research—by far the Foundation's major responsibility—a number of such goals are pursued, directly and indirectly. Three ways in which this is accomplished are especially worthy of mention here. The first is through research that provides an expanded knowledge of our physical world, giving society a more accurate picture of the natural setting and boundaries in which it operates. One reason why we need to know this is because our technology and its products are increasingly impinging on these, and often with detrimental effect. A case in point has been the matter of possible ozone reduction in the stratosphere, which would allow an increase in ultraviolet radiation to reach the Earth and thus might result in a growing incidence of skin cancer and other possible biological, agricultural, and ecological effects. Research in stratospheric chemistry has resulted in calculations indicating that man's release of increasing amounts of certain fluorocarbon compounds used as refrigerants and aerosol

propellants may be reducing the stratospheric ozone concentration. Modeling studies, laboratory studies, and atmospheric measurements are being used to refine the calculations, project possible future effects, and improve understanding of the atmospheric processes crucial to determining the likelihood and extent of such ozone reduction.

Other atmospheric research this year has provided us with important information to increase our understanding of mesoscale weather processes and violent storms. Sufficient information of this kind, applied wisely in such fields as industry, agriculture, and energy distribution, could result in annual savings of hundreds of millions of dollars for the Nation.

As this year's report indicates, research in environmental sciences is also making a contribution to our understanding of the Earth in a way that can benefit society. Seismic studies, for example, are providing valuable information that will help us to predict earthquakes and allow us to develop construction methods and carry out other measures to reduce their impact on humans.

A second way in which the Foundation's support of basic research relates to the pursuit of social goals is through the ability of such research to improve our resource base and the economics of resource utilization. This is accomplished in a number of ways. For example, while work in geology and geophysics gives us clues as to the location of additional conventional resources—such as mineral deposits—chemistry research leads to the development of new materials that can be synthesized from other resources, often from abundant matter not previously considered a resource. At the same time, engineering and materials research expands our knowledge in ways that allow us to increase the usefulness and life span of all resources and the products, and improve the services they perform, as in the case of research in superconductivity, corrosion and erosion, and embrittlement of metals. Through these aspects of research we as a Nation can greatly improve our economic advantages and stave off Ricardian scarcity. We can find substitutes for resources that are becoming limited in supply and higher in cost, and we can discover ways of using resources that accomplish more with less—less expenditure of materials and energy.

This ties in with the third way that basic research supported by the Foundation's

programs is helping to meet society's goals, that is, through the closer study of nature's ways of utilizing her resources—the highly efficient physical, chemical, and biological processes that sustain the varied systems of life on Earth. We are just beginning to learn about many of these and explore ways we might adapt them to technological use. Among these are the processes of photosynthesis and photohydrogenolysis (the separation of hydrogen and oxygen by light), nitrogen fixation, and biocatalysis using enzymes. These and other natural processes perform complex physical transformations with a minimum of energy and waste. If research reveals all the secrets of these processes and we learn to apply them on a large scale in industry and agriculture, vast new benefits could accrue to society. We could function with a great reduction of energy use, could be far less wasteful of resources, and could reduce our environmental impact considerably.

Throughout the pages of this report you will read of various other research endeavors in the environmental, physical, and biological sciences, the results of which might help achieve goals as varied as improving our balance of payments or warning us of a change in the Earth's heat balance. There is also that research by man on man—the social and behavioral sciences—through which we are attempting to learn more about ourselves and our institutions. The importance of this cannot be underestimated for history seems to show that man's ability to "know thyself" has usually lagged dangerously behind his ability to effect change, in both his environment and his society. The result has been much destruction and waste through technology's misuses, and much human suffering through social and political abuses.

There are, as this report points out, questions being raised these days about the usefulness of the social sciences. But also, as the report states, "there is virtually no person, organization, or agency of Government today that is not a user of social science methods and techniques. . . ."

As one might expect, the social sciences are bound to be involved in some controversy occasionally as they deal, among other things, with subjects of strong personal and economic interest to various individuals and groups in the society. They also sometimes suggest changes in institutions and ideas which conflict with long-held values or deeply ingrained habits. Nevertheless, many findings in social science

research can be applied rapidly and effectively.

The Foundation's program of Research Applied to National Needs (RANN) continues to be NSF's principal instrument for supporting a wide range of applied research, particularly research that is close to the frontiers in its field. The focus of RANN research support during 1975 remained on the areas of energy, environment, productivity, and exploratory research and problem assessment. It also devoted considerable attention to the matter of moving research results into use in the public and private sector through its Intergovernmental Science and Research Utilization program.

As you will learn from the report on the RANN program, its work is directly related to the strong need we have to innovate, to come up with the ability to tap vast new resources and make use of processes that could greatly improve our productivity. But in pursuing this course it also focuses on research that carefully evaluates the risks, hazards, and social effects of these advances. It is a program that considers the means to effect new growth—but to do it wisely, with consideration of its long-range implications and its possible impact on the world we will leave to future generations.

Experience is teaching us that the condition of that world will depend increasingly on the extent of international cooperation. Therefore, the Foundation actively pursues such cooperation in its global research programs and in its efforts to exchange scientific information with the other nations of the world. Such projects as the Ocean Sediment Coring Program involving the work of the *Glomar Challenger*, with its international contingent of scientists, and the Global Atmospheric Research Program, dependent on the land, sea, and air cooperation of dozens of nations, continued to reveal valuable information about the past and present natural forces that determine the condition of life on Earth. In addition to these national and international programs and our Arctic and Antarctic research as well, the Foundation initiated a new Climate Dynamics Program aimed at improved understanding of the processes that create climate change. Observations suggesting that we may be about to enter a period of such change, one that could have a widespread impact on human affairs, adds a sense of urgency to the need for such knowledge.

Throughout this statement there has been an emphasis on resources and the ways in which

increased knowledge could expand them. The one resource that must be developed in order to develop all others is our human resource—our youth. From them we need to draw and train the future scientists and engineers, the men and women who will be able to make the bold new advances necessary to overcome some of the difficulties projected over the coming decades. The Foundation's Science Education program is directed toward this end, and toward the purpose of creating a more scientifically literate population capable of conducting its affairs wisely in a society where science and technology interface crucially with so many of its important activities. As stated ahead, in the section on Science Education, "Major events in 1975 provided a good indication of how many important issues will be interwoven with science and technology from now on. . . ."

Some of those issues, and the knowledge required to deal with them effectively in the years ahead, will be the subject of a special bicentennial project being sponsored jointly by the National Science Foundation and the Xerox Corporation. This project—KNOWLEDGE 2000—will consist of three symposia. Each symposium will explore the knowledge capabilities that will be required to meet the challenges of the United States and the world during the next 25 years. With both scholars and practitioners from this country and abroad, the symposia will have as the major purpose an identification of the important areas where knowledge is required, as well as the major concerns and issues confronting the Nation and the world at the outset of our Nation's Third Century.

The products of the symposia discussions will be edited video-tape cassettes and community-oriented discussion guides which will receive the widest possible distribution to various citizen groups and organizations across the country.

An exploration of knowledge needed and directions to be taken by the Nation's science community is, to some extent, conducted now on a continuing basis by the science policy activities of the NSF. These activities are carried on through the Foundation's R&D Assessment Program, its Planning and Policy Studies, and Science Advisory Activities. Altogether they assist the Foundation, and the Director in his capacity as the Science Adviser, in understanding the Nation's position and needs regarding research and development. They indicate the

pulse of our scientific progress and attempt to give a prognosis on the Nation's scientific and technological health. Through the support of the advisory offices—the Science and Technology Policy Office and the Office of Energy R&D Policy—the Science Adviser is able to help coordinate the R&D activities of the scientific and mission agencies of the executive branch. Because of the increasing importance of the role that the Science Adviser might play at the highest level of Government, the President this year announced his intention of transferring the science advisory functions back to the White House, and legislation is now being drawn to carry out this action.

Throughout this statement I have stressed the importance of gaining and applying new knowledge—knowledge to increase our access to resources, to improve the products we produce from them, and to integrate these into our technological and social systems in a way beneficial to all. Such knowledge is the only resource we can gain that truly has no limits. And as has been stated many years ago, "Knowledge is the only instrument of production that is not subject to diminishing returns." But it should be reemphasized that the gaining of this precious

resource, like the accumulation of any capital, requires hard work and sacrifice. Nature yields her secrets grudgingly, and many we seek are among her most zealously guarded. To uncover them is going to take time and the commitment of our best talent. We have little choice but to devote that time and talent. The notion that we are approaching the end of our rope, that it is time to call a moratorium on man's ascendancy, has been offered but cannot be accepted. We should not, and cannot, back off from the challenges ahead. Though the situation may be somewhat different, there is still great truth in what John Stuart Mill wrote over 100 years ago:

History shows that great economic and social forces flow like a tide over communities only half conscious of that which is befalling them. Wise statesmen foresee what time is thus bringing, and try to shape institutions and mold men's thoughts and purposes in accordance with the change that is silently coming on.

In this age of change we must all strive to become and act as those wise statesmen. It is only in this way that we can master change and construct a world and a human heritage we can be proud to leave to future generations.

The image is a composite illustration. At the top, a fisherman is shown from behind, pulling a net full of fish. Below this, a green banner contains the text 'Research Project Support Activities'. In the center, there is a black square containing a white spiral galaxy. At the bottom, a lizard is perched on a log, with a white, dotted, cloud-like shape behind it.

Research Project Support Activities



Research Project Support Activities

The Scientific Research Project Support (SRPS) program is the Foundation's principal means for supporting and strengthening basic research in all fields of science—a fundamental component of the Foundation's mission. SRPS is primarily a program to support the orderly development of systematic knowledge and understanding of natural and social phenomena. Most of the new knowledge is expected to prove useful in the long run, and some fraction of it may prove useful immediately, but for the most part, it is supported with no precommitment to a particular application.

Most proposals to this program are submitted by academic institutions in the United States and focus on a specific scientific question or questions that the research proposes to answer. Despite the great number and diversity of proposals (some 14,000 each year in more than 80 program areas), they are individually evaluated by people capable of understanding their intent and significance. The review process brings to bear critical minds to judge the merit of the project that has been proposed. In this process some 20,000 scientists from all parts of the country were called upon in fiscal year 1975 to evaluate the proposals. A great many of the reviewers are from universities, but many are also called upon from Government, industrial laboratories, and nonprofit research organizations as well. Those proposals that were successful—about half of those submitted—support the research efforts of more than 11,000 scientists. In addition, more than 6,500 graduate students have an opportunity for research experience under the direction of some of the Nation's best scientists—a beneficial byproduct of the quest for new scientific knowledge. Grants were made to 476

institutions, including 313 colleges and universities.

Proposals submitted to the SRPS program are generated by the intellectual initiative of working scientists; in this sense, the proposals are characterized as unsolicited. The Foundation attempts to keep the door open to scientific creativity and diversity of thought by avoiding a strict channeling of funds into pre-selected scientific endeavors. Nevertheless, Foundation activity does influence the character of submitted proposals to a certain extent. Conferences and workshops are supported to focus attention on research areas of opportunity, and the budget allocation process both at the Foundation and in the Congress influences to some extent the level of activity in a given area. However, such encouragement and influence cannot alone create progress in scientific thought. The individual scientists and groups of scientists who prepare and submit proposals to the Scientific Research Project Support Program are the keystones to developing new scientific understanding and to preparing the Nation to face future problems.

In response to the rapidly emerging importance of the Nation's energy problems, the allocation of funds among disciplines in 1975 took cognizance of the long-range need for an increased knowledge base to help solve those problems. Through leadership provided by the newly established Energy-Related General (ERG) Research plan, the general areas of research that were energy-related were determined; assistance was provided to the external research community in organizing phenomenon-oriented workshops to explore scientific research needs in areas likely to be important to one or another aspect of energy; the ongoing research efforts on phenomena that

were clearly important to the Nation's energy future were examined in detail, i.e. catalysis, corrosion, combustion, nitrogen fixation; and, finally, funds for such research were allocated.

From the beginning the research areas selected for additional emphasis were phenomena-oriented; this recognized the fact that a single research finding might be applicable to several energy technologies. This "multidirectional" nature of energy-related basic research required that the research areas identified cut across the disciplinary structure which supports the SRPS program. Some 44 research areas were identified, and during fiscal year 1975, 34 workshops were held on specific topics within these research areas (some representative titles: Energy and Inflation; Photochemistry and Solar Energy; Corrosion Problems in Coal Conversion Systems).

This special research operation—an unusual approach to research management—worked essentially as it was planned. The additional funds received for support of energy-related basic research were distributed for projects that were indistinguishable in quality from those projects considered to be non-energy related. Obviously, activities in the various areas of science identified as important to energy can't be neatly separated from those generated by the general sensitization of the research community to energy needs. However, NSF participated, and in some areas led the way, in this sensitization and followed it with funding opportunities.

The Foundation also participated in the U.S.-U.S.S.R. Cooperative Agreement on Science and Technology in 1975 and supported U.S. scientists engaged in cooperative scientific activities

4 RESEARCH PROJECT SUPPORT ACTIVITIES

jointly approved by the two countries. In 1975 these groups worked in the areas of physics, science and technology information, electrometallurgy, microbial synthesis,

computer applications to management, chemical catalysis, and science policy studies.

The following chapter discusses some of the highlights of recent

research supported through the Scientific Research Project Support program. Also included are scientific highlights of activities of the National Research Centers.

Table 1
Scientific Research Project Support
Fiscal Years 1973, 1974, and 1975

(Dollars in millions)

	Fiscal year 1973		Fiscal year 1974		Fiscal year 1975	
	Number	Amount	Number	Amount	Number	Amount
Astronomy	170	\$8.80	161	\$9.30	188	\$10.93
Atmospheric Sciences	232	11.93	242	12.24	266	13.82
Biological Sciences	1,584	56.22	1,641	58.93	1,760	77.88
Chemistry	675	25.08	730	26.65	835	32.73
Earth Sciences	296	9.76	284	11.01	300	12.97
Engineering	663	26.16	711	28.09	711	34.26
Physics	298	34.88	315	36.73	350	42.20
Social Sciences	635	23.63	617	24.92	649	26.30
Materials Research	409	34.97	469	35.56	563	43.53
Oceanography	287	12.66	299	13.34	355	15.28
Mathematical Sciences	758	14.06	766	14.50	851	16.46
Computer Research	131	9.90	165	9.76	191	11.78
TOTAL	6,138	\$268.05	6,400	\$281.03	7,019	\$338.14

Table 2
Scientific Research Projects, Average Distribution of Funds by Type of
Expenditures for Fiscal Years 1973, 1974, and 1975

	Fiscal year 1973		Fiscal year 1974		Fiscal year 1975	
	Amount	Percent of total	Amount	Percent of total	Amount	Percent of total
Professional Personnel						
Faculty	\$6,332	14.5	\$6,543	14.9	\$6,790	14.1
Research Associates	3,232	7.4	3,337	7.6	3,630	7.5
Research Assistants	5,022	11.5	4,830	11.0	5,240	10.9
Other Professional	1,878	4.3	1,844	4.2	1,905	4.0
Total Professional Personnel	16,464	37.7	16,554	37.7	17,565	36.4
Other Personnel	3,275	7.5	3,161	7.2	3,240	6.7
Fringe Benefits	1,922	4.4	2,064	4.7	2,300	4.8
Total Salaries and Wages	21,661	49.6	21,779	49.6	23,105	47.9
Permanent Equipment	2,402	5.5	2,371	5.4	3,540	7.3
Expendable Equipment and Supplies	3,144	7.2	2,986	6.8	3,250	6.7
Travel	1,310	3.0	1,361	3.1	1,580	3.3
Publication and Printing	655	1.5	615	1.4	695	1.4
Computing Costs	1,092	2.5	1,098	2.5	1,070	2.2
Other Costs	2,926	6.7	2,898	6.6	3,160	6.6
Total Direct Costs	33,190	76.0	33,108	75.4	36,400	75.5
Indirect Costs	10,481	24.0	10,802	24.6	11,824	24.5
Total Average	\$43,671	100.0	\$43,910	100.0	\$48,224	100.0

ENVIRONMENTAL SCIENCES

Research in the environmental sciences in recent years has notably enhanced understanding of such major phenomena as the plate tectonics model of drifting continents, the origin and growth of ocean basins, the dynamics of the atmosphere and the oceans, the processes that produce weather and climatic variations, the interactions between the solar wind and the Earth's magnetic field at the edge of space, and the web of life in the ocean deeps.

Attention of scientists and the general public alike has been drawn to the coordinated, large-scale experiments and to the sophisticated instruments—spacecraft, rockets, remote sensing devices, electron and ion probes, submersibles, deep-sea drilling platforms, worldwide seismic networks, and high-pressure and high-temperature apparatus—that have been responsible for many of these scientific successes. A substantial portion of the Nation's research budget for atmospheric and earth sciences and for oceanography has necessarily gone for the support of such equipment and large-scale ventures commonly referred to as "big science."

Receiving less attention is the fact that many advances in the environmental sciences have been, and continue to be, made by individuals and small groups of scientists working on their own specific problems. Indeed, the multitude of these individual advances has paved the way for the large-scale experiments and demonstrated the need for sophisticated new equipment. NSF's programs in environmental sciences are the major source of Federal support for "little science" research in most of these fields.

Research activities described in the following sections include examples of both large and small projects, and illustrate the fact that

much good science is done with equipment that can be afforded by most of the colleges and universities. Many of the individual scientists also benefit by having access to facilities and information such as those provided by the National Center for Atmospheric Research, the Ocean Sediment Coring Program, and the World-Wide Standardized Seismic Network.

Atmospheric sciences continued to progress in 1975 in a number of areas related to the dynamics and physics of the lower atmosphere, energy transformations in the ionosphere and magnetosphere, in solar studies, and in the causes and history of climatic change. In cooperation with other Federal agencies and academic groups, NSF is providing equipment for the International Magnetospheric Study planned for 1976 to 1979. Major emphasis was also given in the past year to mesoscale weather processes and violent storms, to atmospheric electricity, and to tropospheric and stratospheric chemistry, particularly of those substances that affect the terrestrial heat budget and that may have long-range effects on weather, climate, and life itself.

In the earth sciences, research emphasized testing of the plate tectonics model of the movement of continents and sea floors, the results of which will now be coordinated under the International Geodynamics Project. Major cooperative geodynamics studies included those on subducting plate margins in the Tonga Deep by Cornell University and along the west coast of South America by the Universities of Texas at Dallas, Wisconsin at Madison, and the Carnegie Institution of Washington. Many smaller scale projects also contributed to geodynamics and to such topics as natural hazards, fuel and mineral resources, interpreting seismic

mechanisms and the earthquake risks of certain regions, testing methods for possible earthquake prediction, and the origin and occurrence of coal and oil shale.

The Foundation provides more than half of the Federal support at the relatively few academic institutions engaged in basic research in oceanography. Trends in this research during the year were related to the employment of equipment for multichannel seismic profiling of subcrustal structure on the continental shelves, deep-sea studies by submersibles and automated equipment, and paleo-oceanographic research. The establishment of a new program for marine chemistry reflected increasing interest in this field, particularly as related to coastal and estuarine processes. Progress was also made in the use of isotopes of helium and oxygen in measurements of present and past oceanic circulation patterns, of past water temperatures, and of effects of those conditions on sediments and marine life and on the detailed climatic history of the past 1 to 2 million years.

The scientific value of submersibles was demonstrated in the French-American Mid-Ocean Undersea Study of the Mid-Atlantic Ridge. Observations of this spreading center at which ocean floor basalt is erupted have been complemented with laboratory experiments on interactions between seawater and the oceanic crust. Chemical analyses of red particulate matter observed in open ocean waters for the first time above the eastern Pacific's Galapagos Spreading Center suggest that high concentrations of iron and manganese are being ejected from the crust at the spreading center.

Studies of volcanic ash in cores from the Ocean Sediment Coring Program show that there was a

fourfold increase of global explosive volcanism during the past 2 million years, the time of worldwide con-

tinental glaciation, as compared with the average for the past 20 million years. These results give a possible

insight on the relationship of atmospheric dust to the Earth's heat budget.

ATMOSPHERIC SCIENCES

Stratospheric Chemistry

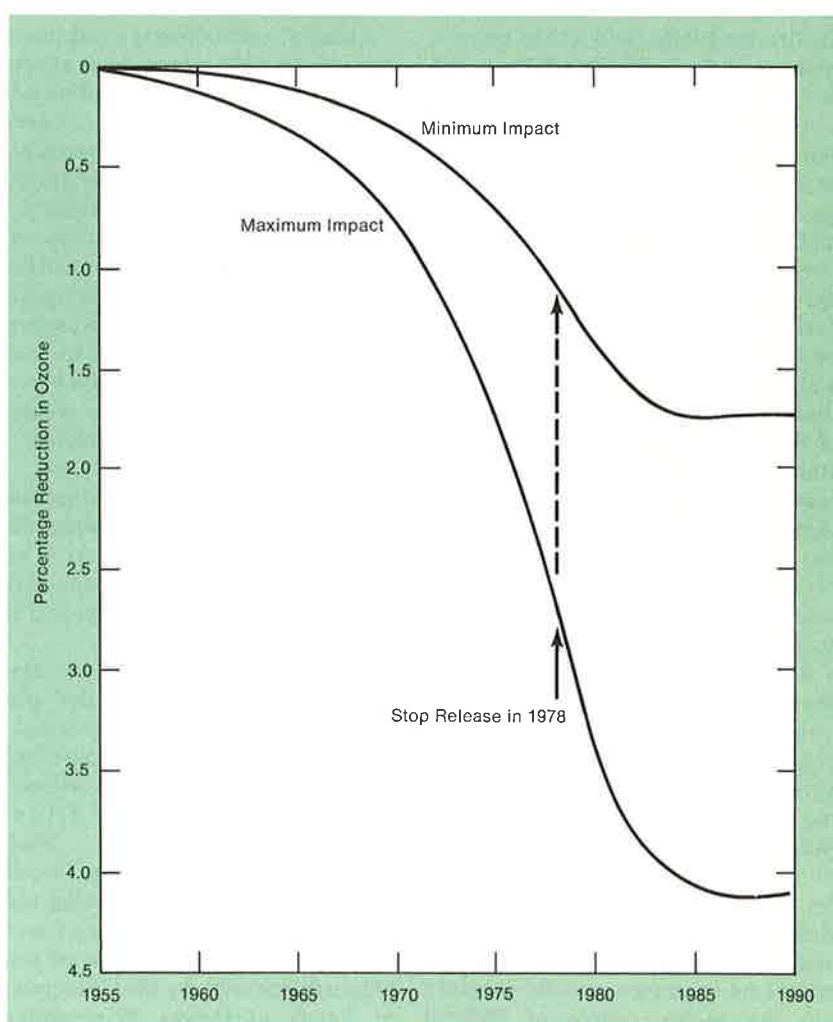
Some 15 to 25 miles above the Earth's surface, in the stratosphere, an ozone layer shields the Earth's surface from harmful solar radiation, particularly ultraviolet rays. In recent years reports have indicated that various chemical substances resulting from man's activities are reacting with and depleting the ozone layer. A 5-percent reduction in the layer could cause, on a global average, a 10-percent increase in ultraviolet rays reaching the Earth.

A considerable amount of upper atmosphere research is being supported by NSF, including several projects at the National Center for Atmospheric Research (NCAR) that are helping to determine the nature and magnitude of processes that may be depleting the ozone. The studies run the gamut from numerical modeling through several types of direct sampling to remote sensing. Calculations made with a one-dimensional, time-dependent, computer-based model of the stratosphere have been used to predict the effect of halocarbons—chlorofluoromethanes and methyl chloride among them—on ozone. "Best case" and "worst case" rates of ozone reduction were considered, and a model was used to simulate the effect of stopping the release to the atmosphere of chlorofluoromethanes at different times. (Chlorofluoromethanes are now used as refrigerants, as propellants in many aerosol spray products, and in the manufacture of plastic foam, as well as intermediates in the manufacture of several kinds of plastics.)

In the worst case situation, if release continues through 1978, the

total ozone reduction by 1985 might be as great as 4 percent from these compounds alone (not counting other sources of ozone reduction, such as oxides of nitrogen). Since the medical

effects of a 5-percent reduction in ozone have been labeled serious by many experts, the modeling studies indicate the possible risk involved in delaying decisions concerning the



Calculations made with an NCAR numerical model predict that stopping the release of chlorofluoromethanes to the atmosphere in 1978 would result in a rate of ozone depletion by 1985 of between 1.7 ("best case") and 4 percent ("worst case"). The ozone continues to be reduced after surface release of the reducing agent ceases because of the time it takes the agent to mix upward into the stratosphere. A 5-percent reduction in ozone has been predicted to be a hazard to human health.

control of human impacts on the ozone layer. Improved modeling is anticipated from a new two-dimensional model that runs from sea level to 60 kilometers and includes tropospheric chemistry.

In direct sampling, NCAR's balloon-borne cryogenic sampler has retrieved fluorocarbons from the stratosphere in concentrations that agree well with the predictions of the one-dimensional model. It is believed that at the present time no other sampler can fly so high or collect

such large samples. The sampler freezes 10-liter samples of air in tubes submerged in liquid neon (28° K); later analysis can detect trace gases occurring in concentrations as small as one part per trillion.

A balloon flight on June 3, 1975, lifted the sampler to 35 kilometers, and the system took 16 samples at various altitudes as it descended. The samples are being analyzed for a dozen gases, including carbon monoxide and dioxide, and fluorocarbons 11 and 12. The results

will help determine the concentrations of the trace gases collected at various heights, permitting estimation of the rates at which the substances travel upward into the stratosphere.

NCAR scientists hope to fly the sampler four times a year from various locations. They are also continuing to use aircraft to sample chlorine constituents of the stratosphere, following up on successful experiments on Air Force jets along flight paths that cross the Equator.

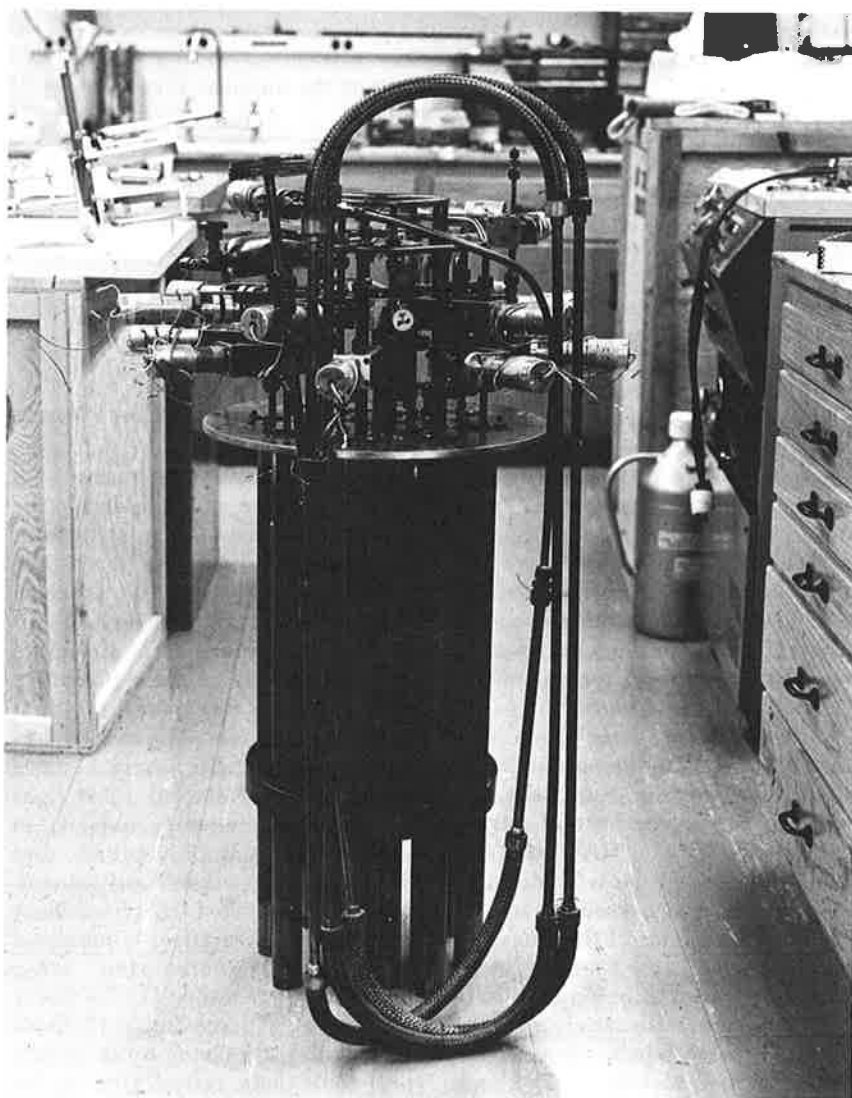
The Upper Atmosphere Project's Limb Radiance Inversion Radiometer aboard Nimbus 6, launched June 12, 1975, is sensing ozone in the stratosphere remotely. The radiometer should have a useful life of 6 or 7 months, yielding a detailed profile of the time evolution of the ozone layer.

Advances in Solar Physics

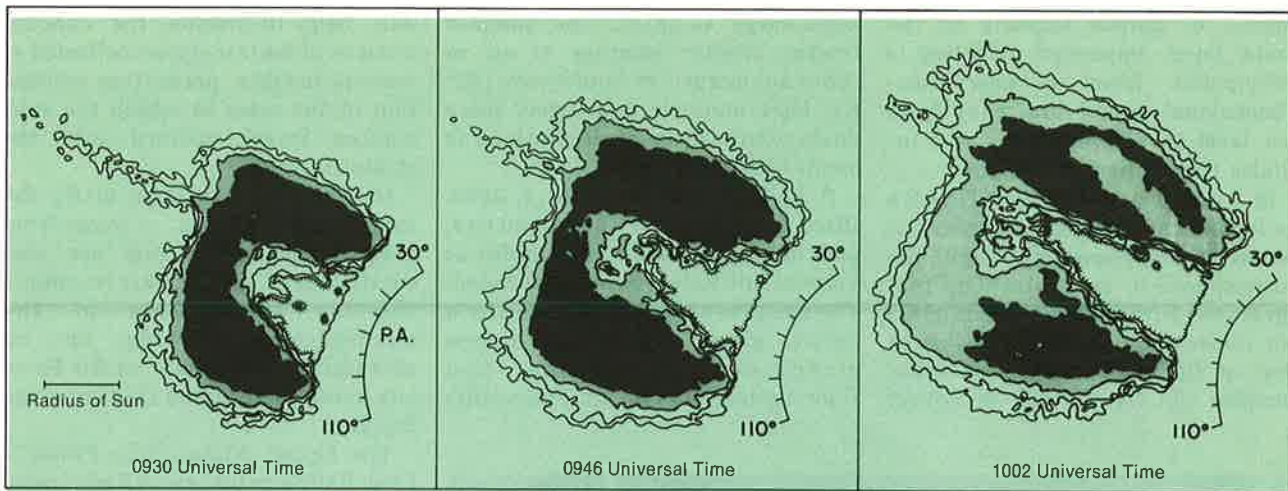
SKYLAB, the first general-purpose, manned scientific laboratory in space, carried one of the most sophisticated solar physics observatories ever launched: the Apollo Telescope Mount (ATM). The ATM solar telescopes produced a vast reservoir of new information about the Sun and the interplanetary medium.

A white-light coronagraph on the ATM, developed by a team at NCAR's High Altitude Observatory (HAO), brought back nearly 36,000 pictures of the solar corona taken over a period of 8- $\frac{1}{2}$ months. More good observations of the Sun in "eclipse" were produced during this time than in all the previous history of ground-based eclipse observations. The photographs cover a wavelength band in the visible region from 3,700 to 7,000 angstroms, and give information over a space from 1.5 to 6 solar radii.

One immediate result from the coronagraph was the determination that coronal transients—vast, outward-moving loops of matter



This NCAR balloon-borne cryogenic sampler can be lifted more than 30 kilometers into the stratosphere to sample trace gases, including chlorofluoromethanes and carbon tetrachloride, at various altitudes. [Photo by NCAR]



On June 10, 1973, a vast outward moving loop of matter, called a coronal transient, was observed from SKYLAB, as it moved through the Sun's corona. This sequence shows changes in the mass density of the transient. A coronal streamer appears ahead of the transient at first, but later seems to be swallowed up.

traveling through the corona—are both larger and more numerous than previously suspected. The HAO SKYLAB team closely studied a number of typical transients, correlating their coronagraph data with data from the other ATM experiments, from other satellites, and from ground-based observatories.

The totality of ATM observations, with their high angular resolution and ability to diagnose the state of the solar atmosphere over a broad temperature range ($10,000^\circ$ to $10,000,000^\circ$ K), permitted the analysis of the heat budget of the solar atmosphere to be confronted in a realistic way for the first time. Particular attention was paid to questions of mass and energy fluxes, temperature and density structures, and indications of magnetic field configuration in transient events. In addition, HAO researchers looked for evidence of connections between events in the corona and eruptive prominences and flares occurring lower in the solar atmosphere.

One well-observed loop transient, on June 19, 1973, apparently resulted from the eruption of a quiescent prominence on the solar limb. The leading edge of the transient tra-

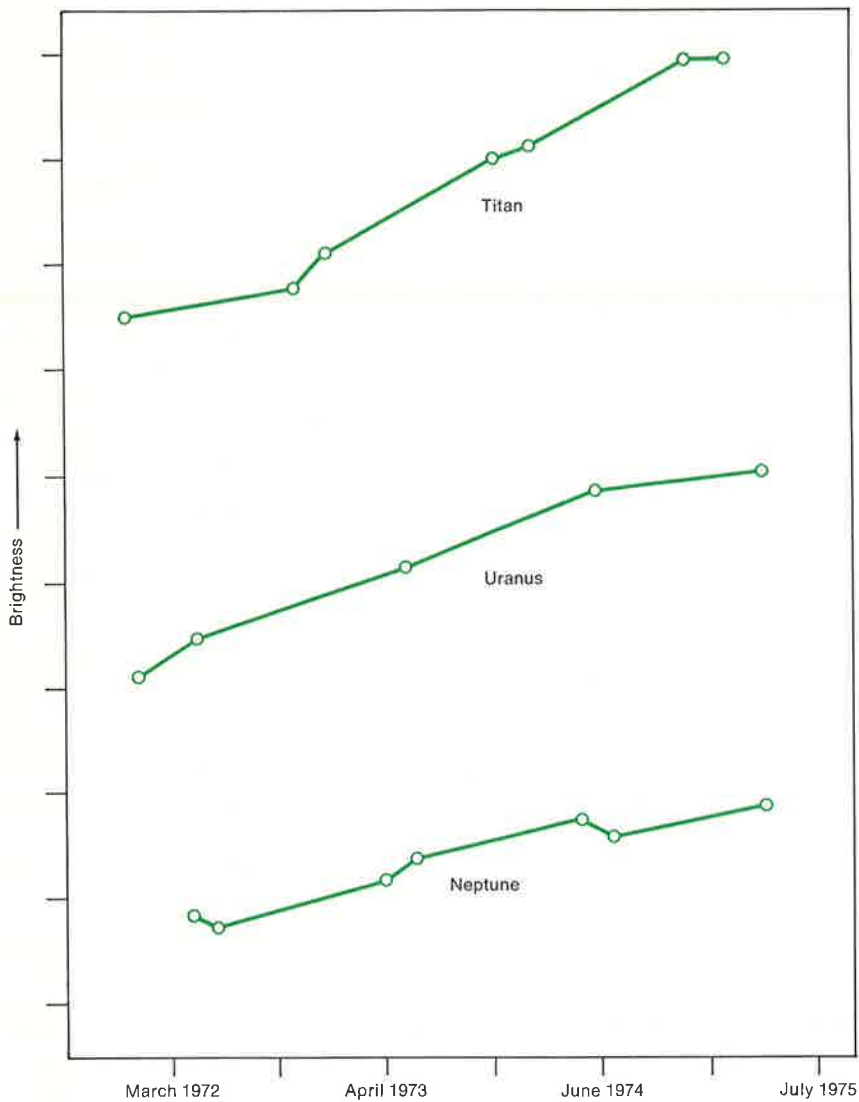
versed the distance from 3.6 to 5 solar radii at a speed of about 500 kilometers per second. HAO scientists estimated the mass ejected into the corona above 2 solar radii at about 1.8×10^{16} grams. The potential energy associated with the ejected transient material was at least 2.4×10^{31} ergs, and the kinetic energy was estimated at 5.6×10^{30} ergs. These numbers represent a sizable fraction of the material and energy available in the overall solar coronal expansion. This transient was one of the largest observed, although it was in many other respects typical of the majority of transients seen.

An interesting correlation was made when a solar flare occurring at the surface of the Sun sent out repercussions in the form of a transient observed by the HAO team and a shock wave and solar wind disturbance observed by researchers on Pioneer 9. Estimates of the mass and energy content of the transient made by the HAO team were found to be in good agreement with estimates of the solar wind disturbance inferred from Pioneer 9 observations of the shock wave. These studies are the first demonstration of the correlation of large, flare-associated coronal mass

ejection events with major solar wind disturbances reaching the Earth.

Varying Brightness of the Planets

The terrestrial environment is bounded on the upper side by the solar atmosphere—the constant solar wind that envelopes the Earth. The study of the dynamic interaction between solar and terrestrial atmospheres is one part of the more general problem of solar-planetary relationships. As part of that research, scientists at Lowell Observatory, Flagstaff, Ariz., have monitored the reflected solar light from several planetary objects, in particular, Uranus, Neptune, and Titan (the largest satellite of Saturn). From 1972, reflected light from these bodies has systematically increased in a highly correlated way, suggesting that either (1) the Sun's light output is increasing, or (2) these three bodies are changing in such a way that their reflectivity is increasing in rough synchronism. If indeed the bodies are changing, presumably there must be some



Observations at Lowell Observatory, Flagstaff, Ariz., show that reflected solar light from Neptune, Uranus, and Titan (largest satellite of Saturn) has systematically increased since March 1972, suggesting either that the Sun's brightness is increasing or that the reflectivity of all three planetary bodies is increasing. [After G.W. Lockwood, Lowell Observatory]

common cause. One possibility would be particle bombardment of these planetary objects by the solar wind. Another possibility remains that the solar light output is varying.

One method of monitoring the

Sun's brightness involves measuring the reflected sunlight from the outer planets and comparing them with stars which are nearby in the sky. By comparing the brightness of a planet with nearby stars, two uncertainties

encountered in direct measurements of solar radiation are avoided. First, the long-term stability of the receiver is not a significant factor in the accuracy of results since different sets of comparison stars can be used from time to time to cancel the effects of planetary motion. Second, the effect of absorption of light by the Earth's atmosphere, which is a serious limiting factor in direct measurements, cancels out to a large degree in differential measurements, such as are used in comparing the planets with stars.

A review of older data obtained in the period 1950 to 1965 tends to suggest that correlated brightness changes of Uranus and Neptune have occurred before, and that the Sun could be attributed as the cause. The Sun's brightness may be varying the visible region by 1 or 2 percent. If so, this phenomenon could be of importance to paleoclimatologists and to researchers working on dynamic models of the terrestrial atmosphere using data on global air circulation and solar radiation. By extension, there may be an impact on our ideas of current and long-term climate and its effect on world food production.

An alternative explanation of increased brightness may be that the Sun is basically constant in the visible region, but varies, for example, in the ultraviolet in such a way as to cause changes in the atmospheres of the planets which, in turn, change their reflecting power. There is recent evidence that changes in the solar ultraviolet flux are related to changes in the Earth's upper atmosphere, especially the ozone layer. Perhaps such changes could take place in the outer planets as well. At this time it is not clear what is varying, but further study is warranted in view of the possible implications.

EARTH SCIENCES

Old Rocks and Diamonds

Among the important geochemical discoveries made in fiscal year 1975 were the successful outcome of a search for very ancient rocks in Minnesota and the accidental discovery of diamonds during a study of old volcanic centers in Wyoming and Colorado.

The search for ancient Precambrian rocks has been actively carried on ever since 1971, when 3.8-billion-year-old rocks were discovered in Greenland. These rocks are more than 300 million years older than the oldest rocks known at that time, and their discovery indicated that rocks of similar age might be found elsewhere. Samuel Goldich at Northern Illinois University last year climaxed more than a decade of study of the gneisses and granites of the Minnesota River Valley region by demonstrating that some of the rocks record events 3.8 billion years old, making them as old as the oldest Greenland rocks. Dr. Goldich and several colleagues with the U.S. Geological Survey also demonstrated that the rocks have a complex history. In addition to the 3.8-billion-year-old event, there is evidence for later episodes of metamorphism and igneous intrusion at 3.3, 2.7, and 1.8 billion years.

It is likely that rocks of similar age will be discovered on other continents. Such discoveries will provide scientists with a chance to examine in detail the chemical and geological character of a previously unknown period of Earth history. The information should also make possible direct comparisons between the histories of the Earth and Moon, because the youngest analyzed lunar rocks are also about 3.3 to 3.8 billion years old.

Fiscal year 1975 also saw the unexpected discovery of diamonds during a study of a group of 50- to 100-million-year-old volcanic centers in Wyoming and Colorado.

The investigators, Malcolm E. McCallum at Colorado State University and David H. Eggler at the Carnegie Institution of Washington, Wash., D.C., were studying the volcanic centers whose rocks contain pieces of the Earth's mantle that were broken off 50 to 200 kilometers below the surface and brought up in the eruptions.

In one fragment, several small diamonds were discovered when the sample was being cut for analysis. The diamonds announced their presence by severely scratching the polishing wheels, and they were positively identified by later chemical and mineralogical tests.

At present, the total amount of diamonds found is limited to a few crystals less than a millimeter in size, collected from one specimen from Wyoming, and there is nothing to indicate that an economic diamond deposit has been found. But the discovery of diamonds indicates that the specimen probably formed at a depth of 150 kilometers or more and thus helps unravel the nature of the Earth's interior under the Rocky Mountains.

Fine Structure of the Crust and Upper Mantle

The first field test in a project to investigate whether seismic reflection techniques used by the petroleum industry can be extended and modified to study the deep structure of the crust and upper mantle was successfully completed in fiscal year 1975.

Detailed continuous seismic cross sections extending to depths of 50 kilometers were obtained in March 1975 in Hardeman County, Tex., by the VIBROSEIS technique, using a carefully controlled vibrator as the seismic source, together with sophisticated analysis techniques.

The deep structure of the continents, below those rocks that can be

seen or reached with a drill, is virtually unknown. Such knowledge is vital because the nature of the rocks at the surface, which are of obvious economic importance to us, is controlled by processes in the deeper crust and in the upper mantle. Detailed structural information from the deeper crust and upper mantle could well hold the key to such fundamental problems as the origin of continents and could perhaps supply the reason for large-scale vertical crustal movements such as the subsidence of sedimentary basins, or the uplift of the Adirondacks. Such data will, of course, yield a vast new supply of important information on Earth resources and their environments.

In the first test, good reflections were obtained throughout the Texas section. Interpretation, in terms of crustal evolution, must necessarily await the compilation of more data from other geological settings. Other field tests may be scheduled at the Rio Grande Rift, near Socorro, N. Mex. This is a major structure in the Earth's crust, associated with a possible molten layer at shallow depths and very high heat flow. Another possible site is the Carson Sink area in Nevada, an important region of basin and range faulting.

The project, which was initiated a few years ago as the Consortium for Continental Reflection Profiling, is conducted by four universities: Cornell, the lead institution; University of Wisconsin; Princeton; and the University of Houston. In many ways the project is the most exciting effort now going in geophysics. If successful, it seems certain to open up entirely new vistas in geology. It is for this reason that the project was selected as one of the six new opportunities that promises to advance the aims of the U.S. Geodynamics Program on a broad front. The project has the active interest and cooperation of the petroleum industry.

OCEANOGRAPHY

Chemical Exchange Between Oceanic Basalt and Seawater

Within the framework of the seafloor spreading process, molten igneous rock material flows up along the axis of mid-ocean ridges, solidifies, spreads laterally away from the axis, and over a period of geological time is gradually covered by a blanket of deep-sea sediments. Over the past 10 years, several lines of research have suggested that seawater percolating through the newly formed, hot, and fractured basaltic rock near the crest of mid-ocean ridges is an important mechanism for transferring certain chemical elements to and from seawater and the oceanic crust.

Recently, laboratory experiments and analyses of seafloor basalts have shed further light on this process. The laboratory experiments, carried out by J.L. Bischoff of the University of Southern California, F.N. Dickson of Stanford, M.J. Mottl of Harvard, and A. Hajash of Texas A&M, have involved the chemical reactions between seawater and oceanic basalts at elevated temperatures (200° to 500° C) and pressures (500 to 800 bars) thought to be representative of the oceanic crust about 1 kilometer below the sea floor at a mid-ocean ridge crest. Results indicate that the overall chemical reaction at lower temperatures involves primarily the precipitation of anhydrite, or calcium sulfate, and the alteration of some of the basaltic glass to the clay mineral, montmorillonite. At higher temperatures, near 500° C, iron and copper sulfides and oxides are precipitated, and the anhydrite is replaced by tremolite, a calcium, magnesium, and iron silicate mineral of the amphibole group. The major chemical changes in the seawater associated with these reactive products are the nearly total loss of dissolved magnesium and sulfate and substantial increases in

the dissolved calcium, silicate, iron, manganese, nickel, and copper concentrations.

These laboratory findings are similar to those obtained from the analyses of the aqueous composition and mineral alteration products in the Iceland geothermal fields and from the chemical differences observed between altered and unaltered specimens of seafloor basalts dredged from mid-ocean ridges.

The quantitative determination of how much seawater is reacting at what temperatures with how much basaltic rock material near mid-ocean ridges remains a very difficult and unresolved question. Nevertheless, it is becoming clearer that the large-scale circulation of seawater through oceanic crustal rocks could readily account for the aluminum-deficient metalliferous sediments found associated with mid-ocean ridges and could also be important in the genesis of certain iron and copper sulfide ore deposits. In addition, this process may significantly affect the geochemical budgets of certain elements and exert considerable control over the chemical composition of seawater.

Deep-Sea Ecology

The deep sea is a poorly known, alien environment of high pressure, low temperature, sparse food, and total darkness. However, it proves to be a potent testing ground for ecological principles, because conditions for life are so different from those in the terrestrial, freshwater, or shallow marine environments from which most ecological theory has been developed.

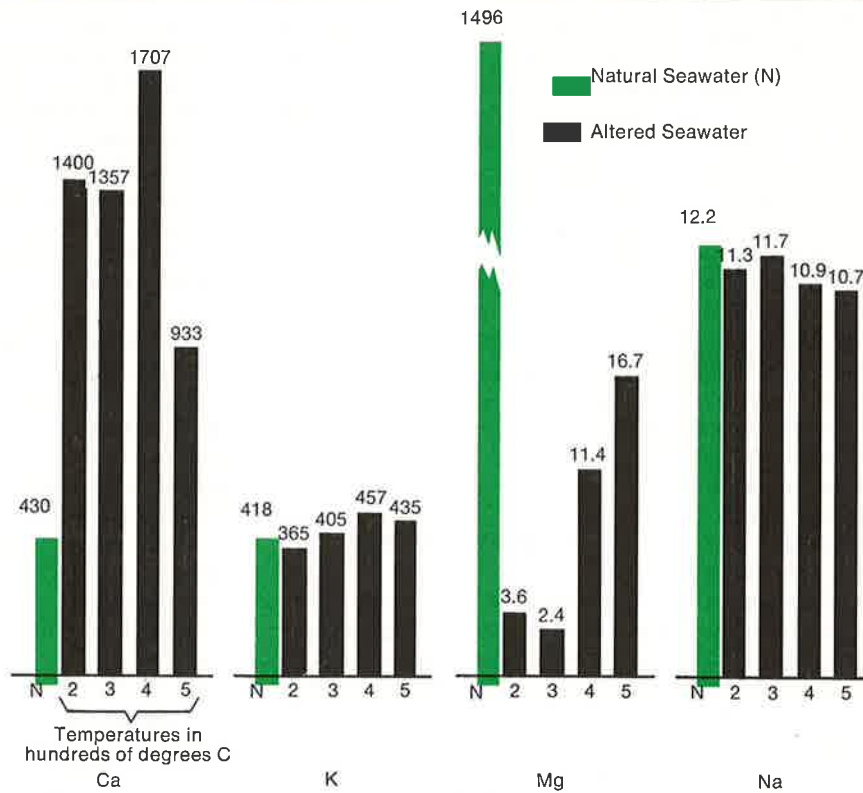
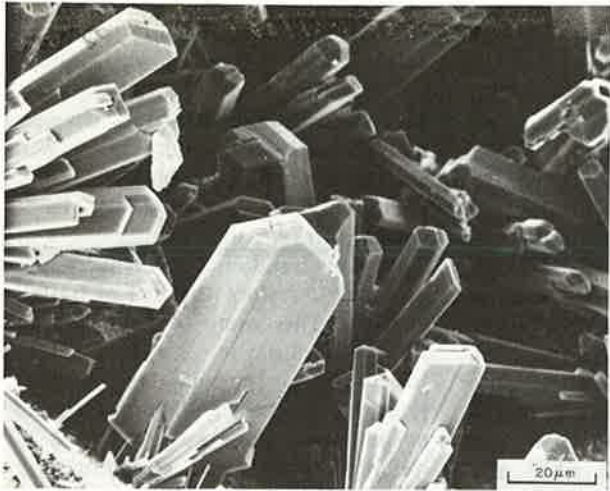
For many years, Robert Hessler of the Scripps Institution of Oceanography has investigated the question of what controls the makeup of deep-sea communities. Using corers in the shape of boxes,

animal traps, epibenthic sleds to catch small animals, and lighted cameras attached to baited weights, he has probed near-shore troughs and abyssal plains of the deep sea. Dr. Hessler and John Isaacs, also of Scripps, have documented deep-ocean sharks, eels, amphipods, and fish in an abundance that was largely undetected before the use of baited cameras. This fauna appears to be an invariable link in any food chain involving large particles of food (such as dead fish) dropping to the ocean floor. Any such particle is quickly located and consumed by these mobile scavengers, who then scatter again.

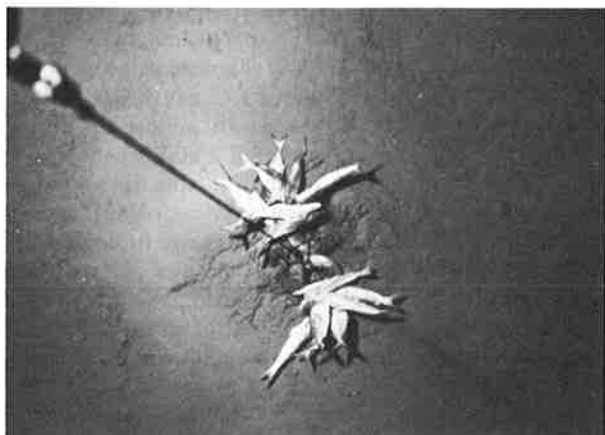
In inshore waters, large bits of food are visited by a variety of slower, crawling creatures as well—crabs, echinoderms, and polychaetes. On barren central ocean bottoms these groups are not evident, perhaps because they cannot compete with the mobile swimming forms for access to the rare large parcels of food.

Dr. Hessler recently sampled the bottom community at 9,600 meters in the axis of the Philippine Trench, one of the deepest parts of the ocean. Records from his baited camera reveal a striking reduction in the variety of scavengers—no fish or prawns are present, and only one species of amphipod, in extraordinary numbers, responds to the sudden appearance of a large food item.

From these results, Dr. Hessler tentatively poses an extension of his theory concerning the feeding processes governing ocean bottom community structure—in the deep trench waters there is a general increase in the average size of settling food particles. Small particles, which are barely nutritious when they reach the depth of the abyssal plains, would have no food value by the time they settled to the great trench depths. Only large particles are likely to reach the trench floor.



Laboratory experiments involving chemical reactions between seawater and ground-up basalts, held for two weeks at temperatures and pressures thought to be representative of the oceanic crust about 1 kilometer below the sea floor at a mid-ocean ridge crest, produced minerals such as albite crystals (left) and honeycomb-shaped forms of nontronite (right). The changes in concentrations of calcium (parts per million-ppm), potassium (ppm), magnesium (ppm), and sodium (parts per thousand) at increasing temperatures show enrichment in calcium and depletion in magnesium for the altered seawater (bar graph). [Photos by Andrew Hajash]



In one of the deepest parts of the ocean—9,600 meters at the bottom of the Phillipine Trench—a camera records what happens when a supply of fish is dropped as bait. Within 10 minutes, extraordinary numbers of a single species of amphipod have started feeding on the fish. These mobile scavengers, specifically adapted to consume larger particles of food, form the dominant fauna in the Trench. Subsequent photos were taken after 12-½ hours and after 16-½ hours. [Photos by Robert Hessler]

Therefore, the mobile scavengers such as amphipods, which are specifically adapted to consume larger particles, form the dominant fauna in the trench. The absence of

fish at great depths is postulated to result from physiological stress from the deep-sea environment which places them at a competitive disadvantage. Dr. Hessler is elucidating

the factors responsible for the low diversity of species in the trench; resolving this question would constitute a major contribution to our understanding of community theory.

BIOLOGICAL AND MEDICAL SCIENCES

Several lines of biological research likely to be important for long-term aspects of the energy problem received increased support in fiscal year 1975. One, biological catalysis, has great potential beyond its pre-

sent applications in reducing energy requirements for many processes in chemical industries. Nature's catalysts, in the form of enzymes, far exceed the efficiency and specificity of the catalysts man is now able to

make, but substantial progress has been made in understanding the structural features that are responsible for the remarkable effectiveness of enzymes. There is every reason to believe that further progress in

molecular studies of enzymatic processes and their regulation in living systems will lead to the synthetic production of more effective catalysts and the increased utilization of enzymes for industrial purposes.

The actions of micro-organisms in converting one material to another is another research area with energy-related potential. In addition to the familiar fermentation processes, there are biological pathways that yield hydrogen, methane, or other potential fuels. The ability to "construct" organisms with specific metabolic capabilities, together with the elucidation of the poorly understood pathways of these conversions, could improve their usefulness for a variety of processes.

A major concern associated with the extensive development of most energy sources is the impact on the environment. While increasing attention is being directed by several Federal agencies to environmental effects on human health, science is less prepared to deal with the indirect effects on human welfare that result from damage to the other forms of life on which we depend. Continued strengthening of the ecological sciences and a much better understanding of population biology and species interrelationships are required for assessing the potential impacts on renewable resources.

The development of programs of the new Energy Research and Development Administration will be of considerable interest in relation to NSF programs in the biological sciences. Certainly the work there dealing with environmental effects seems likely to take advantage of approaches and personnel developed under NSF's International Biological Program biome projects, as well as the resource base of the systematics collections. In addition, more attention may be directed to the plant sciences generally in ways that can be strongly complementary to NSF activities.

Photosynthesis and nitrogen fixa-

tion are also receiving increased attention from NSF because of their inherent scientific interest and potential applicability to energy development. Research on photosynthesis ranges from that dealing with the primary photochemical event and the organization of the molecules that capture light energy to the processes of distributing and utilizing the compounds that serve as energy intermediates. This research may have potential for exploring new approaches to the design of novel systems for capturing and utilizing solar energy and for using biological systems more effectively for this purpose.

Interest in biological nitrogen fixation is directed at understanding the molecular and genetic mechanisms by which biological organisms fix atmospheric nitrogen and understanding the specificity of association shown by some classes of organisms. Enhanced understanding of the biological parameters in this process has the potential for reducing the requirements for industrial nitrogen fertilizers.

In the biological sciences, much of this energy-related research is equally applicable to problems associated with food production. Greater efficiency in the conversion of solar energy to food, reduction of the dependence on available nitrogen fertilizers, and a better base of ecological knowledge are all factors that would contribute to enhancing and stabilizing the world food supply. The agricultural production system and the State and Federal programs of agricultural research have performed most effectively in the past, but there is a sense of unease on the part of many scientists about the prospects for future research. There appears to have been a lack of attention to the continued development of the new knowledge base which is required for future agricultural development, particularly in the plant sciences. This concern has received increased atten-

tion during the past several years from NSF's programs in biological and medical sciences. Also, failure of plant sciences to capitalize fully on the advances in molecular biology continues to be a major concern.

The following specific examples are chosen as representative of several other areas in biology where new information has altered basic insights on biological phenomena and where opportunities for continued development are afforded.

Comparative Physiology

The field of endocrinology—a discipline involving hormones secreted by specialized glands—has advanced significantly by applications of modern techniques of biochemistry and physiology. A good example of this comes from the studies of Paul Licht and Harold Papkoff of the University of California, Berkeley and San Francisco campuses, respectively. Prior to their studies, the role of the pituitary gonadotrophins (hormones) in lower vertebrates remained confusing and contradictory. Previous studies used mammalian hormones for studies on fish, amphibians, and reptiles, on the assumption that these hormones would mimic their counterparts in each of the animals. No one expected that the use of heterologous hormones (i.e., those from a different animal) would provide the complete answer to the precise role of the natural pituitary hormones. But, since sufficient quantities of purified homologous hormones (i.e., the natural pituitary hormone) were not available, the mammalian hormone gave some information. But now the collaborative studies of the endocrinologist, Dr. Licht, and the biochemist, Dr. Papkoff, have resulted in purifying the pituitary gonadotrophins, the luteinizing hormone (LH), and the follicle-stimulating-hormone (FSH) from fish, amphibia, and reptiles. (By and large, the LH action is that of controlling the secretion of steroids,

while the FSH action is that of facilitating cell division.)

The purifications required considerable ingenuity in obtaining sufficient numbers of pituitaries without the needless slaughter of large numbers of exotic animals solely for the purpose of acquiring their pituitary glands. So, from the Japanese frogleg industry they were able to get 2 tons of frozen frogheads (90,000 animals); the traditional rattlesnake hunts in the western United States were the source of reptilian pituitaries; and the byproducts of the turtle soup industry and an authorized experimental alligator hunt in Louisiana were additional sources of reptilian pituitaries.

Studies of purified LH and FSH have shown that homologous hormones are much more active than their heterologous counterparts. LH consists of two subunits, one of which determines the ability of the molecule to be effective in a particular group of vertebrates. Furthermore, from a study of LH and FSH actions of the natural products, it appears that the pituitary gonadotrophins early in the evolution of tetrapods consist of two different glycoproteins, each of which has the LH and FSH actions. In reptiles there has been a shift to the use of a single molecule which has both LH and FSH action. These observations have led to the striking conclusion that mammals have retained the older, and ancestral, amphibian pattern, while reptiles have evolved in the direction of a single molecule with dual functions.

The investigators have been able to hybridize subunits of these pituitary glycoproteins in order to study the functional importance of subunits from different species. This provides a powerful tool for studying the relationship between hormone and receptor, since it is only the homologous combination that is significantly active. The study of non-mammalian systems will contribute to the understanding of mam-

malian systems by determining the specific role of various gonadotrophin subunits and thereby provide the background for understanding the various actions of LH and FSH. The recent discovery of multiple forms of FSH in mammalian species now appears quite reasonable in light of the heterogeneity found in the ancestral forms. The application of this information for breeding "threatened" species such as the alligator (*Alligator mississippiensis*) and the green turtle (*Chelonia mydas*) could be of major and immediate benefit.

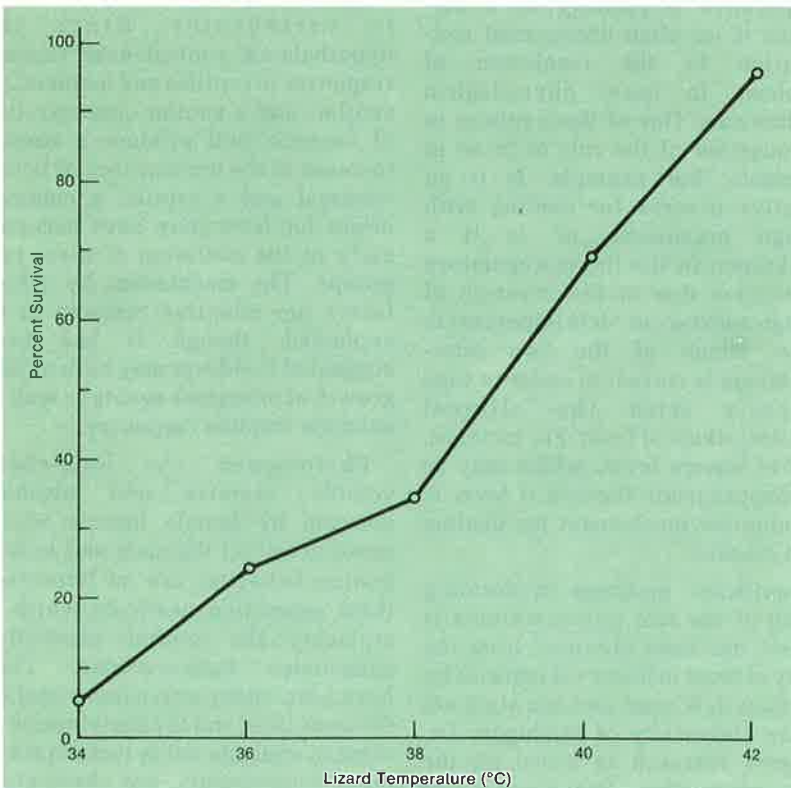
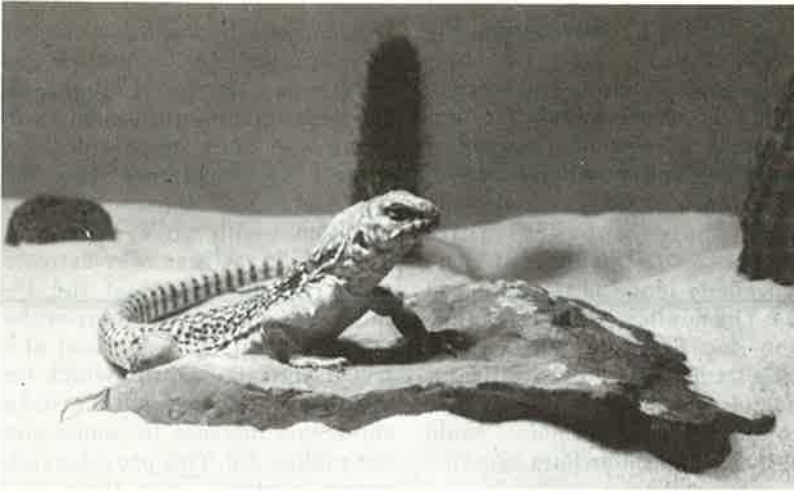
One of the great strengths of comparative physiology as a discipline is its often unexpected contribution to the resolution of problems in basic physiological mechanisms. One of these relates to the question of the role of fever in mammals. For example, is it an adaptive process for dealing with foreign organisms, or is it a breakdown in the thermoregulatory mechanism due to the invasion of foreign substances? It is important to know which of the two interpretations is correct in order to cope properly with the clinical manifestations of fever. For instance, aspirin lowers fever, which may be an inappropriate therapy if fever is an adaptive mechanism for dealing with disease.

Significant progress in deciding which of the two interpretations is correct has been obtained from the study of fever in lower vertebrates by Matthew J. Kluger and his students at the University of Michigan. Dr. Kluger's research is based on the observation that lizards regulate their body temperature behaviorally by positioning themselves so as to obtain heat from their environment. Dr. Kluger wanted to know if lizards infected with a fever-producing bacteria would position themselves in an artificial temperature gradient in order to increase their body temperature above their typical or preferred level. He found that within 3 hours after injecting killed

Aeromonas hydrophilia bacteria pathogenic to reptiles and amphibians, the desert iguana, *Dipsosaurus dorsalis*, positioned itself to increase its body temperature about 4° F. By regulating the body temperature of *Dipsosaurus* after infection with live *Aeromonas hydrophilia*, these investigators were able to show that the 4°-F-increase in body temperature markedly enhanced survival of infected animals. Lizards which were unable to obtain external heat did not show this increase in temperature, but rabbits did. This provides rather strong evidence that fever is an adaptive response widely prevalent in vertebrates. Since the hypothalamic control over thermal responses in reptiles and mammals is similar, and a similar concentration of bacteria will produce a similar increase in the temperature of both a mammal and a reptile, a common origin for fever may have occurred early in the evolution of these two groups. The mechanism by which fevers are adaptive remains to be explained, though it has been suggested that fever may both inhibit growth of infectious agents as well as enhance immune responses.

Pheromones, the long-chain volatile acetates and alcohols secreted by female insects which serve to attract the male and induce mating behavior, are an important third generation pesticide which is replacing the second generation chlorinated hydrocarbons. They have been under active investigation for some time, and the combination of organic analysis using techniques of mass spectroscopy, gas chromatography, and nuclear magnetic resonance have allowed the rapid identification of active compounds secreted by a wide variety of insects, particularly moths.

Since various compounds may be secreted in specific ratios necessary to elicit the fixed behavioral patterns used in reproduction, it has proven necessary to develop a simple and rapid bioassay which permits the



When placed in a simulated desert environment with an air temperature range of 30° to 50° C, healthy desert iguanas (*Dipsosaurus dorsalis*) (top) of moderate size (about 50 grams) selected temperatures of about 38° to 39° C—that of their normal body temperature. Iguanas infected with a harmful bacteria chose higher temperatures of 40° to 42° C—comparable to that of a moderate fever—and by so doing markedly enhanced their survival. In another experiment (graph at bottom), researchers found that at the end of three days of keeping infected iguanas at different temperatures, 96 percent of iguanas maintained at temperatures of 42° C (moderate lizard fever temperature) were alive; only 34 percent were alive at temperatures of 38° C (normal lizard body temperature); and less than 10 percent survived at 34° C.

These and other studies suggest that some kind of fever is an adaptive response of the body for dealing with infection and not directly caused by the disease. [Photo by Matthew Kluger]

determination of behavioral responses. Wendell Roelofs of the Cornell University Agricultural Experiment Station, Geneva, N.Y., has combined successfully the analytical techniques of organic chemistry with the use of electroantennograms to identify the active fractions of pheromones. The electroantennogram consists of snipping off an antenna from a live male moth and placing it in a dish of saltwater with the top of the antenna sticking out of the water. A silver electrode is placed in the dish and a glass electrode filled with saltwater is placed against the tip of the antenna. This permits the recording on an oscilloscope of the electrical response of the olfactory receptors in the antennae to puffs of air containing the chemical fractions from the pheromone glands.

This technique has proved so successful that Dr. Roelofs can identify the chemistry of unknown pheromones using as few as ten to 20 insects containing less than a nanogram of attractant. In one case he was able to identify the attractant chemical within a half hour after the insects arrived in his laboratory. Since pheromones are relatively simple compounds, it is easy to synthesize them. When they are placed in plastic capsules, the pheromone evaporates slowly through the capsule over a long period of time. In this way the mating behavior of a specific insect pest can be disrupted so as to prevent the production of crop-destroying larvae. It also prevents killing beneficial insects with broad spectrum pesticides. While this approach to the control of insect pests requires the formulation of specific compounds in the right ratio for each major pest, the tools are now available to do this swiftly and economically. This line of research holds great promise for the control of pests such as the fire ant and the gypsy moth, species for which the second generation pesticides have become ineffective or unusable.

Energy and Plants

In photosynthesis light energy is transformed into chemical energy. This transformation of light energy to adenosine-triphosphate (ATP), the chemical energy, occurs in a specialized organelle of the green plant cell, the chloroplast. In the 1960's, the British biologist Peter Mitchell postulated a chemiosmosis hypothesis on the transformation of electrical energy into ATP on the basis that an electrical voltage potential developed by a hydrogen ion gradient established across the inner and outer surfaces of a chloroplast membrane accounts for almost all of the ATP formed for a given electron transport. By careful measurements of the time when ATP is formed as compared to the time when the hydrogen ion gradient is formed, Norman Good of Michigan State University was able to show that there are local, discrete hydrogen ion gradients, and hence local potentials within and not from surface to surface of the membrane. This observation accounts for many puzzling experiments which were inconsistent with the original Mitchell hypothesis. From a practical point of view, Dr. Good's modified chemiosmotic hypothesis permits further elegant investigations which will add to our understanding of this fundamental energy transformation.

The splitting of water molecules by plants is another example of the use of energy from photosynthesis. Water is composed of hydrogen and oxygen. If only hydrogen could be easily separated from oxygen of the water molecule, an inexhaustible source of fuel could be obtained. With the usual chemical and electrical methods available, the oxygen and hydrogen can be separated, but at such a cost of energy that it would be economically feasible only under the most unusual circumstances. Bacteria, algae, and certain types of plants, on the other hand, use light energy from the Sun to effect the separation. Under the influence of an

enzyme, hydrogenase, the energy of light is used to split the water into its components, hydrogen and oxygen, through a process called photohydrogenolysis.

Martin Gibbs of Brandeis University screened a large number of different algae for hydrogenase activity in order to obtain a species that would produce large amounts of hydrogenase. He has been able to isolate several types of algae which have high levels of activity. Out of curiosity he also tested several mosses; one had extraordinarily high levels of hydrogenase. This was unusual because mosses had not been reported to produce hydrogen, at least not under conditions similar to those of algae.

According to theory as well as observation, hydrogen production is turned on in the light, for that is where the energy for processing the water comes from, and turned off in the dark. Dr. Gibbs found that naturally enough the mosses evolved hydrogen in the light, but the strange thing was that when they were placed in the dark, they kept right on evolving hydrogen—in some cases even better than in the light. The immediate suggestion is that some other substance—not water—is the primary substrate for hydrogenase to produce hydrogen. It is likely that during the light period, hydrogen from water is incorporated into an as yet unknown compound which in turn is the primary donor of the hydrogen released in the dark by the moss. Direct photohydrogenolysis is being used by a number of researchers as a model concept for developing new biological sources of energy. The observation of Dr. Gibbs suggests that the concept should be modified in order to avoid fruitless attempts for practical application.

It's not unusual for research in a given area to be done for a period of years during which time data are accumulated and insights are developed, and nothing very exciting seems to happen. But when a critical mass of information is available and

a number of researchers in the field have the insight, there is a sudden understanding of a process—a breakthrough occurs and the whole field moves at an exciting pace. In another area of plant activity—production of sugars and starches—who would have thought that the key enzyme, ribulose biphosphate carboxylase (RuBPC), that fixes carbon dioxide into starches and sugars is at the same time the key enzyme for carbon dioxide production—the reverse of fixation? A veritable Dr. Jekyll and Mr. Hyde of an enzyme.

Richard G. Jensen, University of Arizona, has worked on the isolation, purification, characteristics, and regulation of the activities of RuBPC. When Dr. Jensen first began his studies he was interested primarily in the basic properties of an important enzyme thought to be concerned only with fixation of carbon dioxide in plants. But there were anomalies in its behavior and Dr. Jensen persisted in examining them, despite the consensus that he might be wrong and wasting his time. Dr. Jensen's work and that of his associate, James Bahr, as well as of others such as W. L. Ogren, show that RuBPC, which should only catalyze carbon dioxide in the photosynthetic production of starch and sugar, has a second enzymatic function. As such, it catalyzes the destruction of ribulose biphosphate to produce, not fix, carbon dioxide. This immediately reduces the amount of carbohydrate synthesized by a plant.

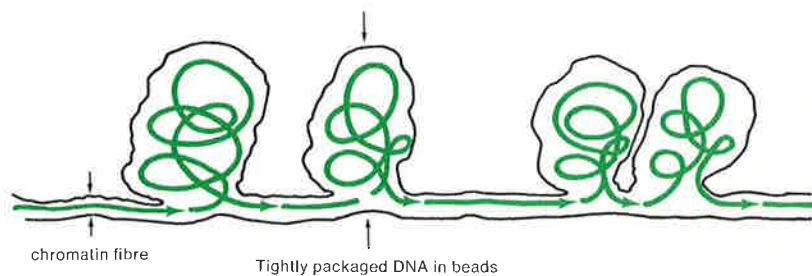
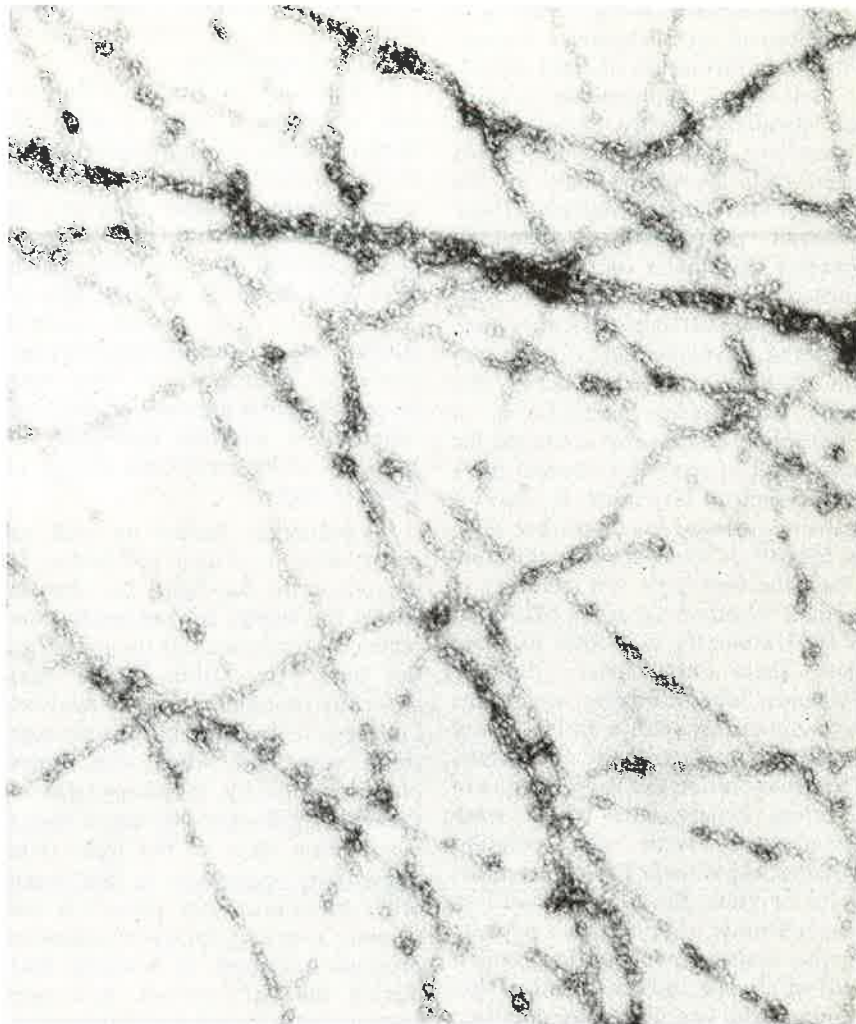
This new finding has tremendous implications for photosynthetic efficiency and crop productivity. Researchers are devising methods by which the RuBPC as an oxygenase enzyme can be regulated and controlled in order to increase the production of sugars and starches in plants. Indeed, the implications of this basic research have attracted the attention of commercial agriculture organizations because of the potential economic values involved. Pilot studies on a commercial level sustain the predictions made by the basic research studies.

Chromosome Structure and Gene Regulation

Although DNA, the long molecule that contains a cell's "operating instructions," exists "naked" in some simple organisms like bacteria, in higher organisms it is combined with proteins to form chromatin. These proteins are important both in determining the condensed form of DNA that allows it to fit into the nucleus and chromosomes, and probably in controlling the way the genetic information in the DNA is expressed. (The DNA of a human cell chromosome stretched end to end would measure 1 meter, but the nucleus itself is only about 10 microns across.)

Chromatin proteins are of two main types: the histones and the acidic (non-histone) proteins. Histones, which account for the bulk of chromatin proteins, are small, very basic proteins of which there are five subclasses. Very exciting recent work has highlighted how histones are arranged on the DNA and what effect this arrangement has on its topography. It was announced in 1973 by two groups, including C. Woodcock of the University of Massachusetts, that in electron micrographs of spread chromatin, structures that look like beads on a string can be observed, with the beads having a 100-angstrom diameter and the string about 30 angstroms (the diameter of DNA chain itself is 20 angstroms). These dimensions and general arrangement in the spread chromatin have since been verified by X-ray and neutron diffraction methods, carried out by several other groups.

Even more recently, several groups, including those of H. Weintraub of Princeton University, Brian McCarthy of the University of California, San Francisco, and K. E. Van Holde of Oregon State University, have treated chromatin with either nucleases (enzymes which break DNA) or with shearing forces and have recovered a particle whose dimensions are consistent with those



Geneticists have recently found that at periodic intervals, chromatin fibers, about 15 angstroms in diameter, are tightly packaged into beadlike structures, about 75 angstroms in diameter, containing DNA and histones. The diagram shows the possible arrangement of the closely packed DNA within the beads. [Photo by C. Woodcock]

of the beads mentioned above and whose chemical composition is found to contain both DNA and histones. This indicates that the DNA in the string is more susceptible to attack than it is in the bead. Work by these and other groups has established that four of the five histones form a complex with the DNA to compose the bead, while the fifth histone may exist largely or entirely on the DNA in the string. This overall arrangement decreases the length of the DNA by a factor of seven and thus is a major factor in DNA condensation. Further, it has been shown that generally DNA linked to histones, especially to the four present in the bead, is not transcribed into RNA messages. Thus, this exciting discovery concerning the arrangement of histones along DNA chains may permit the analysis of the role of histones in turning genes on or off.

Also, it has recently been possible to isolate the region of the DNA that codes for the histones through the work of E. Weinberg of Johns Hopkins University, Mary Lou Pardue of Massachusetts Institute of Technology, and Dr. McCarthy. In rapidly growing cells (like those in sea urchin embryos) a large amount of the RNA message is copied from the histone genes and used as a template for the synthesis of large amounts of the histone proteins. These RNA messages were isolated and used as a probe for the identification of that portion of the DNA that contained sequences that specified the histones. Furthermore, it was then shown that histone messenger RNA differed from other messenger RNA's by not containing polyadenylic acid. This distinction has facilitated the isolation of histone messages from any tissue.

The histone genes were found to be

clustered together on the DNA and to be repeated tens to hundreds of times (depending on the organism), probably in tandem array. At present the scientists are attempting to determine the exact molecular sequence of DNA within the genes. They hope to learn how the entire set of repeated histone genes is turned on during that portion of the life cycle when the histone proteins must be synthesized (histone proteins are synthesized by cells only during the time that DNA is replicated—the S phase, which accounts for one-fourth to one-third of a cell generation time). It is possible that other genes which code for proteins, which the organism requires in large amounts, are also repeated many times. At present, however, most of the other genes that have been isolated from the DNA of higher organisms exist in single or at most very few copies.

Interestingly, Dr. McCarthy has found that the DNA of the cancer virus SV40 forms a complex with only four of the histones (those found in the beads), and has determined that the histone complexes are randomly arranged without regard to the DNA sequence. This result supports the suggestion that specific control of DNA genes may arise from interactions of the other class of proteins in chromatin, namely the acidic proteins, which are found as many discrete types, but about which little is known at present.

As the foregoing presentation suggests, understanding gene regulation in the cells of higher organisms has become an area of vigorous research activity. And while the general pattern of control in simpler cells has been known for some time, it is noteworthy that Westley Hatfield of the University of California, Irvine, received the Eli Lilly Award

this year for his identification of a heretofore unsuspected type of control. The operator-repressor model presented by Jacob and Monod in 1961 has now been clearly documented for several microbial regulatory systems. However, it is also clear that this model as originally conceived is unable to explain many patterns of gene regulation even in the simpler bacterial systems. In fact, it is beginning to appear unlikely that any single model for the regulation of gene activity will emerge that will be universally applicable. Dr. Hatfield's evidence supports the existence of one such alternative regulatory mechanism—autoregulation—in which the product of the gene regulates the expression of that gene. This type of control requires no additional regulatory protein whose sole function is the control of another gene or group of genes. In an autoregulated system, the regulatory gene product regulates its own synthesis and may or may not play other metabolic roles within the cell.

Autoregulation is being studied in the biosynthetic pathway of the branched chain amino acids (isoleucine, leucine, and valine) in *E. coli*. The biosynthesis of these amino acids is an intricate example of integration, involving both common precursor metabolites and three different enzymes which catalyze reaction in the pathways leading to each of the three amino acid end-products. Explaining the molecular mechanisms would require an inappropriate amount of detail here; it is important simply to note that this simple micro-organism is now known to have an extraordinarily complex and interdependent system for regulating its metabolism.

However, this same proximity has traditionally made it quite difficult to separate the trees from the forest; i.e., one is able to see so much detail on the Sun's surface that it is extremely hard to separate out the global properties of the Sun. The heart of the new concept at SCLERA is its ability to identify the global properties.

The test program, begun in 1972, not only established the feasibility of the project but led to several startling discoveries about the Sun itself, as a direct consequence of the technological advances made by SCLERA in pursuit of the primary goal.

Among the global properties now identified are: (1) the excess brightness of the Equator with respect to the pole of the Sun, (2) the extremely small departure of the shape of the Sun from a sphere, i.e.,

a small solar oblateness, and (3) pulsation of the Sun. The discovery of this excess brightness resolves the discrepancies that have existed among solar oblateness observations for the past three quarters of a century. The small solar oblateness gives information about the mass distribution of the solar interior and, in particular, says that the core of the Sun cannot be rotating much faster than the Sun's surface. Knowledge of the pulsations of the Sun gives a great deal of information about the solar interior, in much the same way as seismic techniques aid petroleum industry surveys for oil. The latter discovery is the most exciting, because it offers a great deal more information about the properties of stellar interiors than any other observational technique, and the results of the study promise to have a profound

impact in astrophysics.

Not only do these discoveries pertain to solar physics, but two of them bear directly on another classical experimental test predicted by Einstein's General Theory of Relativity: the observation of small irregularities in the orbit of the planet Mercury. The observed small solar oblateness shifts the weight of this evidence back to Einstein's theory; it had been shifted away by a past oblateness measurement which was biased by the yet undiscovered excess brightness.

Continuing work at SCLERA holds promise for the future in several areas of observational astronomy. These areas include measurement of the gravitational deflection of starlight, as well as further knowledge concerning the structure of the Sun.

CHEMISTRY

Host-Guest Chemistry—An Application of A Lesson from Nature

The striking catalytic properties and selectivity of enzymes are an old story in chemical research. Not until very recently, however, have scientists learned enough to begin to try realistically to design synthetic compounds that behave like enzymes—a long-time goal of great import, both scientific and practical. A current example is work under way on several uses of such compounds—recovery of nutritionally important amino acids from mixtures produced by commercial syntheses, and separations of inorganic materials from nuclear reactor wastes—by Donald J. Cram and his co-workers at the University of California, Los Angeles (UCLA), in what they have called "host-guest chemistry."

Enzymes are structurally complex and quite large, ranging in molecular weight from perhaps 10,000 to several hundred thousand. Dr.

Cram's immediate goal, however, is to learn to design relatively small molecules that perform specific tasks in an enzymelike manner. By now, he and his colleagues have synthesized about 180 candidate host compounds with molecular weights of less than 2,000. Several of these compounds exhibit some of the selective binding properties of enzymes.

An enzyme—the host, in Dr. Cram's nomenclature—is a protein with an active site lying inside a cleft in the overall structure. The smaller substrate molecule, or guest, fits into the cleft and binds to the active site to form a complex that is held together by a variety of small attractive forces. The physical and chemical properties of the complex may differ markedly from those of the uncomplexed host or guest. While only the enzyme's active site interacts directly with the guest molecule, the rest of the protein provides a scaffold that shapes the active site. Shape provides selectivity. A given enzyme "recognizes" and binds only to the

molecule whose reactions it catalyzes, or to inhibitors that regulate the enzyme's activity. This selectivity extends even to chiral recognition—the ability to distinguish between and behave differently toward compounds that are mirror images of each other as determined by whether they rotate a beam of light either right or left.

Among the Cram group's first objectives were host compounds that would display chiral (right or left handedness) recognition of potential guests. The first guests studied were the amino acids. They are biologically important, and almost all exist in either right-handed (D) or left-handed (L) form. Nonbiological synthesis of an amino acid produces a mixture of the two. The D and L forms must then be separated (resolved) if the compound is to be used as a dietary supplement, since most living organisms can use only the L form metabolically. The usual separation method is fractional crystallization of derivatives, which is effective but

cumbersome.

The UCLA chemists wished first to select for synthesis the simplest host molecule that might form complexes with amino acids and discriminate between the D and L forms as well. The compounds they selected for synthesis contained binding sites and other features (steric barriers) complementary to those of the L amino acids. Now they have shown experimentally that the chosen host compound, confronted with a mixture of the D and L forms of the amino acid valine, complexes preferentially with the L form. The principle could be adapted to one of several different processes that would extract L amino acids automatically and continuously from mixtures with the D form, release the amino acid from the host molecule, and recycle the host for further extraction.

The UCLA team has worked also on host molecules for various metals. In particular, Dr. Cram has made hosts containing "counterions," chemical groups whose negative charges exactly balance the positive charges on the guest metal ion. When the charges are matched in this way, and when the guest and its niche in the host are well matched in size, very stable complexes are formed. Selective complexation of metals by host compounds is a promising tool for separatory processes like saline water conversion and solution mining. In the future, Dr. Cram and his colleagues will be studying selective complexation as a means of separating the lanthanide and actinide series of elements from nuclear reactor wastes. Complete separation of the actinides as a group might allow them to be recycled into reactors, thus avoiding the enormous difficulties associated with their disposal as wastes.

Synthesis of a Metallic Polymer

Metals are elements that possess certain characteristic physical properties such as high electrical

conductivity, high reflectivity of light, good thermal conductivity, ductility, and malleability. Throughout the history of science and technology it has been believed that these solid state properties belonged uniquely to metallic elements—substances that cannot be synthesized by any chemical reaction; it appears that this concept is now no longer true.

Very recent investigations carried out by Alan G. MacDiarmid, Alan J. Heeger, and Anthony F. Garito at the University of Pennsylvania, with Foundation support, have resulted in a major breakthrough in the synthesis of a metallic-like substance. For the first time, pure crystals, suitable for solid state studies, of an inorganic substance which contains no metal atoms, yet exhibits many of the electrical and optical properties commonly associated with a metal, have been synthesized. Remarkably, the compound, polymeric sulfur nitride (polythiazyl), $(\text{SN})_x$, is a covalent inorganic polymer which consists only of the very common nonmetallic elements, sulfur and nitrogen. The compound was first prepared in 1910 and has been cursorily examined from time to time since then throughout the years. In 1973, Mortimer Labes at Temple University (whose research was also supported by NSF) showed that fibrous bundles of the substance could be prepared, but that this material always contained significant amounts of impurities, particularly oxygen. The initial problem in studying $(\text{SN})_x$ was thus a chemical one, since without pure crystalline material, established physical methods for examining the properties of metals could not be meaningfully applied to it.

The investigation of a material such as $(\text{SN})_x$ can best be carried out by the close interaction of chemists and physicists, since such a study involves a wide variety of both chemical and physical experimental techniques and concepts. The investigation of $(\text{SN})_x$ at the Universi-

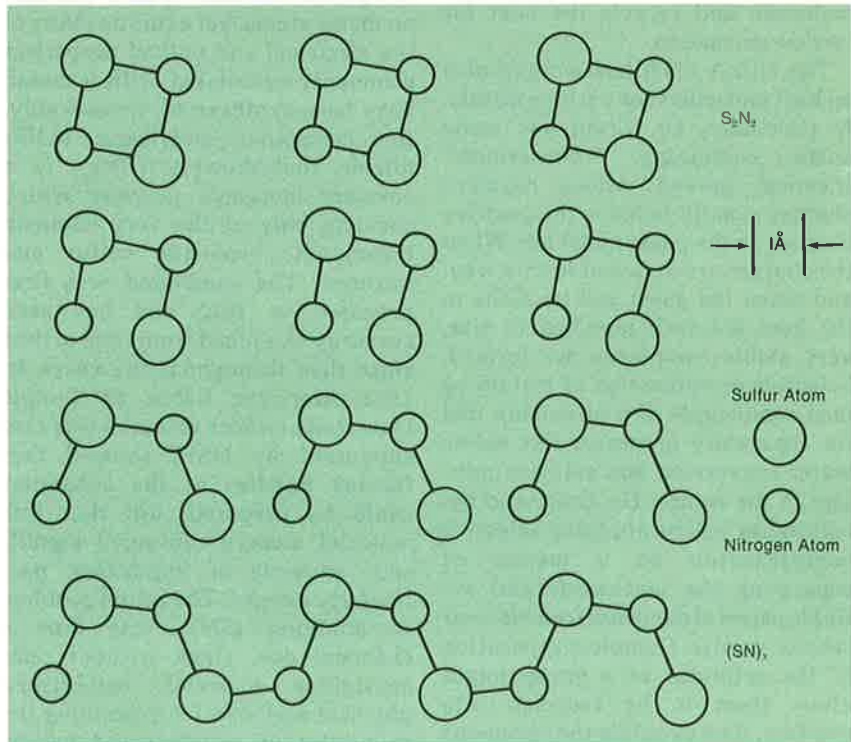
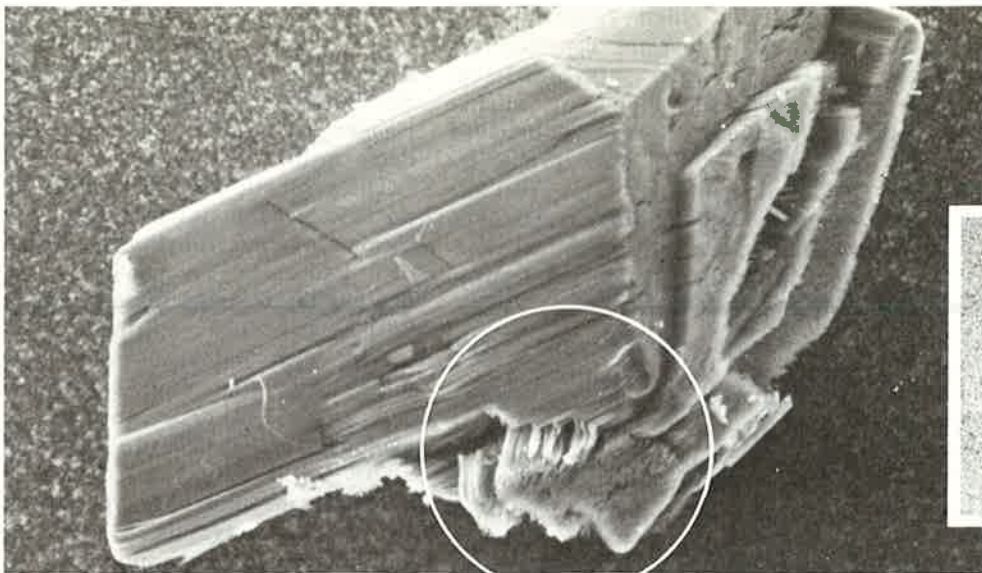
ty of Pennsylvania has developed into a tightly knit collaborative program between Dr. MacDiarmid of the chemistry department and Drs. Heeger and Garito of the physics department.

The synthetic method used in the present research involves first the formation of a sulfur chloride, which can be made inexpensively by heating the common mineral sulfur with chlorine. The resulting liquid is mixed with industrial-grade ammonia to give the orange crystalline compound, S_4N_4 . The vapor of this compound is then passed over heated silver sulfide catalyst which converts it by means of a known reaction to colorless crystals of another sulfur-nitrogen compound, S_2N_2 .

The investigators found, by means of an X-ray study, that this compound exists as a square planar molecule, and that upon standing at room temperature for a few hours it becomes an intense blue-black color and at the same time becomes paramagnetic. Then, on standing for several days at room temperature, the paramagnetism slowly disappears and the solid spontaneously changes to brilliant goldlike crystals of $(\text{SN})_x$. An X-ray study has shown that $(\text{SN})_x$ consists of an almost planar chain of alternating sulfur and nitrogen atoms. The intermediate paramagnetic properties are believed to be caused by molecules of S_2N_2 which have "opened up" by the spontaneous breaking of one of their bonds, before they then join with adjacent molecules to form the polymer.

Photographs taken through an electron microscope show that the crystals of this metallic polymer are composed of bundles of sulfur-nitrogen fibers stacked parallel to each other. A crude mechanical analogy might be made between a crystal of $(\text{SN})_x$ and a bundle of straight pieces of insulated wire held together with a rubber band.

An important feature of the polymer is that the fibers are aligned exactly parallel to each other, which



Although the crystal of synthetic polymeric sulfur nitride in the photograph is imperfect (see insert for "perfect" crystal), it illustrates the fibrous nature of the polymer, which, though free of metal elements, behaves optically and electrically as if it were a metal. Subsequent photographs show enlargements of the encircled corner. From top to bottom, the diagram shows how molecules of a sulfur-nitrogen compound (S_2N_2) "open up" by the spontaneous breaking of one of their bonds. They then join with adjacent molecules to form one polymer chain in a crystal of polymeric sulfur nitride $(SN)_x$. [Photos by University of Pennsylvania]

permits electricity to pass more easily along the fibers than across them. This means that the metallic reflection of light and the metallic electrical conductivity are not the same in all directions, as they are in a regular metal. Instead, the metallic-like properties (high electrical conductivity and high reflectivity of light) are exhibited mainly in the direction parallel to the sulfur-nitrogen fibers. These metallic properties appear to persist to very low temperatures, as far as 1° K, report Richard Green, Paul Grant,

and Bryan Street at IBM in San Jose, Calif. In addition, they, along with Laurance Suter of Stanford University, saw superconductivity at 0.26° K in single crystals of $(\text{SN})_x$.

The $(\text{SN})_x$ crystals may be flattened into thin sheets like crystals of a regular metal. Very thin films of $(\text{SN})_x$ are partly transparent to visible light and appear dark blue in color. Preliminary chemical studies show that crystals of $(\text{SN})_x$, like those of many metals, corrode only slowly in air or when immersed

completely in water.

These studies suggest that $(\text{SN})_x$ may be the forerunner of a new series of synthetic polymeric metals of very considerable scientific interest whose properties might be chemically altered to fit a variety of possible future applications. For certain specialized uses, it is possible that synthetic metals may one day replace ordinary metals just as synthetic fibers such as nylon have partly replaced naturally occurring fibers like silk and cotton.

A Tracer of Spiral Arms

Many regions of our galaxy emit faint radio signals that are characteristic of molecules in space. Since the discovery of the first molecule by radio techniques (at the University of California, Berkeley) in 1968, the list has been growing. It now includes several dozen inorganic and organic molecules of considerable complexity. Their formation in space in measurable quantities had not been expected. Their discovery provided new insight to processes and conditions in the source region: the interstellar medium that pervades such galaxies as our own.

One of the most pervasive of the interstellar molecules is carbon monoxide (CO), familiar as a product of incomplete combustion and a pollutant in the Earth's atmosphere. Its constituents, carbon and oxygen, are "interstellar pollutants"; they are formed in the nuclear burning of hydrogen by giant hot stars and combine to CO in relatively dense and cool regions of the galaxy. This occurs in the vicinity of and inside dust clouds, which shield the molecules from the starlight that effectively destroys CO elsewhere. Until recently the CO emissions have

been studied in relatively small localized condensations of cold, dense material where CO is formed and lasts long enough to be detected.

A new radio receiver, three times as sensitive as its predecessors and cooled with liquid helium to reduce internal noise, has enabled radio



Spiral Galaxy M-81, photographed with the 4-meter telescope at Kitt Peak National Observatory, shows the dark dust lanes among the spiral arms. The similar spiral structures of our galaxy, the Milky Way, long known but difficult to map, are now revealing themselves to a new liquid helium-cooled radio receiver at the National Radio Astronomy Observatory, three times as sensitive as its predecessors. The device makes possible the study of radio emissions from carbon monoxide molecules in cool, dust-shrouded regions of the galaxy and their contrast with the familiar hydrogen emissions from slightly hotter areas. [Photo by Kitt Peak National Observatory]

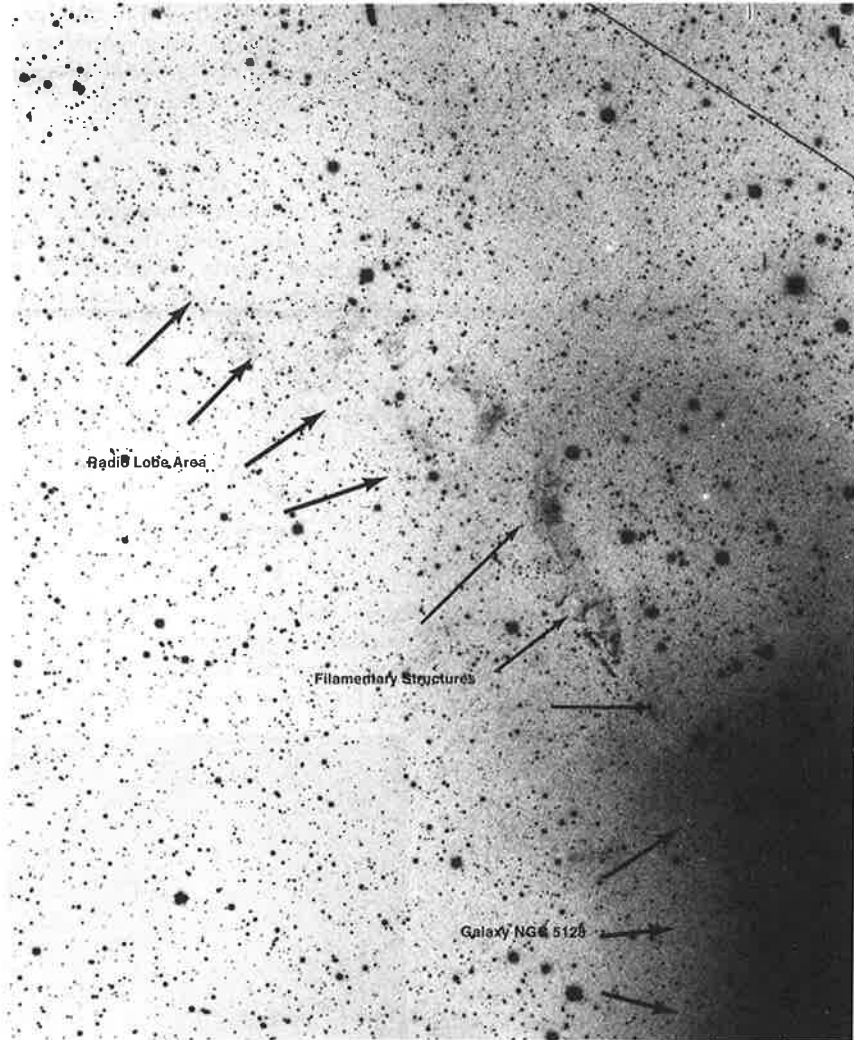
astronomers at the National Radio Astronomy Observatory to map the CO concentrations throughout our galaxy. Like the more familiar 21-centimeter wavelength radiation from hydrogen, the radio frequency signals from CO easily penetrate the vast clouds of dust that hide most of our galaxy from study by optical telescopes. The CO radiation from the cool regions complements the hydrogen emissions from slightly hotter areas. Together they can be used to make a more comprehensive picture of the spiral structure of our galaxy than hydrogen could alone. Carbon monoxide is the first known molecule that can be used directly as a tracer of galactic spiral areas.

The new receiver and the CO radio signals can also be used to probe molecular densities in the unusually high vacuum of the interstellar medium, an environment which cannot be reproduced in the laboratory and which defied earlier techniques. Molecules of CO and other materials can now be studied even if their number density is ten times smaller than the previously detected clouds.

The delicate balance between heating by starlight and cooling by shade, formation of large molecules on the surface dust grains and their destruction by starlight, high vacuum and compression waves—are all part of a challenging interstellar ecosystem that generates stars and may have spawned life itself. If we can understand this system we will know more about the galaxy, the evolution of stars, the probability of finding extraterrestrial life, and about new aspects of chemistry and physics that are important to us on Earth.

The Galactic Connection

Telescopes in the Northern Hemisphere cannot see a part of the sky because it is always blocked by the Earth. For example, the center of our own galaxy is poorly seen and our nearest neighbor galaxies, the Magellanic Clouds, are not visible



Galaxy NGC 5128, called Radio Source Centaurus A by radio astronomers, shows as a dark smudge at the lower right in this white-sky photograph taken with the new 4-meter telescope at Cerro Tololo Inter-American Observatory in Chile. Like other peculiar galaxies, NGC emits extraordinarily strong radio waves from nearby "radio lobes." The link between galaxy and lobes, however, defied discovery until Cerro Tololo astronomers detected the faint filamentary structures shown here linking NGC 5128 with a strong radio lobe near the photograph's center. The filaments, believed to be ionized hydrogen regions with aggregations of new blue stars and areas of great excitation, are now suspected to be jet-like streams of matter thrown off by the galaxy into the radio lobe region.

from observatories in North America. To "look down" astronomers must go to the Southern Hemisphere and use a telescope at a clear and dark site. The Association for Universities in Research in Astronomy, cooperating with the University of Chile, is just beginning to operate a new telescope at such a

site, Cerro Tololo, Chile, for the National Science Foundation. This telescope is one of the largest on Earth and a sister to the 4-meter Mayall telescope at Kitt Peak National Observatory. The initial scientific operations have already produced a major discovery.

Normal galaxies, including our

own, emit radio waves at a rate about 10,000 times that of our Sun. Some galaxies are peculiar in that they emit radio waves about one million times stronger than those of normal galaxies. Much of this radio flux seems to originate at one or two locations on either side of the peculiar galaxy—probably “above” and “below” the nucleus rather than in the galaxy itself. Astronomers had long been searching for some phenomenon that connects radio lobes to a galaxy and that would provide a clue to their relationship.

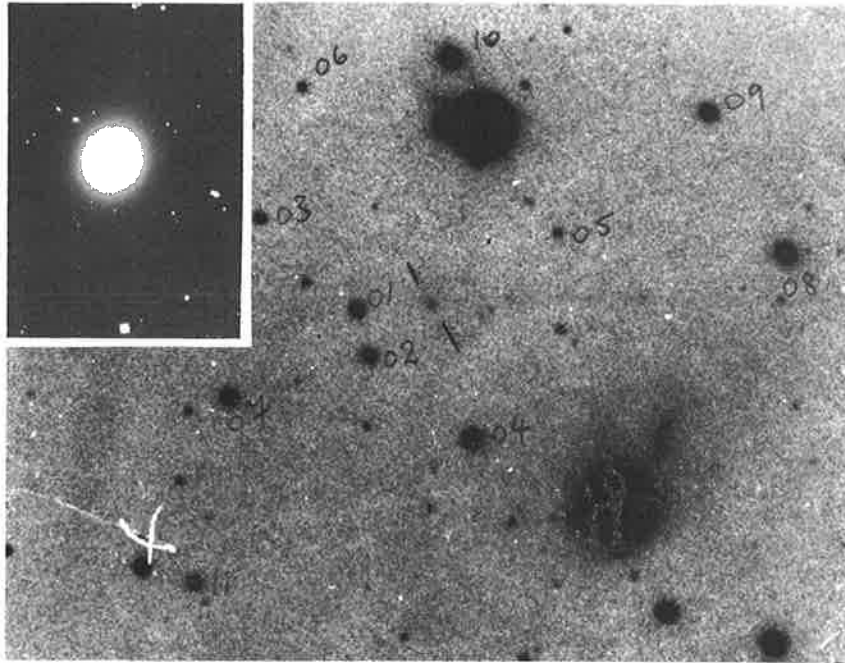
Now, astronomers at Cerro Tololo have discovered faint filamentary structures that appear to connect the peculiar galaxy NGC 5128 (known to radio astronomers as Centaurus A), near the star Canopus, with a radio lobe to the northeast of the galaxy. The structures comprise aggregates of hot, bright young stars, clouds of ionized hydrogen, and red filaments that indicate the presence of both neutral hydrogen and ionized sulfur radiations.

The phenomenon is far from being understood. However, it appears that the parent galaxy is ejecting jetlike streams of matter towards the radio lobe. Violent activity may be occurring in this “bridge,” along with some new star formation. The “peculiarity” of the galaxy is therefore in all likelihood rooted in its nucleus, which appears to be the site of highly energetic events that generate the energy for this activity as well as for the strong radio emission.

Future studies of Centaurus A will compete with other important early objectives of the Cerro Tololo telescope. These include studies of the center of our own galaxy as well as of our nearest neighbor galaxies, the Magellanic Clouds. The formal opening of the telescope to scientific visitor operations was planned for January 1976.

The Most Far-Out Galaxy

Using a revolutionary observing system that cancels out the glow of



The newly discovered galaxy 3C123, just north of the Pleiades (and shown here between the two dashes at the center of this photograph) is the most distant galaxy so far known. The giant, elliptical galaxy—8 billion light years away and receding from Earth at 45 percent of the speed of light—was detected with an image tube scanner developed by Lick Observatory astronomers to cancel the effects of background light. The distant galaxy appears to be a “normal” elliptical galaxy such as M 87 in the Virgo Cluster (insert).

the night sky, Hyron Spinrad of the University of California, Berkeley, on July 1, 1975, discovered the most distant galaxy so far known with the 120-inch reflector at Lick Observatory.

The galaxy was found to be at the location of a very powerful celestial radio source (3C123). It appears as only a fuzzy smudge—too faint for spectrographic investigation—in a direct photographic plate with the world’s largest telescope, the 200-inch at Hale Observatory. Fortunately, astronomers at Lick Observatory (L. Robinson, J. Wampler, and J. Miller) have developed a pioneering system called an image tube scanner which makes it possible to accumulate spectroscopic data over several nights of observation and cancel out the effects of background light. This is analogous to the obser-

vation of ordinary stars in the daytime. Pushing through old barriers of sky brightness with this new system, Dr. Spinrad was able to measure the redshift in light from 3C123 with the Lick 120-inch. He found that this distant galaxy has an enormous redshift, a shift that indicates that it is receding from the Earth at a rate equal to 45 percent of the speed of light.

Only quasars are known to have larger redshifts, but they are still the subject of controversy and bafflement among astronomers. In keeping with the theory that greater redshifts signify greater distances, Dr. Spinrad was then able to derive the distance of the galaxy as 8 billion light years, 3 billion light years farther than the most distant galaxy known before. The galaxy, then, is about ten times the size of our own

Milky Way.

Another extremely valuable aspect of the discovery is the fact that 3C123 appears to be a "normal" giant elliptical galaxy that can be compared to well-studied and less distant galaxies. What Dr. Spinrad is

recording, in fact, is a spectroscopic picture of a galaxy as it existed when the universe was only half as old as it is now, and long before the Sun and the solar system were formed. In further observations Dr. Spinrad hopes to find whether there is a blue

cast to light from 3C123 that would indicate that its stars are in an early stage of stellar evolution. Another quest will be for changes in luminosity in this galaxy that might indicate activity or possibly cosmological effects.

MATHEMATICS

Triangulating of Manifolds

In mathematics, manifolds are geometric objects. Examples of such are a spherical surface, the surface of an inner tube or football, or still more complicated surfaces (or their higher dimensional analogues). The more complicated manifolds can be difficult to describe precisely, and one standard technique is to describe how a manifold can be decomposed into certain standard building blocks: points, line segments, triangles, pyramids, and higher dimensional analogues of these, called simplexes. Such a description is known as a triangulation of the manifold, provided that the simplexes all fit together neatly where they meet.

"Neatly" is something that must be defined precisely, and there is one part of this precise definition that topologists had found puzzling. They were agreed that the technical condition in question—that the link of each simplex must be a sphere—was something they did not know how to dispense with in proving some theorems which involved triangulation. This is despite the fact that nobody knew whether triangulations existed which satisfied all the other conditions of the definition but failed to satisfy the requirement of sphericity. To be on the safe side, such descriptions, if any, have also been called triangulations; the possibly neater ones, satisfying the spherical simplex condition (until recently all known triangulations) were named PL (for piecewise linear) triangulations.

The distinction took on added significance in February 1969* when Robion C. Kirby of the University of California, Berkeley, and Lawrence C. Siebenmann, then at Princeton University, now at the University of Paris, Orsay, surprised the mathematical community by constructing a six-dimensional manifold which they could prove to have no PL triangulations whatsoever.

The Kirby-Siebenmann results were momentous achievements and widely recognized as such, but it nevertheless remained an open question whether all triangulations were PL triangulations. In January 1975, Robert D. Edwards of the University of California, Los Angeles, showed that there are non-PL triangulations. Building on earlier work by himself and Richard T. Miller of Michigan State University (in part done independently by William T. Eaton and Carl P. Pixley of the University of Texas at Austin), he succeeded in showing that a certain standard topological construction known as suspension, when applied twice over to a certain well-known triangulated three-dimensional manifold which has some but not all of the properties of a 3-sphere, produces a genuine 5-sphere (i.e., the surface of a six-dimensional solid ball). Since the triangulation carries over from the three-dimensional manifold to the 5-sphere, the 5-sphere is triangulated. Moreover, the three-dimensional "almost" sphere is so embedded in this triangulation that its not being a genuine sphere specifically contradicts the condition for PL triangulations. This result is perhaps

the best result in topology for the year. It poses the further question of whether all manifolds can be triangulated, if not with PL triangulations (as Drs. Kirby and Siebenmann showed), then with non-PL triangulations. This question is wide open at the present time since the algebraic machinery which Drs. Kirby and Siebenmann drew upon applies only to PL triangulations.

The Mathematics of Chemotaxis

Chemotaxis is said to take place when the motion of an organism is affected by inhomogeneities in some chemical attractant or repellent in its environment. Currently, there is strong interest in this phenomenon on the part of applied mathematicians generated by two questions: (1) To what extent can chemotaxis explain the ordered motion and eventual patterning of cells which are significant elements in forming the architecture of a developing organism? and (2) Can important clues to sensory transduction (e.g., sound waves translated into the brain response) in higher organisms be found by studying chemotaxis in simple creatures like bacteria? Lee Segel of Rensselaer Polytechnic Institute has been conducting research on the application of mathematical techniques to develop insight into this fundamental area of biological inquiry.

* See the *National Science Foundation Annual Report, Fiscal Year 1969*, pp. 32-33.

Recently, Dr. Segel has achieved several results in his investigation. He has incorporated receptor kinetics in a model for bacterial chemotaxis, successfully dealing with the chemical interaction between the attractant and those molecules capable of sensing the attractant (receptor molecules). This could be a key factor in understand-

ing sensory transduction. In a recent paper, he demonstrated the influence mathematics can have on such a basic experimental problem—mathematically characterizing motility (the capability for motion) with precision. Along with M. Sussman, a laboratory biologist, he is currently using interactive computer simulations with random elements to

study the behavior of certain aggregating amoebae. Still in its earliest stages, the work is the mathematization of the biologist's ideas concerning the mechanism of chemotaxis in cellular slime molds, colonies of which become integrated as complex organisms and which are one of the standard models in developmental biology.

SOCIAL SCIENCES

Without substantial increases in knowledge about individual and collective behavior, there can be little hope of achieving mastery over the rapid changes taking place in nearly all aspects of the social and cultural environments in which people live. The social sciences hold the strong promise of contributing such increases in knowledge, but because they are young and underdeveloped relative to the physical and biological sciences, and because the phenomena they deal with are highly diverse, intricate, and subject to irregularity, the results of social research are often disappointing when measured against the immediate practical demands of current and recurring social problems.

At such times, questions tend to get raised about the usefulness of social science, without realizing that there is virtually no person, organization, or agency of Government today that is not a user of social science methods and techniques, and without an appreciation of the extent to which the social sciences have already expanded the choices available to society by successfully challenging long-held assumptions about social functioning upon which many policies and practices were previously built.

The uses of social science are as varied as its tangible products, which consist of methods for collecting, organizing, and analyzing social information; techniques for measur-

ing human preferences, values, attitudes, and behavior; and systems for modeling and simulating social processes. Its greatest usefulness, however, is indirect—consisting of the generation of basic knowledge about human behavior in groups as small as families and as large as nations.

The gradual cumulation of such knowledge—accruing through the studies of anthropologists, economists, psychologists, sociologists, political scientists, and investigators in related social science disciplines—affects the whole of society through a process of enlightenment which is not easy to trace or describe, except to say that it operates on a timetable considerably different than the one we see happening in terms of day-to-day or even year-to-year events.

Long periods in the diffusion of basic knowledge are not unique to social science; they are also characteristic of other fields of science. However, while the ultimate effect on society can be as great for physics as for sociology, there is an important difference in the way feedback to the science itself makes further advances possible. Unlike other fields of science, the social sciences usually proceed with the active participation of their subjects of study. When fundamental insights take hold, significant strides in the progress of both science and society become feasible.

The maintenance of a strong basic research capability in social science is crucial to ensuring that understanding of the workings of society is achieved and disseminated in scientifically accurate form, and to assuring that existing policies, practices, and beliefs are subject to reexamination against the gains of such new knowledge. NSF's programs in the social sciences are primarily oriented toward the support of research aimed at a basic understanding of social phenomena, though not to the neglect of timely and practical applications where opportunities arise; the programs are also watchful of unexpected payoffs capable of assisting with the handling of some current problem.

This year, as in past years, a number of projects were supported that produced results of basic, long-term import, while others resulted in findings of more immediate consequence to current concerns. Both types are described here.

Fiscal Policy and the Economy

Recent theoretical and empirical work has questioned a basic economic principle, widely accepted since the work of Keynes, that the Federal budget can influence the aggregate level of income and employment. In its simplest form the so-called "monetarist" thesis asserts

that each dollar of additional Government spending, no matter how it is financed, simply "crowds out" the same amount of private spending. As a consequence, fiscal policy is powerless to alter the overall level of aggregate income. The ensuing debate and the mounting problems of the economy have prompted an extensive reexamination of macroeconomic theory.

Of major significance in this reappraisal of the foundations of fiscal policy is the research of Alan Blinder of Princeton University and Robert Solow of the Massachusetts Institute of Technology. In a recent study they modify the Keynesian model, but essentially reaffirm its theoretical underpinnings of fiscal policy. At the same time their empirical analysis of the lags and uncertainties in the operation of fiscal policy underlines our areas of ignorance about the econometrics of policy multipliers. Their investigation of the 1968 to 1970 income surtax episode, in particular, emphasizes the extreme difficulties, if not impossibility, given the present state of knowledge, of "fine tuning" the economy. They conclude that "any stabilization move so subtle as to seek to alter the unemployment rate by a single point or less runs the risk of being nullified by unpredictable (or at least unpredictable) shifts in the strength of private (or public) demand."

They do make an important distinction, however, between "fine tuning" and what they call "continuous adaptation." The former presupposes the ability to forecast accurately both the course of private spending under present policy and the marginal effects of changes in that policy—an ability they find lacking.

Nevertheless, they argue for "continuous adaptation." Specifically, they feel that it is better to make many small fiscal (and monetary) policy moves in whatever direction current forecasts indicate than to wait until growing excesses or deficiencies in aggregate demand call unmistakably for a major change.

The main reason for this is the nonlinearity of economic behavior. As they put it: "It is more than twice as hard to make a smooth correction in a boom or slump once it has gone twice as far." Moreover, they observe, "occasional big changes in tax rates and the volume of spending are more unsettling to private decisionmaking than a steady stream of small changes, none big enough to disturb the private calculus."

The eclectic model of income determination which Drs. Blinder and Solow formulate and the many issues they explore with it cannot be summarized in a paragraph or two. Their own analysis points to the great amount of theoretical and empirical work that remains to establish a foundation for rational fiscal policy. This can only be realized in the context of econometric models of the whole economy, an enterprise to which the Foundation is devoting substantial long-term support.

Human Origins

In the past 2 years, new discoveries of early man fossils in east Africa (from Kenya to Ethiopia) have transformed man's view of human evolution. In 1973, scientists placed the emergence of man at no more than 1.75 million years ago; today it is placed at almost twice the previous figure (3 million years), largely as the result of Donald Carl Johanson's (Case-Western Reserve University) findings in Ethiopia. Moreover, the "near man" creatures known as the *Australopithecus*, long thought to have been our ancestors, have now been removed from the direct line of descent. The line has been shifted instead to a creature with a substantially larger brain case (800 cubic centimeters compared to 400 cubic centimeters), discovered by Richard Leakey, son of the late L.S.B. Leakey, and identified only by its catalog number, 1470.

The apparent coexistence of the *Australopithecus* species and the 1470 types over a period of 2 million

years raises problems, especially for those scientists who are convinced that competition should have led to the elimination of one or the other lines. Neither do the new fossil finds fit neatly into existing ideas about human evolution, since they raise difficult problems for the paleoanthropologists who must decide the specific anatomical traits on which to separate the "near man" (e.g., *Australopithecus*) from the "true man" (designated by the genus name, *Homo*). Some think brain size is the critical dimension, while others emphasize tooth size and shape, and still others argue for erect posture. Indeed, the question "What is man?" is still being asked. Perhaps most importantly, because some evidence of tools has been found with these early hominid creatures, the estimated time of emergence of "man the toolmaker" is pushed back from 4 to 6 million years ago.

Of course, not all specialists in this field of human origins are comfortable with the interpretations being made. Yet perhaps the following paraphrased comments by Boyce Rensberger, *New York Times* science writer, who has interviewed many of the participants in this endeavor, best summarizes the opinions of those engaged directly in investigation:

First, it is believed that man emerged 4 to 6 million years ago from a proto-australopithecine ancestral group. Second, this ancestral group subsequently evolved into several lineages and by at least 3 million years ago three hominid species lived in east Africa. These are two species of australopithecine (one robust and the other gracile) and an early variety of the genus *Homo* (e.g., the 1470 type). Third, the australopithecines walked on two legs and had bodies that were virtually human from the neck down. Their brains, however, remained small for over 2 million years. Fourth, overlapping the *Australopithecus* in

time was the genus *Homo*, who had a body similar to the australopithecines. However, this genus had a larger brain that continued to increase in size. Finally, the *Homo* steadily advanced and their superior competitive ability eventually pushed the australopithecines into extinction.

Many people and many kinds of specialized skills are needed to increase our knowledge about human evolution. If the amount of new knowledge gained in the past 2 years is a measure, then the following statement by Dr. Leakey may not be overly optimistic: "It seems clear that within the next 5 to 10 years man will be able to look back, as a species, and see where he came from."

Trends in Industrial Conflict

Apparently, high unemployment makes trade unions less likely to strike, but loss of real income makes them more likely to strike. What does this imply for the current situation of rising unemployment and also rising inflation and falling real income?

Douglas Hibbs, a political scientist at the Massachusetts Institute of Technology, has established a clear link between high unemployment and low union militancy in ten major western industrial nations in the decades 1950 to 1969. In a recession, workers worry about losing their jobs and are reluctant to call strikes; employers are more ready to face a long shutdown because sales are low.

Dr. Hibbs finds an equally clear and far longer lasting link between strikes and falling real pay. His equations suggest that a 1-percent drop in the rate of growth of real wages produces an average 59 more

days lost in strikes per 1,000 workers spread over the following 5 years; generally the loss in man-days is greatest in the second and third year following the drop in real wages. The losses have been highest in Italy, the United States, and Canada; and lowest in the Scandinavian countries and the Netherlands.

Strikes represent a very significant social phenomenon: They are an important instrument of mass collective economic action and they pose a direct challenge to business and industrial management and, increasingly, government in industrial societies.

The necessary data for analysis of long-term trends exist for most industrial nations. Dr. Hibbs, for example, utilized data on over 100 economic, social, and political variables, some running annually for 35 years, to test a number of rival theories about industrial conflict. Data on the number of strikes, number of strikers per worker, and the man-days lost in strikes from 1950 to 1969 were compiled from appropriate agency sources in the United States and the International Labor Organization, as well as the international academic community. They were combined with other variables and were analyzed through a variety of dynamic time-lagged econometric models. The resulting data file, a file of considerable magnitude, and computer subroutines developed for the analysis will shortly be available for wider use in the academic and policymaking communities.

Contrary to popular beliefs, Dr. Hibbs' findings for the Western European states include evidence that the volume of strikes is not affected by the political success or failure of left-wing parties. The number of strikes does not fall when

they are in power. However, there does seem to be a correlation between the number of strikes and the size of the local Communist party.

The *Economist* (London) cited these results in two recent articles and has speculated on their implications for current conditions. In the United States (as in all other reporting nations), strike levels in 1974 neared record highs and the average length of strikes increased. In many European countries, the number of man-days lost per year per 1,000 workers has nearly tripled. This has become the major issue among many of our oldest "free world" allies. Continuing research is aimed at more detailed and systematic understanding of the causes and correlates of this manifestation of social conflict and seeks to provide a firmer basis for current policies.

Other fundamental aspects of our industrial society and relation to work are under study by economists, sociologists, and social psychologists. For example, a recently completed analysis by Arnold Tannenbaum of the University of Michigan has documented an "inevitable hierarchical gap" between the attitudes of workers and management. He conducted a cross-cultural investigation of worker and management hierarchy in 50 industrial plants in five countries: the United States, Italy, Austria, Yugoslavia, and Israel. Few people are likely to be surprised to find that in capitalistic countries, workers at higher industrial and management levels are happier than those at lower levels, points out Dr. Tannenbaum. But his study also showed the same condition exists in organizations where equalitarianism and participation in management are among the guiding principles.

ENGINEERING

The business of engineering is to produce solutions to society's technological problems, and the business of the Foundation's engineering programs is to encourage the research needed to support this technology. NSF's clientele is found primarily in the Nation's 285 engineering schools, where the Foundation provides about 25 percent of the support for basic engineering research. Among the more than 2,150 departments in these engineering schools, it is possible to identify at least 12 distinctly different engineering disciplines; these disciplines may be related to the activities in nearly every one of the areas of the physical, biological, mathematical, social, and environmental sciences. Obviously, then, support of engineering research represents a unique challenge not only because of the large number of departments involved, but also because of the wide range of research areas.

The diversity of organization in engineering schools has led NSF to structure its engineering programs along functional lines—such as heat transfer, fluid mechanics, automation, and so forth—to be more responsive to requirements of the field as a whole. Because many subspecialties are common from one university department to the next, a program director who is an expert, say, in fluid flow, can cover that subspecialty in mechanical engineering, aeronautical engineering, and chemical engineering. While this crossing of department lines means more university contacts to deal with, it also means that the Foundation can more effectively cover the multitude of disciplines with fewer and better program directors.

Engineering research explores the scope and limits, as well as the assets and liabilities, of the wide range of natural phenomena that appear to have practical application (a current example would be surface acoustic wave interactions in ferroelectric-

semiconductor material combination systems). Because of the diversity and range of specialties in engineering, NSF tries to focus its support in areas where there will be a sufficient concentration of resources to make a difference in a particular area of engineering.

The engineering program especially seeks opportunities to hasten technological innovation by shortening development time and reducing the costs to the technological entrepreneur. By selective funding in areas that show promise (such as single-mode, coherent, optical communication systems in integrated form), NSF hastens the development of the technology needed to evaluate the potential of an area. This same exploration allows many different potential industrial users to estimate and minimize their development cost and to shorten the time over which they must take a risk in developing a new project or process.

This year NSF has made several changes in its pattern of support in engineering. In addition to stressing basic long-range research, the Foundation emphasized the support of food- and minerals-related research—especially as it relates to allied industries—because of their importance nationally and internationally.

For example, a great amount of material processed by industry is in a particulate form, yet most of the processing research has been done on fluid systems. Particulate and solid processing have long been neglected due to the very severe theoretical and experimental problems associated with the field. But the time now appears ripe to push ahead in the basic engineering research to attack these problems, which have high potential payoff for the process industry. Accordingly, NSF instituted a new program, Solid and Particulate Processing. An area of great importance in industrial processing, this field includes gas-

solid interactions, liquid-solid interactions, separation technologies, and rheology.

To provide resources for this new work, NSF placed less emphasis on industrial technology. While industrial technology remains an important field, some of the work did not contain the mixture of basic research that the program should support, while other aspects of industrial technology could be dealt with in other existing programs.

Important results coming from several research projects are described on the following pages.

Cryogenic Thermal Insulation Research

The storage and transportation of cryogenic fluids such as liquefied natural gas, oxygen, nitrogen, hydrogen, helium, etc., demand effective thermal insulation. The boiling points of these fluids at atmospheric pressure range from 120° to 4.2° K (the equivalent of -153° to -268.8° C). Depending on the specific application, the necessary insulation may be either of the unevacuated type, consisting of a porous material packed in gas at atmospheric pressure, or of the evacuated type, which employs high vacuum.

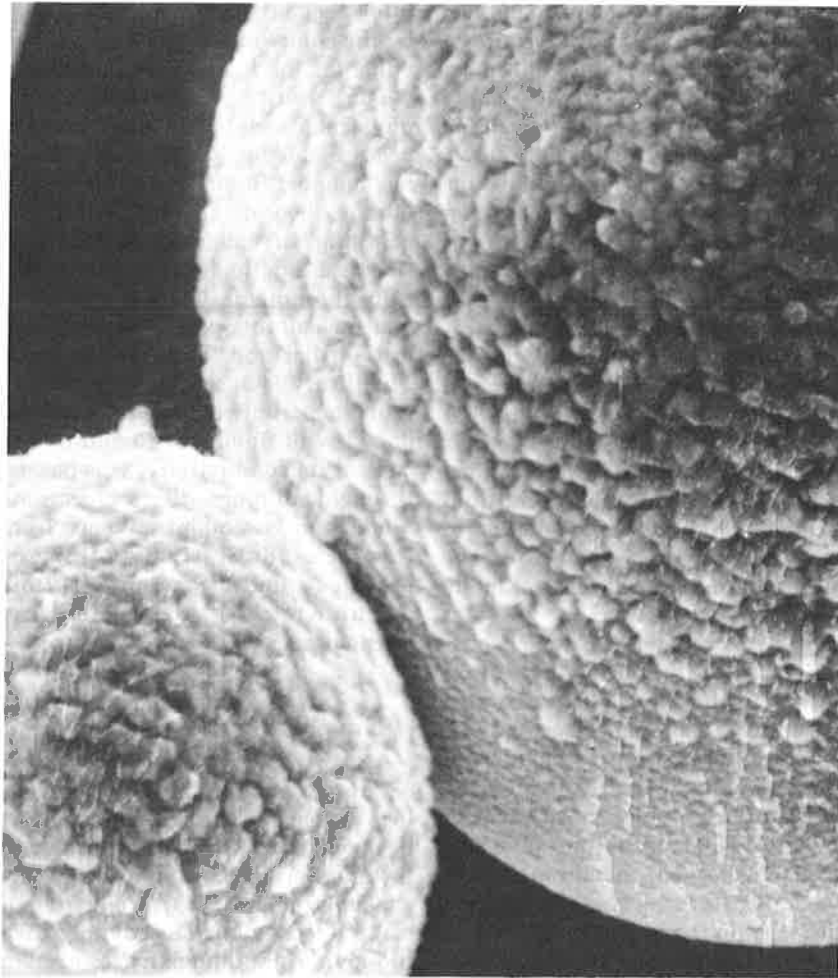
Recent advances in low temperature technologies are due largely to developments in evacuated insulation of either multilayer or microsphere design. These developments have been accompanied by comprehensive research programs directed at obtaining an understanding of the mechanisms of thermal energy transport in evacuated insulations. One of these programs is being conducted by C.L. Tien and his associates at the University of California, Berkeley. The study at Berkeley has been focused on multilayer insulations, but a measure of understanding of the

thermal performance of microsphere insulation has also emerged.

In essence, the evacuated cryogenic multilayer insulation, referred to as "superinsulation" owing to its high effectiveness, consists of a series of radiation shields placed in the evacuated space between two boundaries. The radiation shields, separated either by spacers of low thermal conductivity or by crinkling or embossing the shields, each consists of a thin plastic substrate coated on one or both sides with a thin metallic film of high reflectance. The study at Berkeley has shown that while the thermal properties of a shield are governed by the thin metal film, the films exhibit a significant size effect: Not only does the thin film radiate more heat as its thickness decreases, but the effect becomes more pronounced at lower temperatures. This interferes with the insulating efficiency of the system and will require trade-offs in the search for optimum designs.

Normal heat transfer, which usually forms the basis for insulation performance evaluation, is found to be little affected by the conventional spacers. The contribution of conduction to the transfer of heat within the system depends primarily on contact pressure between surfaces and on deformation characteristics. Lateral heat transfer is governed by conduction along the shield and by lateral radiation tunneling, i.e., multiple reflection along the shields. The use of highly scattering fibrous spacers such as Tissuglas and Dexiglas is found to reduce substantially lateral radiation in multilayer insulation.

The development of microsphere insulation is stimulated by the need in certain applications for easier installation and reduced dependence of thermal performance on compressive load than is provided by the multilayer insulation. This "second generation" superinsulation, which is currently under intensive study by Dr. Tien's group, comprises packed hollow glass spheres of sizes from 15 to 150 microns in diameter; the spheres are typically coated on the



Scientists trying to solve the problem of insulation for storage and transportation of cryogenic fluids have focused on these hollow glass microspheres, 15 to 150 microns in diameter, which help resist thermal conduction by being coated with low-emittance aluminum and having a surface roughness to reduce contact. [Photo by C.L. Tien]

exterior with metal film of low emittance. The method derives its high effectiveness from the resistance to conduction of the hollow spheres, the point contact from sphere to sphere, the radiation attenuation by the metal coating, and the light weight and reduced heat capacity of the hollow spheres. Rough surfaces, disclosed when the spheres are examined under a scanning electron microscope, interfere with optimum contact between spheres. Current research is attempting to develop deposition techniques

that will take this phenomenon into account while ensuring optimum sphere-to-sphere contact for insulation purposes.

Electrokinetic Charging

The buildup of electric charge in the effluents from conduits carrying hydrocarbon liquids (or other liquids of low electrical conductivity) is a well-known problem in the petroleum industry; several accidental explosions have been

attributed to this phenomenon. The charging can be particularly intense when fuels are passed at high speed through filters with a very large wetted area. An understanding of the charging characteristics of flows through filters is essential for evaluating hazards in fuel handling and processing operations.

Previous work on this subject has been largely empirical. Apparently the only scheme for predicting charging characteristics in filtration is based on dimensional arguments and several simplifying assumptions that imply that the charging current is independent of any physicochemical property of the filter or solid/fluid interface. This is in contradiction to the commonly held picture of the charging process as an electrokinetic one.

Ain A. Sonin and Ronald F. Probst at the Massachusetts Institute of Technology have recently postulated a relatively simple electrokinetic model for the charging mechanism in liquid hydrocarbon filtration, a model that resembles those used for flows of aqueous saline solutions through charged membranes, but which differs in several key respects with the existing charging model. The unique feature of the Sonin-Probst model is the introduction of a current-voltage relationship across the filters. The charging mechanism is based on the assumption (common in the description of many electrokinetic phenomena) that the filter contains fixed charges distributed either on its interior surfaces or within its solid matrix. As a result there appears only one additional parameter not ordinarily specified for filters or porous materials: a fixed charge density expressed as a fixed charge per unit volume of filter. This fixed charge density is a property of a given filter-permeant combination, and must be known if the model is to be used for engineering predictions. In the MIT experiments, the fixed charge density was determined experimentally, in the sense that all the various kinds of test data obtained could be brought

into excellent agreement with theory by the choice of a single (reasonable) value for the fixed charge density.

The resulting relatively simple physical model for the charging process during flow through filters has enabled Sonin and Probst to obtain theoretical results for the charging current generated by filtration as a function of the volume flow rate, the potential across the filter, and measurable physical properties of the filter and the permeant fluid. The theory is in excellent agreement with experiments where heptane, doped with Shell ASA 3 additive to control its conductivity, was passed through millipore filters of various kinds, and is a major advance from the semiquantitative nature of previous understanding of this economically important phenomenon.

Novel Optical Glass Lenses

The production of quality glass lens systems in the United States has been declining steadily, especially in the mass production of lenses for the consumer market. The production of camera lenses has already migrated to Japan. And, though lenses used in the first and second generation copying machines such as the Xerox, IBM, and 3-M systems were produced in the United States, there is a strong possibility that the lenses for third generation machines now under development will be produced in Japan. There are on the horizon other potential large markets for high quality lenses. These may well include optical communications, the videophone, and home television playback systems—markets of sufficient potential magnitude to justify efforts to reverse the trend.

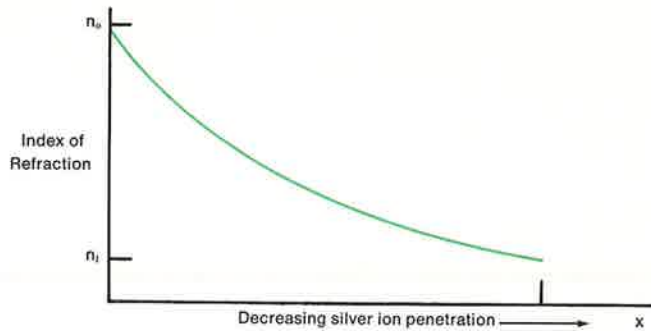
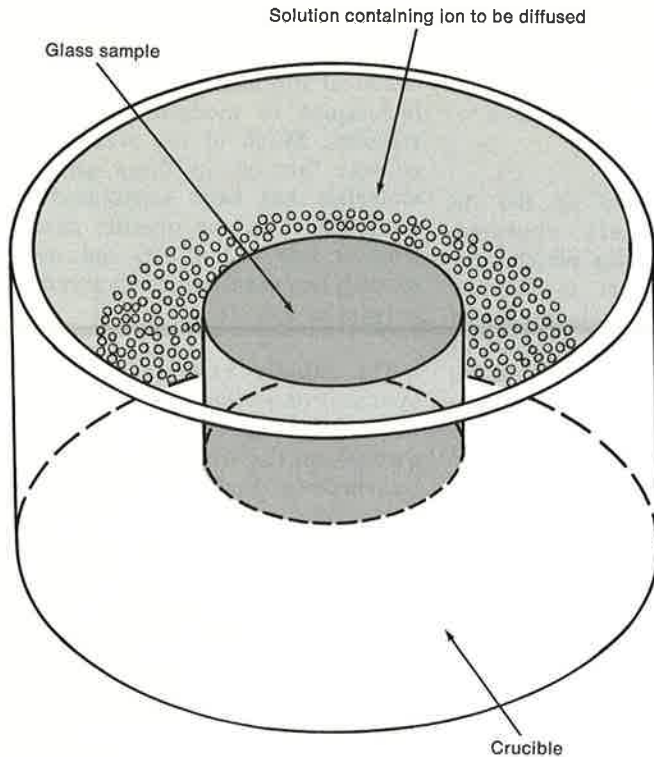
High among the factors which have precipitated the trend to foreign manufacture are the high costs of labor in the United States. Traditional lens manufacturing is highly labor intensive. A typical lens system is composed of a combination of simple lens "elements," each hav-

ing two spherical (including planar) surfaces to be finished. The system cost breakdown includes: materials, 10 percent; surface finishing, 60 percent; mounting, 30 percent. It is clear that to make lens manufacturing more competitive, the greatest cost reduction can be realized if the number of optical surfaces to be finished and elements to be mounted can be reduced.

One method for reducing the more costly operations is to use a smaller number of elements having especially designed aspheric surfaces to accomplish the desired optical effect. Notwithstanding some 30 years of effort, however, the production of aspherics is still an art better suited to the laborious fabrication of prototypes than to mass production. A new concept which will reduce the number of surfaces to be finished involves the production of lenses of simple, mass producible shape but made of glass whose index of refraction varies in a continuous manner within the lens element; namely, a gradient-index lens.

In the past, little study has been done on the design of gradient index lenses because it was not certain what materials could be produced; conversely, there has been little industrial incentive to produce samples of such glasses because there were not design techniques available to turn them into lenses. A collaborative research effort with the support of the National Science Foundation, involving the University of Rochester and Bausch and Lomb, Inc., is approaching the gradient-index lens system problem simultaneously, taking advantage of the mutually complementary attributes of university and industrial R&D capabilities.

The University of Rochester determines the desired properties of the glass for a given lens, determines the direction and magnitude of its gradient index, and provides Bausch and Lomb with the design of lenses which uses the unique capabilities of gradient-index materials. Bausch and Lomb possesses the resources to



Designing a gradient into the index of refraction of glass, rather than hand-forming an aspheric surface, is a way to produce complex optical lens systems with a minimum number of lens surfaces. To produce a varying index of refraction, a glass cylinder is floated in a hot solution containing silver ions which are diffused into the glass (left). A profile of the resulting nonhomogeneous glass index of refraction is shown at right. [After Duncan Moore]

produce and test samples of this glass in accord with the lens design, and is developing new methods of manufacturing glass with index gradients required by the lens design.

During the first phase of this effort, this collaborative research has produced a gradient-index lens made to a specific lens design for use as a collimator in instruments such as spectrometers. This accomplishment represents the first systematic design of such lenses. (Others were

made in France in the late 1960's by an empirical trial and error method but with wide variations in quality.) So far the number of surfaces has been reduced from six to two (one lens element instead of three). Based upon the success of producing collimator lenses, the research is now being directed towards lenses for the mass consumer market. Initial gradient-index lens design has been accomplished for photocopying applications and results are highly

encouraging. Other possible optical systems with gradient-index components include high quality camera lenses, microscopes, and eyepieces for a wide variety of applications.

The commercial use of gradient-index components will result in a slight increase in materials cost but will cause a steep decrease in the cost of surface manufacturing. The total impact could be a more cost competitive optical industry in the United States.

MATERIALS RESEARCH

As the examples on the following pages show, research in materials covers a broad spectrum—from investigations related to the understanding of how certain materials behave under extreme environmental conditions to studies of the interactions between atoms and molecules in matter. About half of the research supported by NSF's programs in

materials research has long-range implications for the Nation's energy programs, because nearly all major new energy systems have associated materials problems that must be solved prior to their widespread utilization. These problems are likely to benefit from NSF-supported fundamental research in such areas as superconductivity, characterization

of surfaces, new ways to make polymers, new materials for solar cells, corrosion and erosion, and hydrogen embrittlement of metals. Other areas of materials research that have become more visible in the past year (with the establishment of new NSF organizational units having explicit program titles) are Ceramics, Polymers, and Solid State

Chemistry.

In the area of condensed matter sciences, several topical areas of research are attracting special interest, e.g., phase transitions, surface phenomena, mixed valence effects, new superconducting materials, the electron-hole plasma, and superionic conductors. A noteworthy advance occurred recently at Brandeis University where Karl Canter, Allen Mills, and Stephan Berko were studying the surfaces of metals by monitoring the annihilation of positrons. In the course of these studies, they discovered an enhanced production of positronium, a simple atom composed of an electron and a positron. Because of its simple nature, positronium is an excellent system upon which to base an experimental test of the theory of quantum electrodynamics, and many attempts have been made in the past to produce and study it. However, the positron is an unstable particle with a short lifetime, and earlier attempts had been unsuccessful. The successful Brandeis team produced the positronium in a vacuum, using a slow positron beam and a solid target that was well separated from the radioactive source of positrons. This unexpected result, from an experiment designed for a different purpose, illustrates the critical interrelation between the development of new analytical techniques and the pursuit of fundamental science.

The fields of metallurgy, ceramics, and polymers have all experienced significant research advances in the past year. For example, a basic study of abrasive materials for grinding, by Milton Shaw and Rangachary Komenduri at Carnegie-Mellon University, has resulted in the discovery that synthetic diamonds can be nucleated by the very high temperatures and pressures present during grinding at the surface of an abrasive grain of tungsten carbide coated with nickel and graphite. Implications of this observation include the possibility of studying the formation of new high-

temperature, high-pressure stable phases of materials by a simple technique, as well as using the method to convert solid lubricants to abrasives.

Research conducted at the 16 university materials research laboratories (MRL), for which NSF provides core support, is directed primarily at larger scale problems requiring major experimental facilities and involving investigators from several scientific and engineering disciplines. These efforts complement the more traditional mode of individual support provided by the other programs. The MRL experimental facilities are also shared by faculty and students engaged in individual research projects, many of which are supported from other sources. Over the past year significant contributions to the knowledge of materials and their behavior have been made by these laboratories. Interdisciplinary research on surfaces, involving sophisticated theoretical and experimental approaches, is receiving increased emphasis at a number of MRL's including Brown, the Massachusetts Institute of Technology, Pennsylvania, and Stanford. This work concerns both idealized systems, which provide essential fundamental understanding, and more complex systems having practical implications for heterogeneous catalysis.

At Brown, MIT, Northwestern, and Pennsylvania, faculty members from materials, engineering, and physics departments contribute to programs focused on the mechanical properties of a variety of materials. Combining atomistic, microstructural, and continuum concepts, these studies are aimed at improved understanding of the basic mechanisms underlying the failure and related properties of important structural materials. They can also lead to techniques for developing materials with improved properties. Another major effort at the University of Pennsylvania in-

volves the study of anisotropic organic conductors, based on careful chemical synthesis and utilizing the techniques of modern solid state sciences. Much of the widespread current interest in these unusual materials has been stimulated by work there on the organic charge transfer salt TTF-TCNQ and, more recently, on the conducting polymer, polysulfur nitride.

The rapidly expanding field of synchrotron radiation research continues to generate excitement throughout the world. The Stanford Synchrotron Radiation Facility, in operation since mid-1974, has already reached saturation in use by visitors. Just before the end of fiscal year 1975 the Foundation made \$300,000 available to begin the construction of a second experimental area; this will more than double the use capability of the facility in the X-ray region of the electromagnetic spectrum. The facility is currently being used by physicists, chemists, biologists, and materials scientists to probe the properties of matter with an intense variable wavelength source of X-ray radiation. In 1975 the Foundation also assumed responsibility from the Air Force Office of Scientific Research for the synchrotron radiation facility at the University of Wisconsin, where equally exciting research is carried out in the ultraviolet region of the spectrum.

The development of advanced conventional and hybrid (conventional plus superconducting) magnet systems continued in 1975. Much of the work on high magnetic fields is carried out at the National Magnet Laboratory of MIT. This facility can generate the world's highest d.c. magnetic fields and is available about half of its time to visitors from throughout the Nation. Research programs involve studies of the properties of solids using high magnetic fields as a tool as well as many applied projects supported by NSF and other agencies.

Metallic Materials Property Enhancement Using Pulsed Lasers

Scientists at Battelle Memorial Institute, Columbus, Ohio, have discovered that bursts of radiation from a high-powered pulsed laser can be used to shock-harden and strengthen metals and alloys. When a laser pulse of a trillion watts per square centimeter and a duration of about 30 trillionths of a second is beamed onto a metallic surface, a few micrometers of the material surface are rapidly heated and evaporated. The momentum exchange resulting from this vaporization creates a high-amplitude shock wave which propagates through the material, producing internal atomic defects in the material's structure. These defects harden and strengthen metals. A potential application of the research was demonstrated during the first 2 years' work when soft weld zones in a common structural aluminum alloy (5086-H32) were shock strengthened to values approximately equal to those of the as-received (non-welded) material. The key laser and material parameters governing the generation and propagation characteristics of such stress waves and the subsequent

property changes are being investigated by Allen Clauer and Barry Fairand of Battelle.

Theoretical studies employ a one-dimensional radiation hydrodynamic computer code, the first of its kind, that takes account of temperature- and density-dependent ionization effects in the plasma created at the metal's surface. The principal energy transport processes accounted for in the code are thermal conductivity, radiation diffusion, and radiation. The computer model also accounts for the hydrodynamic attenuation of the stress wave as it propagates into the material. The code predictions have been compared to experimental measurements of pressures generated by using different specimen surface and laser beam conditions. These theoretical calculations have proven to be in good agreement with experimental measurements and predict that pressures greater than 100,000 atmospheres can be generated in metals and alloys at a modest expenditure of laser energy.

The materials studied so far include aluminum alloys and an iron-3% silicon alloy, which was chosen because it can be readily etch-pitted to show the magnitude and distribution of plastic deformation.

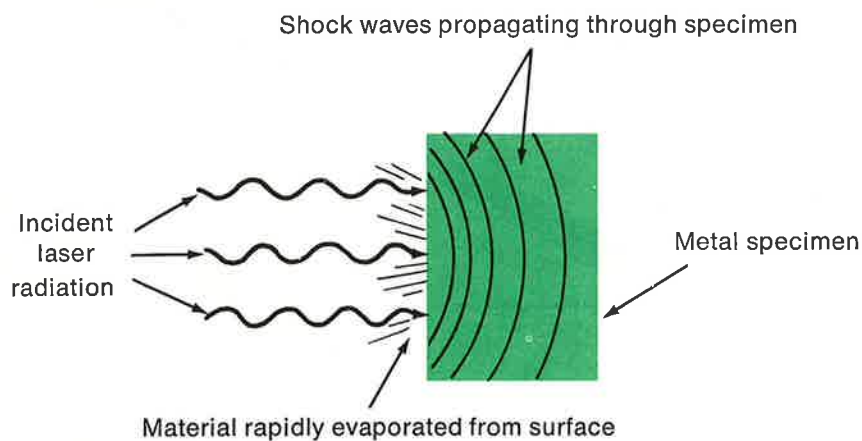
Metallographic analysis has demonstrated that significant plastic flow can be generated in 1-centimeter-diameter discs of iron-3% silicon by the stress wave produced by a high-power laser pulse and that the intensity of the deformation generated is consistent with the computer code predictions of the stress wave amplitude and duration. The intensity of this deformation is sufficient to shock-harden throughout sections of the material up to 1-millimeter thick.

It has been found that the specimen surface condition plays an important role in determining the magnitude of laser-induced shock pressures. The combination of a coating of lead, which vaporizes readily, together with a quartz overlay, which momentarily confines the vaporized material, can increase the pressure amplitude by about 20 percent compared with a free surface.

Gravitational Effects in Quantum Mechanics

Scientists at Purdue University have succeeded in devising and carrying out the first known experiment that simultaneously incorporates the fundamental concepts of quantum mechanics and gravitation. The theoretical ideas were conceived by Albert W. Overhauser, and the experiment was conducted by Robert Colella, both of Purdue University, in collaboration with S.A. Werner of the Ford Motor Company. In what unquestionably will be regarded as one of the classic experiments in science, the relation between gravity and quantum mechanics has been demonstrated conclusively.

Gravity, the attractive force between two masses, is normally associated with large bodies, such as those of the solar system, or with macroscopic objects on or near the Earth. Quantum mechanics, on the other hand, deals with the properties of matter on the atomic scale. One of the basic principles of quantum mechanics is that all matter



A high powered pulsed laser can be used to induce shock waves in a metal or an alloy. The shock waves produce internal atomic defects in the material, resulting in hardening and strengthening of the metals.

possesses both wave-like and particle-like properties. According to this principle, electromagnetic radiation, such as a light wave, is composed of particles or quanta of energy. Conversely, particles such as neutrons, protons, and electrons exhibit a wave-like character. The wavelength of these particle waves is determined by their mass and velocity. Because gravitational forces on atomic size particles are almost infinitesimal—the gravitational attraction between an electron and a proton is 40 orders of magnitude smaller than the electrical attraction between them—the possibility of observing gravitational effects in quantum phenomena had never been seriously considered before.

The Purdue experiment consisted of passing a neutron beam through an interferometer constructed of nearly perfect, crystalline slabs of silicon. The incident neutron beam (or wave) was split into an upper and a lower beam as it entered the interferometer; each of the split beams followed a different reflected path among the slabs. Sensitive detectors measured the intensity of the recombined neutron waves as they exited the interferometer.

In the initial experimental configuration, the upper neutron wave is at a higher potential energy in the Earth's gravitational field than the lower wave. As a consequence, the Purdue scientists predicted and observed that the relative phase of the two waves was shifted with respect to each other. When the two waves arrive in phase at the detectors, a maximum in the neutron intensity is measured; if the two waves arrive 180° out of phase at the detector, they interfere destructively, and a minimum in the neutron intensity results. If the instrument is rotated around an axis parallel to the entering and exiting beam, the relative phase shift changes. At 90° rotation, the two beams are in a common horizontal plane and are gravitationally equivalent. Consequently, the relative phase shift is zero. The illustration shows the

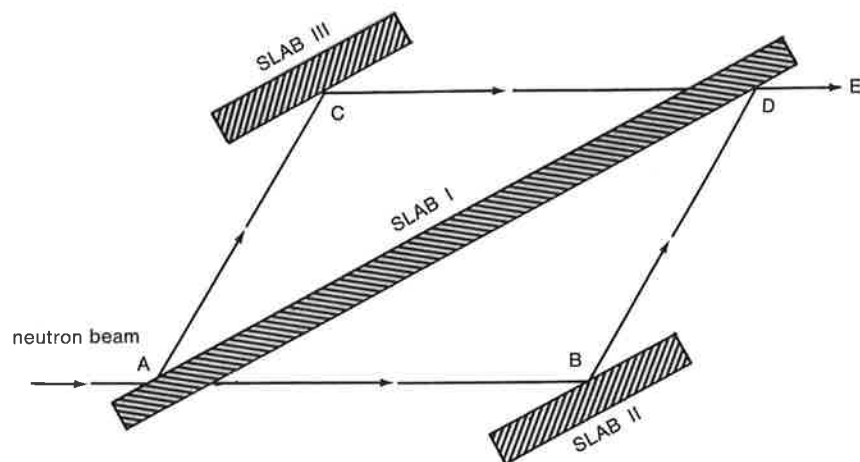
actual results of the experiment in which the neutron intensity measured by the detector is plotted as a function of angle of rotation of the interferometer. The maxima in the curve occur when the phase shift in the waves is such that they interfere constructively; the minima occur whenever they interfere destructively. Within experimental error, the spacing of the oscillations in the curve is that predicted by the theory.

Electron-Hole Drops in Germanium

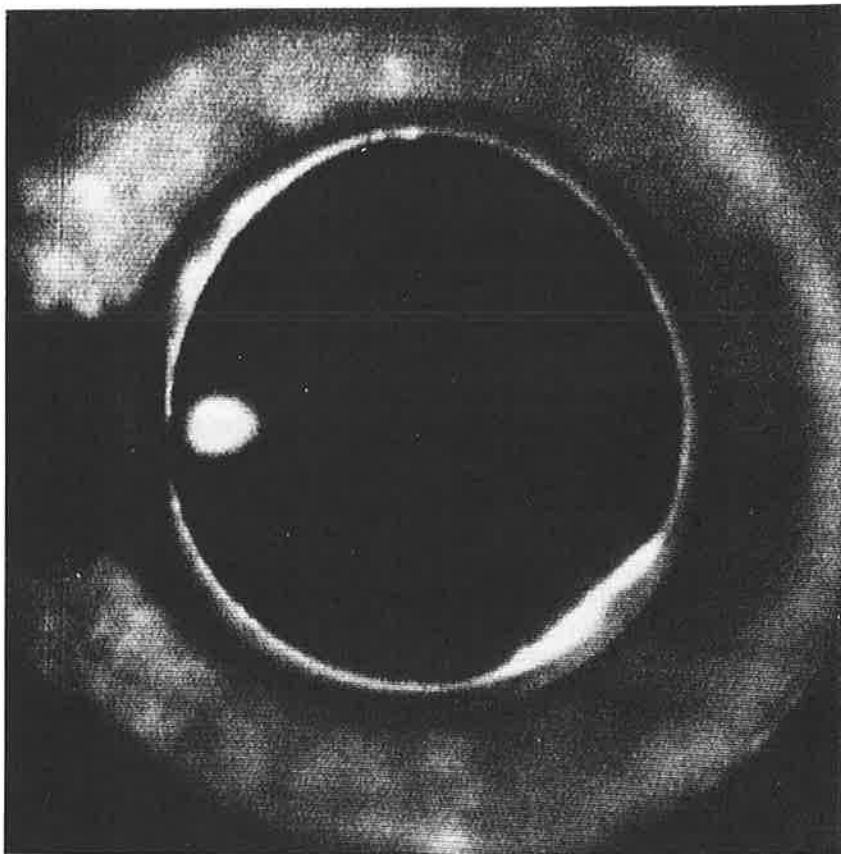
Scientists at the University of California, Berkeley, have succeeded in obtaining photographs of electron-hole drops in a single crystal of the semiconductor germanium. Electron-hole drops are a new state of condensed matter in which a plasma, or gas of negatively charged mobile electrons, and an equal number of positively charged mobile holes condenses into a spherical drop in a manner analogous to that in which water vapor condenses into a raindrop. The electrons and holes which

form these drops are not normally present in pure semiconductors at low temperatures, but must be created by some means of excitation such as an intense laser beam. They live for a fraction of a second and then decay by mutual annihilation of electron-hole pairs. In the process of decaying, the electron-hole pairs within the drop emit a characteristic burst of light, which for germanium lies in the infrared portion of the spectrum. It is this self-emitted radiation or luminescence which permits the drops to be photographed.

The existence of electron-hole drops was first proposed by L.V. Keldysh in 1968 to explain the observation of a sharp increase in the electrical conductivity of germanium when illuminated with infrared radiation above a critical threshold in intensity. These experiments, conducted by A. Rogachev at the Ioffe Institute in Leningrad, generated strong scientific interest, since they appeared to involve a new state of condensed matter. Subsequent experimental and theoretical investigations carried out in the United States and elsewhere in the world established the plausibility



In an ingenious interferometer experiment to observe gravitational effects at the sub-atomic level, a neutron beam is split at A and recombined at D. With the two beams in a vertical plane, the difference in their respective levels of potential energy in the Earth's gravitational field causes a relative phase shift of the two waves with respect to each other. With the apparatus rotated so that the beams are in a common horizontal plane and gravitationally equivalent, no relative phase shift is detected.



Direct observation of an electron-hole drop in germanium is documented in this photograph taken at the University of California, Berkeley. Such drops were first postulated in 1968 as a new state of condensed matter. The phenomenon had been accepted theoretically, but this was the first direct observation.

that electron-hole drops could be generated in germanium at low temperatures. However, prior to the Berkeley work, no one had successfully observed such a drop directly.

The scientists who obtained these photographs included James Wolfe, Robert Markiewicz, Charles Kittel, and Carson Jeffries of the Berkeley

physics department, as well as William Hansen and Eugene Haller of the Lawrence Berkeley Laboratory. They succeeded in producing relatively large and long-lived drops, which could be photographed by applying a non-uniform stress to a one-sixth-inch disc of single crystal germanium (light ring in photograph) immersed in liquid helium near absolute zero in temperature. By using an infrared television camera and optical filters they were able to observe the luminescence from a drop which condensed near the point of maximum stress (bright spot about one-hundredth-inch-diameter to the left of center in the photograph). In unstressed germanium they observed a weaker and more diffuse image which could arise from a cloud of much smaller droplets.

To date, most of the research on this new state of condensed matter has been done with the semiconductor germanium as the host medium. This is perhaps appropriate since germanium was also the model semiconductor for the development of the concepts which led to the transistor. The understanding of the phenomenon of electron-hole drops in semiconductors is still at the conceptual development stage. The phenomenon is well enough understood to predict that it should occur in a large class of semiconductors other than germanium; however, the full richness and variety of the physical behavior of the electron-hole plasma are yet to be revealed.

COMPUTER RESEARCH

The discipline of computer science is barely 10 years old, only vaguely defined, and mushrooming. In these formative times, NSF's Computer Research program is guided by two imperatives: to nurture computer science as a discipline, and to enhance the Nation's basic research

potential by the development of new tools through computer science. Several examples of research conducted along these lines are discussed on the following pages.

In a field as new and as rich as computer science it is not surprising that new areas appear, create a flurry

of activity, and then level off or stagnate; automata theory, mechanical translation, and theory of formal languages are a few such. It is not that these areas may not need development, but researchers in computer science are anxious to follow new leads into uncharted

regions. This kind of progress—a process of extension to new areas and pruning of less productive ones—partly accounts for the lack of definition of the field. For this reason, it is important, from time to time, to stand back to see where computer science has been, where it is going, and what lessons are to be learned. While this would be easier in an established discipline, it is more useful in one that is not.

Such a disciplinary self-examination is now under way; it is being guided by Bruce Arden of Princeton University, and it is expected to take 3 years. Its purpose is to assess the discipline itself—not to examine the impact of computers in other areas. No attempt will be made to define computer science except by inclusion of analyses of areas which are putative parts of the discipline, have a large overlap with it, or seem to have other intimate connection with the intellectual activities of those who call themselves computer scientists. The subfields will be examined for past accomplishment, present status, trends, objectives, relation to other subfields, and such statistical matters as numbers of participants, growth, and funding levels. It is hoped that these data will give some notion of the intellectual health, resources, and coherence of the entire discipline.

There appears to be a consensus among those with an overview of computer science that there have been significant changes in our way of thinking about computer systems in the past few years. These changes have occurred on the theoretical side, in software systems, and in architecture; indeed part of the change has been the dissolution of boundaries between these areas. The confluence of activities in such formerly diverse areas as the theory of algorithms, structured or "top-down" programming, and high-level-language machine architecture points up a need for a coherent national program to focus individual activities on a higher and now visible objective.

The Foundation's three programs in computer science and engineering are complementary efforts, strongly interdependent, and sensitive to this need. Complexity classes, theoretical bounds on algorithms, non-procedural languages, and an integrated approach to design all move toward organizing complexity and freeing the field from the restraints of current technology. Progress in theory has been especially rapid due to the stimulus of aggressive young investigators who have introduced new concepts and new tools. That ferment and excitement will continue to build as the field gains population and strength.

But great untapped opportunities still lie in programming languages and related system design. Recent developments like those reported by Jacob Schwartz at the Courant Institute of Mathematical Sciences, New York University, place us on the threshold of breaking an existing complexity barrier by providing executable languages of great expressive power. Dr. Schwartz has demonstrated a prototype that shows the way, provided we can build the hardware and software systems necessary to carry such languages beyond the stage of executing only "toy" programs. An integrated effort—highly experimental in style and comprising both hardware and software research—is indicated. A sustained effort could produce rich benefits both to basic computer science research and to computer applications and technology.

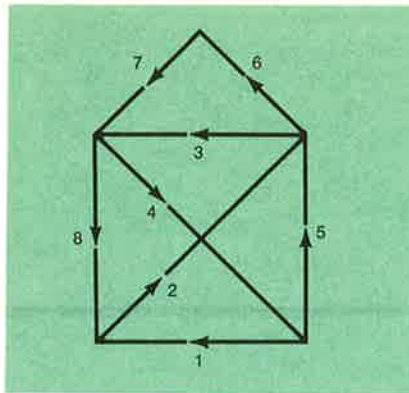
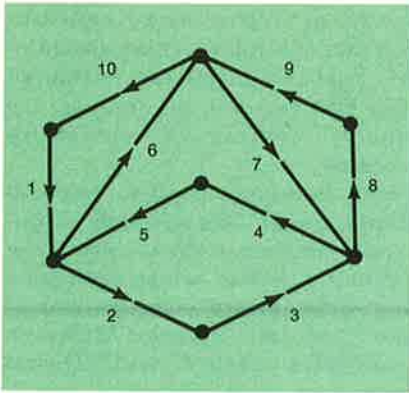
NSF's programs in computer applications in research have as their common goal the advancement of research methodology through the use of computer science and technology. The three programs—Techniques and Systems, Software Quality Research, and Networking for Science—are closely related. All have a foundation in computer science and technology, and all require an understanding of the needs of researchers in the various disciplines. This concentration of programs in one place provides an

opportunity to maintain a perspective over all disciplines. Among projects currently supported, Thomas E. Kurtz at Dartmouth College and Philip M. Morse at MIT are guiding a cooperative effort involving over 40 colleges and universities to conduct research and experimentation into governance and facilitating methods that will promote a general-purpose network for computer services for research and education. The principal emphasis is on exploring and evaluating organizational considerations underlying this mode of resource sharing. At the University of California, San Diego, Kent R. Wilson is directing a project to demonstrate the practicality and usefulness of a multilevel hierarchical computing system for research laboratory automation and scientific modeling. And research at Texas A&M University by R.E. Fairley and his associates includes the development of a special interactive system for modeling the execution of computer programs. The system provides a variety of modeling tools to facilitate interactive program testing, machine-aided documentation, and on-line familiarization of prospective users with new programs.

Assessing Complexity

There is a familiar children's game in which the task is to draw a square, cap it with a triangle, and inscribe its two diagonals without either lifting the pencil from the paper or going over any path a second time. Computer scientists employ a similar drawing; it is an example of the concept of computational complexity which, during the last decade, computer scientists have defined and come to recognize as an idea fundamental to their discipline and rich in ramifications.

In the scientists' example, consider the question whether there exists a closed path (i.e., a path that returns to its starting place) that traces each



The drawing on the left is something like the familiar children's game (right) in which the task is to draw a square, cap it with a triangle, and inscribe its two diagonals without either lifting the pencil from the paper or going over any path a second time. The first drawing is not a game, however; it is an example of the concept of computational complexity which, during the last decade, computer scientists have defined and come to recognize as an idea fundamental to their discipline and rich in ramifications.

edge exactly once. (In the children's puzzle, one need not return to the starting point.) Such a path is called an Eulerian circuit. The question is an easy one, and its ease is summarized in a general theorem which says such a path exists in any graph if and only if each vertex has an even number of edges leading to it. One needs only to check each vertex once to get the answer. One says that problem requires order "N" steps where "N" is the number of vertices.

Now consider whether there is a closed path which meets each vertex only once. Such a path is called a Hamiltonian circuit, and no one knows an easy way to solve for it. In general, one must test each possible path, a process requiring a very large number of steps.

The measure of difficulty, the number of computation steps needed to solve a problem, is called complexity and is now recognized as an intrinsic characteristic of every problem. Furthermore, there are usually several ways to solve any problem, some good, some bad: The best way takes no more work than necessary, but a method cannot be tested for that property unless the intrinsic complexity of the problem

itself, i.e., the theoretical lower limit, is known.

The limit has been discovered for some problems and research is under way on others. In those cases where the answer is known, existing programs can be compared to the theoretical limit to see how well the problem-solving procedures work, and improvements can be sought if the procedures are deficient. Such research is yielding substantial benefits in practical problem-solving situations.

In some cases it has been shown that there is no good solution; the problem is intrinsically very complex if one insists upon a single procedure that solves it for every possible value of the input data. In those cases, researchers are looking for procedures which give good approximate results, or which solve the problem in almost all useful cases. Possibly different procedures are required for different values of the input data, one for small values, another one for large values, for instance.

In still other cases, the fact that some problems which seem very different have the same complexity has led scientists to recognize

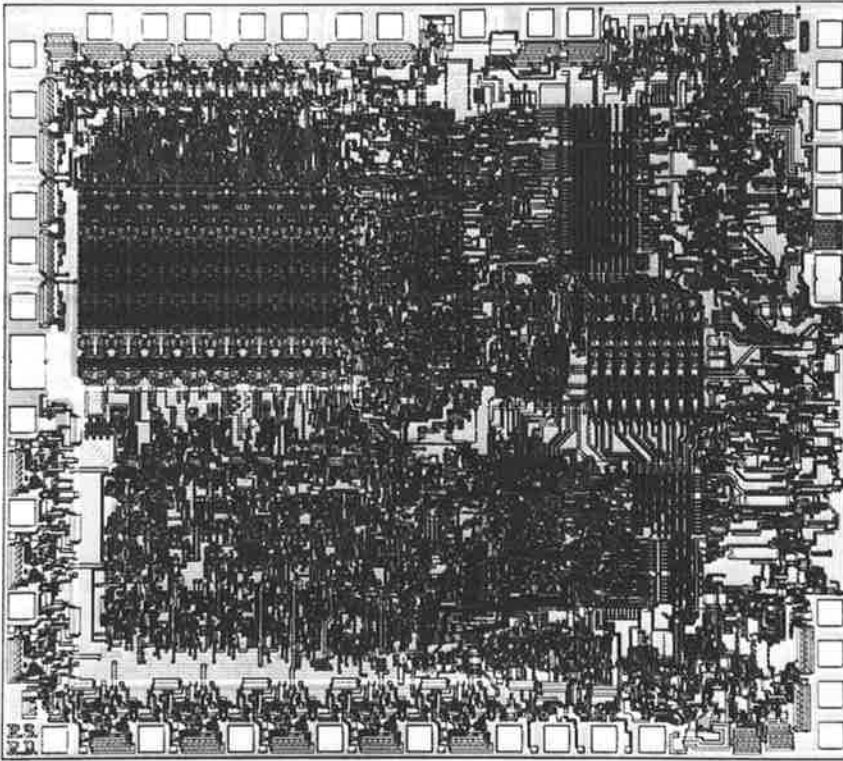
similarities which had not been observed before. When that is true, one problem can be transformed into the other, and if better methods are discovered for solving one, they will work for the other one also.

These are only a few of the ways in which this fundamental concept is influencing computer science, leading to a deeper understanding of problems, problem-solving procedures, and computers. Because of its significance it has become a stimulus for additional research and also an inspiration for further progress.

Architecture

The revolution in the manufacture of electronic circuits that began with the invention of transistors has now proceeded so far that thousands of transistors, diodes, and other components can be built into single wafers of semiconductor material that are a few centimeters in diameter. Recently, complete computer processors called microprocessors, which include arithmetic, logic, and memory, have been built into single wafers; several electronics firms are now offering such microprocessors as standard products. As manufacturing techniques improved and demand increased, prices of microprocessors were reduced enough so that their use could be contemplated in automobiles, appliances, flow meters, and a host of other applications in which they will provide greater convenience, reliability, safety, and economy of operation.

Improving products for various applications is primarily a function of industry. However, microprocessors also inspire new ideas that require research. For example, microprocessors can be used as building blocks in the design of new computers, each computer consisting of several or many microprocessors interconnected to form cooperating families that share input data, in-



There are more than 4,500 transistors in an area 4.2 by 4.8 millimeters in this 8-bit microprocessor integrated circuit made by the Intel Corporation. Microprocessors, already on the market, create significant new possibilities for increasingly flexible computer architectures. [Photo by Intel Corporation]

intermediate results, and control. This additional flexibility in design offers hope of overcoming limitations in the use of sequential computers for

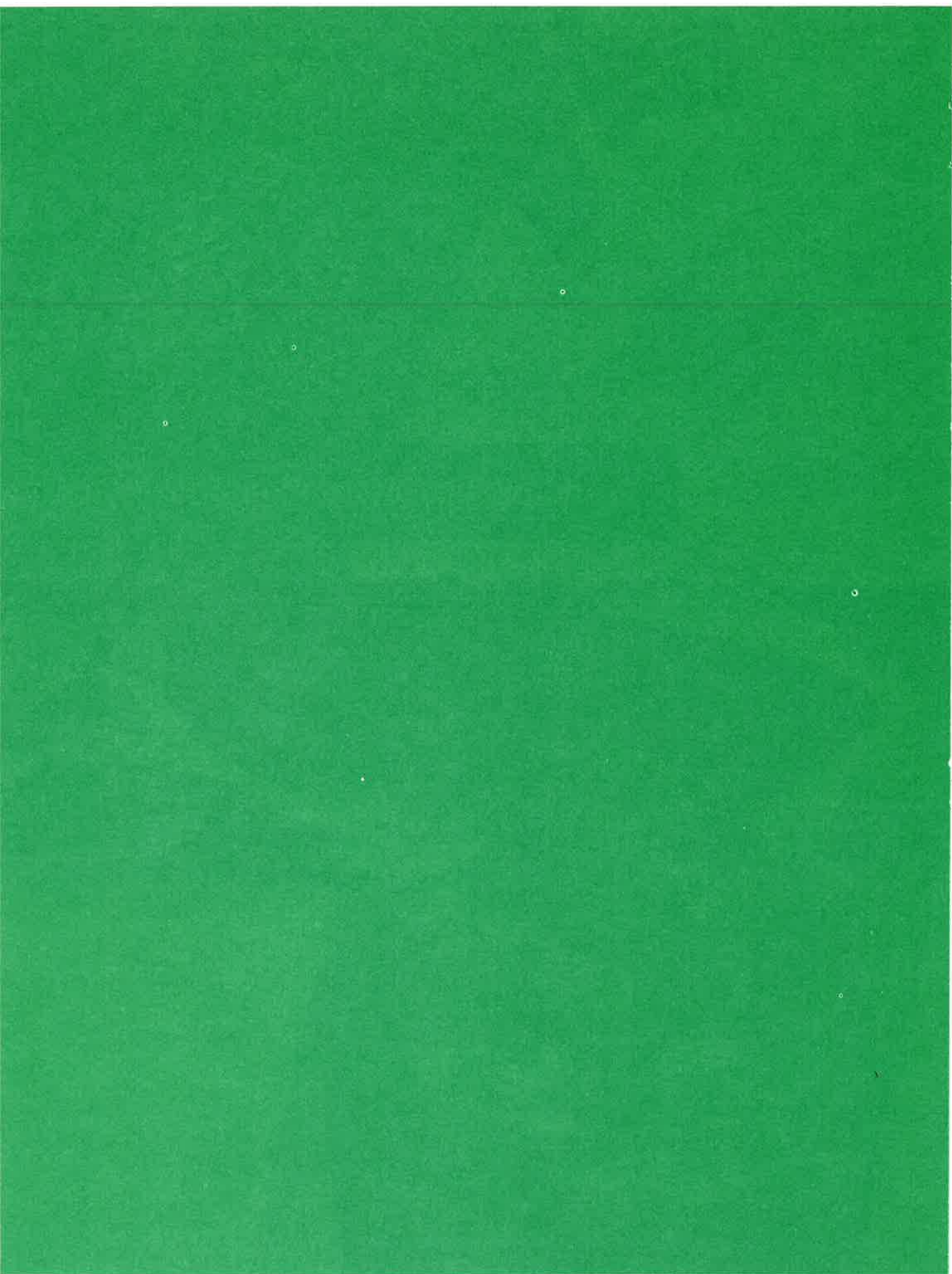
complex problems by subsuming some of the complexity of large systems into the architecture of the machine itself, leaving the user free

to work at a higher level of organization and control. Machine design of this kind is a completely uncharted field that requires the free ranging inquiry typical of university research.

NSF is supporting two research efforts, one at Carnegie-Mellon University and one at the University of California, Irvine, which are taking first steps toward investigations of this type. At Carnegie-Mellon a cooperative project with Digital Equipment Corporation is under way. This effort is a simulation study of a chain of computer models, each containing a processor and local memory, in order to investigate the architectural and programming possibilities such an arrangement may provide. At Irvine, a group is experimenting with an arrangement that interconnects several small computers by a communications loop in order to pass coded messages of data or instructions among the computers to facilitate simultaneous computation toward a common goal. It is expected that experience from these studies will lead toward arrangements using large numbers, possibly hundreds, of microprocessors, with much greater flexibility in organization. In fact, the Carnegie-Mellon group is planning a 100-module implementation project as a followup to the NSF-supported simulation project.



National and International Programs



National and International Programs

National and International Programs group a number of coherent activities that have specific missions in addition to their basic research objectives. Most of the programs have strong international implications; several include large logistics components; and all include elements of interagency coordination. In several cases, the programs resulted from the assignment to the Foundation of a "lead agency" role, or the Foundation's assumption of such a role in specific areas.

Several scientific fields or disciplines have seen a rejuvenation in recent years, and NSF's National and International Programs have contributed materially to the spectacular discoveries that have been made in such fields as geology and astronomy.

The theories of plate tectonics and continental drift received new impetus through conclusive data obtained from core samples drilled by *Glomar Challenger* as part of the Ocean Sediment Coring Program (OSCP). Among the major discoveries of OSCP scientists during the past year was evidence that the early Atlantic, when it was only a rift between Africa and South America, consisted of a series of freshwater lakes. Only when South America slid west of the bulge of Africa and the

lakes became permanently connected to the ocean did a true marine environment develop.

Projects of the International Decade of Ocean Exploration (IDOE) also contributed to the study of plate tectonics and other problems in marine geology. Of particular note was work along the east and west coasts of South America and in a rift valley of the Mid-Atlantic Ridge. Direct observations by submersibles in the latter study showed that the boundary between tectonic plates consists of fissures, down-faulted blocks, and volcanic features that exhibit tension as the plates move apart. IDOE projects have also contributed significantly to the identification of marine geological structures normally associated with petroleum formations and concentrations of various metals.

Astronomy in recent years has seen a string of new discoveries and theories. In particular, radio astronomy has provided new insights into the structure of the universe and has confirmed the existence of previously unknown celestial bodies and interplanetary media. Much of this research has been conducted using the passive radio telescopes of the National Radio Astronomy Observatory. A

significant milestone in instrumentation upgrading was the completion of the resurfacing of the 1,000-foot-diameter antenna of the National Astronomy and Ionosphere Center at Arecibo, P.R. This upgrading increased by a thousandfold the planetary ranging and mapping capability of the telescope. The NASA-sponsored 450-kw S-band transmitter was also installed during the past year. Fine-tuning of the alignment of the new antenna surface will further increase the upper limit of the frequency range of the Arecibo instrument. Construction of the Very Large Array on the Plains of San Augustin in New Mexico continued on schedule. This major instrument, when completed in a few years, is expected to open new vistas in radio astronomy.

National and International Programs also support major activities in the atmospheric sciences, among them the National Center for Atmospheric Research at Boulder, Colo. A new program in climate dynamics made its first grants in fiscal year 1975, using funds reprogrammed from other activities. The program focuses increased attention on climate variations, a factor of crucial importance to man's future.

NATIONAL AND SPECIAL RESEARCH PROGRAMS

A number of NSF's major research programs are of such a nature that their success requires extensive planning, management, funding, or logistics. Various factors may influence those requirements, including international cooperation, coordination with other agencies of Government, a relationship to a specific geographical region, and interdisciplinary scientific in-

vestigations. Activities in these National and Special Research Programs during fiscal year 1975 are described on the following pages.

GLOBAL ATMOSPHERIC RESEARCH PROGRAM (GARP)

For a long time, meteorologists have sought to learn more about the

tropics—regions which receive half of the solar energy that reaches the Earth, driving the general circulation of the atmosphere. Prior to the GARP Atlantic Tropical Experiment (GATE), however, they were frustrated in their studies of the transfer and transformation of that energy because of insufficient data from this sparsely populated area.

The single most important effort in

Table 3
National and Special Research Programs
Fiscal Years 1973, 1974, and 1975

(Dollars in millions)

	Fiscal year 1973		Fiscal year 1974		Fiscal year 1975	
	Number	Amount	Number	Amount	Number	Amount
International Biological Program	30	\$9.20	36	\$8.82	—0—	—0—
Global Atmospheric Research Program	55	3.45	51	3.86	70	\$4.04
Climate Dynamics	—0—	—0—	—0—	—0—	10	1.00
International Decade of Ocean Exploration	92	16.94	116	13.79	147	14.78
Arctic Research Program	62	3.43	46	3.87	32	3.63
U.S. Antarctic Research Program	130	*44.00	110	24.74	132	25.90
Oceanographic Facilities and Support	62	10.99	86	18.23	79	20.64
Ocean Sediment Coring Program	24	9.59	8	11.08	6	10.50
Solar Eclipse Support	10	.68	1	.04	0	0
TOTAL	465	\$98.28	454	\$84.43	476	\$80.49

* Includes Supplemental Appropriation of \$19.74 million for procurement of three ski-equipped aircraft.

GARP during fiscal year 1975, then, was the successful implementation of this GATE field phase—the largest and most complex international scientific experiment ever undertaken.

Preliminary scientific results of the project indicate that GATE will provide significant new insights into the life cycle of tropical convective clouds and large-scale atmospheric waves and their interaction with each other. Among the unexpected initial findings were observations of a rapid latitudinal meandering of the equatorial undercurrent (a subsurface, fast moving, eastward flowing current) and evidence that massive layers of Saharan dust sometimes spread across the entire tropical Atlantic.

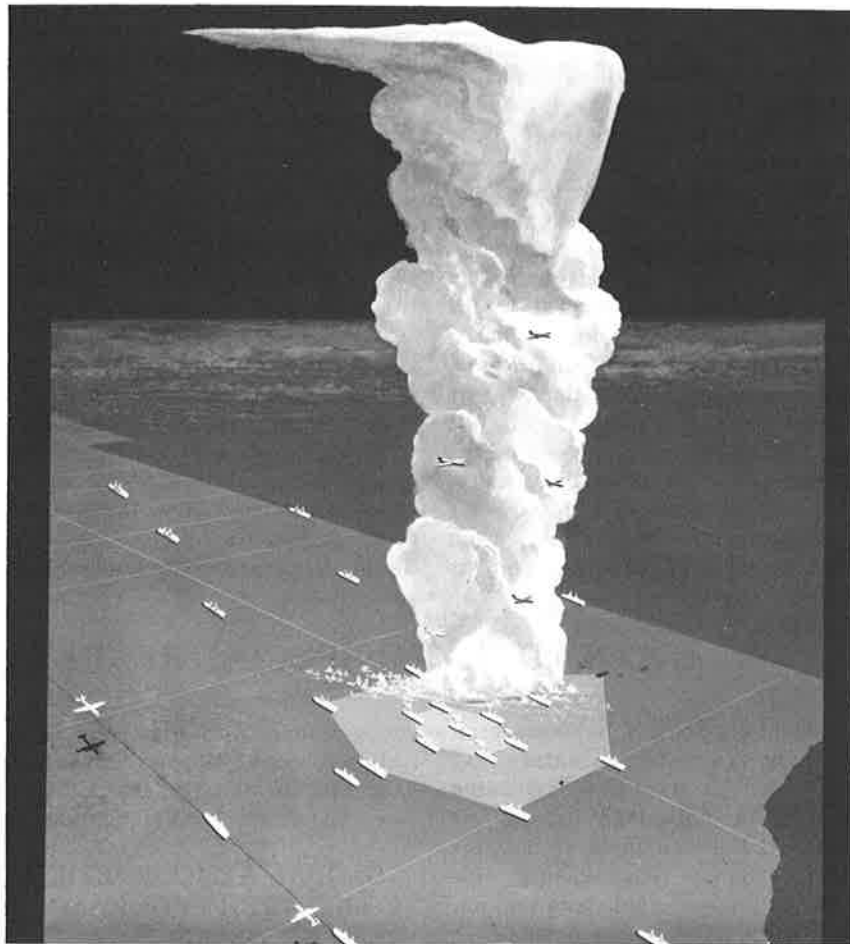
During fiscal year 1975, NSF awarded 35 GATE-related grants in support of approximately 40 participating U.S. university scientists. Moreover, a special project, in cooperation with the National Center for Atmospheric Research (NCAR), placed 46 students (from 27 educational institutions) on U.S. GATE ships as meteorological observers.

International cooperation was consistently high during the experiment. At the Operational Control Center located in Dakar, Senegal, U.S. and U.S.S.R. radio technicians stood joint watches. Scientists involved in the aircraft observational program flew

joint missions. After the close of field operations in September 1974, the scientists of the participating nations

continued to exchange their observations. One paper, jointly written by oceanographers from the United States, the U.S.S.R., the German Democratic Republic, the Federal Republic of Germany, and the Ivory Coast, has been submitted for publication. Analyses and interpretation of data from GATE will continue for many years, with the largest share of that responsibility in the United States resting with the academic community and supported by NSF.

Another notable GARP effort completed successfully during fiscal year 1975 was the second field phase of the Air Mass Transformation Experiment (AMTEX). AMTEX aims at describing and understanding the



In the GARP Atlantic Tropical Experiment (GATE) in the summer of 1974, aircraft and ships were deployed to obtain data on tropical weather systems.

physical processes involved when cold, dry air travels from over a continent (in this case, Asia) to over warm water, becoming a warm, moist air mass. The energy and mass exchanges involved in the transformation are fundamental processes accounted for in modeling the general circulation of the atmosphere. This experiment, performed over the East China Sea, was designed and carried out primarily by Japanese scientists, with Australia, Canada, and the United States also participating.

CLIMATE DYNAMICS PROGRAM

It is clear that there is an urgent need to expand our knowledge of the worldwide processes governing changes in climate. The Sahel

drought and Soviet wheat crop failures dramatically demonstrated the frailty of human ecological systems when confronted with major climate disturbances.

In May 1974, the Foundation established a Climate Dynamics Program whose purpose is to improve understanding of global climatic processes and to assess the impact of climate variations on human affairs. During fiscal year 1975, funds were reprogrammed into this activity, and ten grants were made for climate-related research in geochemistry, oceanography, geology, meteorology, and palynology.

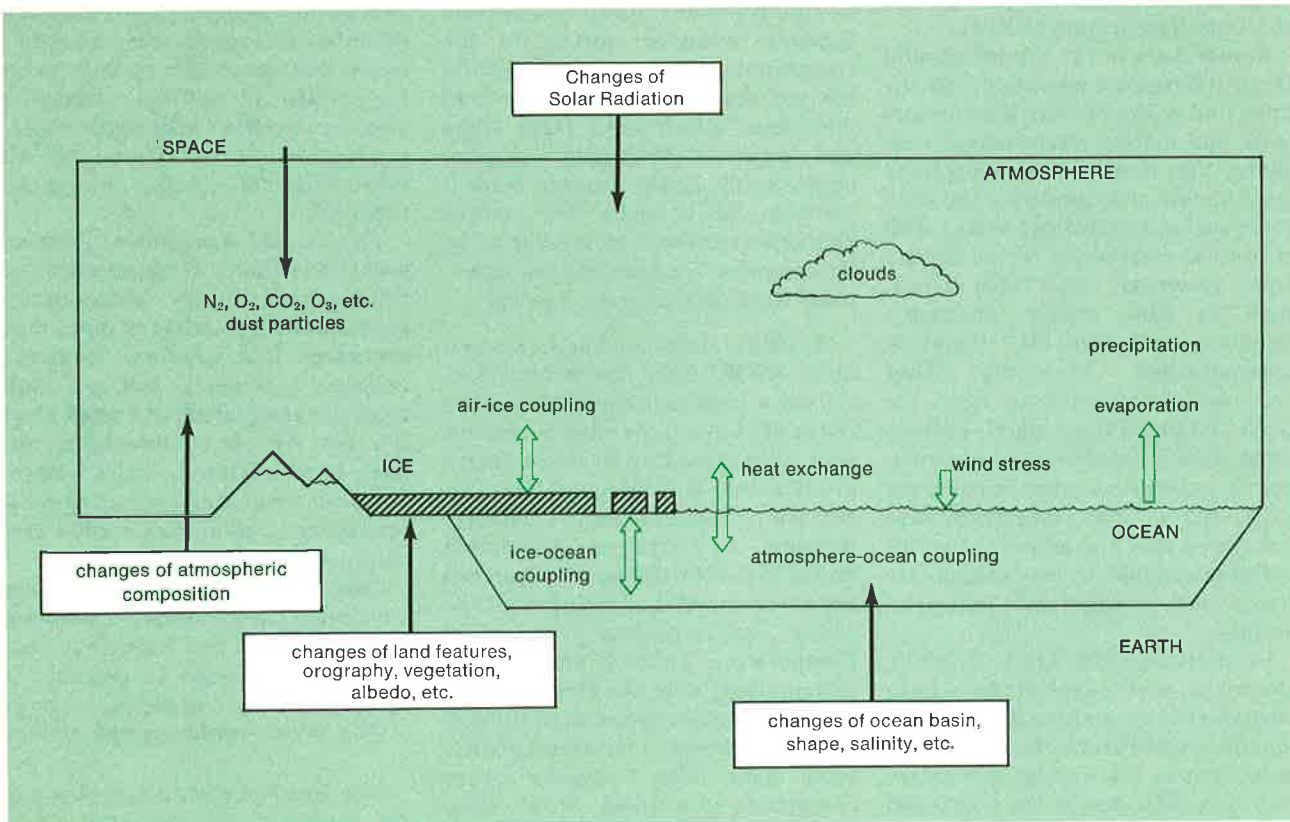
The program emphasizes the following areas:

- Climate data assembly and analysis—Both present and past

climate data are stored in archives which receive information from many sources around the globe. Data from these reserves will be sorted and analyzed by modern computer methods.

- Climate index design, monitoring, and forecasting—The Climate Dynamics Program will search for prewarning indexes of climate change—both short-term and long-term. At periodic Climate Diagnostic Symposia, scientists will analyze the present climate and indicate implications for the future.

- Climate simulation and prediction—The Climate Dynamics Program will sponsor research and experimental application of climate models. Although development of climate models is limited by absence



In this representation of factors involved in the coupled atmosphere-ocean-ice-earth climatic system, solid arrows indicate processes that are external to the system, and open arrows are examples of internal processes in climatic change.

of suitable data and adequate computer resources, answers to many pressing questions regarding climate may be obtained only by simulations. Eventually it may be possible to forecast climate by operating such models.

° Climate impact assessment—Research on the human ecological aspects of climate, including the response of society to predictions of climate change, will be an important element of the program.

INTERNATIONAL DECADE OF OCEAN EXPLORATION

A number of major field experiments have been completed and new findings published by scientists in the Environmental Quality, Environmental Forecasting, Seabed Assessment, and Living Resources Programs of the International Decade of Ocean Exploration (IDOE).

Researchers in the Environmental Quality Program who analyzed the rates and paths by which pollutants enter the marine environment concluded that most of the atmospheric trace metals measured over the open ocean and in Antarctica are the result of normal weathering of the Earth's crust. However, some trace metals, such as zinc, copper, antimony, selenium, and lead, are found in concentrations exceeding those predicted as originating from the crust. Although these metals seem to come from normal volcanic sources, human activities cannot be ruled out as a source. The researchers also concluded that the major routes for pollutant transfer to coastal areas are rivers and sewage and industrial outfalls.

In addition, PCB, DDT, dieldrin, chlordane, and toxaphene have been identified in the air near Bermuda. Of the chlorinated pesticides, toxaphene is present in the highest concentration, possibly due to the continued agricultural use of this pesticide or to its higher vaporization rate (25 times that of DDT). The most obvious source of toxaphene in the marine

atmosphere comes from winds blowing off the southern United States, since toxaphene is almost exclusively used in the South, on cotton.

In the Controlled Ecosystems Pollution Experiment, plastic cylinders suspended in the waters of Saanich Inlet, Victoria, British Columbia, are providing controlled environments for studying the effects of persistent low-level exposure to pollutants on communities of marine organisms. Full-scale enclosures (10 meters by 33 meters) successfully completed 90-day endurance and engineering field tests and are now ready for experimental use.

Projects supported by the Environmental Forecasting Program seek to provide the basis for improved and extended forecasts of weather, climate, and ocean circulation. Scientists of the International Southern Oceans Study completed a 3-month synoptic survey of the Circumpolar Current in the Scotia Sea and the Drake Passage. The field operation, which used three ships and 13 current meter moorings placed across the Drake Passage, made it possible to describe the unique characteristics and variability of the Circumpolar Current and its movement through the Drake Passage.

As part of the North Pacific Experiment (NORPAX), researchers conducted a field experiment 900 miles north of Hawaii, the first in a series that will culminate in an intensive study aimed at finding out how sea-surface temperature anomalies develop. A multilayer simulation model of the North Pacific Ocean has been developed that includes all the major environmental parameters (temperature, salinity, and velocity distribution) over the North Pacific Basin. In another aspect of NORPAX, field experiments confirmed predictions made some 7 months earlier concerning the onset of El Niño conditions in the eastern tropical Pacific. When these conditions occur, nutrient-rich cold waters flowing northward past the South American

Continent move farther off shore than usual, causing severe disruption of fish and bird populations.

The successor to the Mid-Ocean Dynamics Experiment (MODE), called POLYMODE,* is being planned, organized, and conducted jointly by U.S. and Soviet scientists. It will seek to determine the energy source and number of mid-ocean eddies. Before POLYMODE begins, a comparison will be made of the features of the MODE-I area and the proposed POLYMODE site to ensure that data collected from the two areas will be comparable. This study will continue until the start of the intensive field experiment scheduled for 1977.

During fiscal year 1975, geologically based data (estimates of sea surface temperature, sea level height, extent and thickness of glaciers) from the Climate Long-Range Investigation, Mapping, and Prediction (CLIMAP) Program were used in a numerical simulation of the climate for the last ice age. This simulation was then verified with another set of geological data from pollen, mineralogical, and periglacial material.

The Seabed Assessment Program seeks to evaluate the resource potential of the sea floor by identifying and refining understanding of the natural processes that produce metal-rich nodules, petroleum, and gas. Data from the completed field work along the west African continental margin have been analyzed, and a number of new structures typical of those formed in large oil fields have been mapped.

Comprehensive geophysical surveys have been completed along the coasts of Brazil and Argentina. Data analysis has made it possible to update and improve geological maps of the areas bordering the eastern

* The term POLYMODE is derived from the names of the successful Soviet POLYGON Experiment and the United States MODE-I effort, both of which sought to identify the features of medium-scale eddies.



Tubular or "toothpaste" lava lies at 1,050 fathoms in the axial valley of the Mid-Atlantic Ridge. The tube, roughly 1 foot in diameter, is probably less than 10,000 years old. The camera is looking directly down at the tube, which has erupted vertically from the sea floor to a height of 2 to 3 feet and then broken off from its stump at the lower right. [Photo by J.D. Phillips, *Oceanus Magazine*]

Ocean Undersea Study (Project FAMOUS), supported by both IDOE and NSF's programs in environmental sciences, scientists used submersibles for direct observation of the geological processes in a rift valley of the Mid-Atlantic Ridge. Mid-ocean ridges are the most extensive morphologic features on the surface of the Earth. Within the framework of plate tectonics, they represent the diverging or accreting margins of the plates. Much of the knowledge concerning these zones of accretion and the tectonic and volcanic processes that form them comes from the extensive use of sophisticated and expensive tools such as deeply towed instruments, ocean-bottom seismometers, and research submersibles. During the recently completed project in the summer of 1974, scientists aboard the U.S. submersible *Alvin* inspected the floor of the Mid-Atlantic Ridge rift valley, collecting data and samples of water, sediment, and rock. Additional data and samples were obtained by French scientists with their submersibles *Archimede* and *Cyana*. The observational data obtained by these diving scientists, coupled with a wealth of bottom-photographic, side-scan sonar and detailed bathymetric data from surface ships and deep-towed instruments, have shown that the boundary between the tectonic plates is marked by a rough, sediment-free, nearly continuous ridge which extends along the center of the rift-valley floor and on which most volcanic activity takes place. Near vertical faulting is shown to be the principal process forming the rift valley walls, with extensive talus slopes at their base. Numerous fissures in the valley floor tend to increase in width relative to their distance from the center of the valley floor. The nature and number of these fissures indicate that away from the central, volcanically constructed ridge, tectonic processes predominate.

South American continental margin. Comparison of data from both sides of the South Atlantic will enable scientists to reconstruct the early stages of the opening between South America and Africa and identify geological conditions favorable for

producing oil. Scientists from several institutions are also analyzing available data in preparation for a geological and geophysical survey of the east and southeast Asian continental margins in fiscal year 1976. In the French-American Mid-

The Living Resources Program focuses on understanding coastal

upwelling ecosystems in order to develop predictive models as a scientific basis for improved management and use of the ocean's living resources. Data analysis from the extensive JOINT-I experiment off northwest Africa is continuing and will be compared to the results of earlier upwelling studies off the Oregon and California coasts. Preliminary results suggest that precise description of water movement outside an upwelling region is essential for a proper description of the total upwelling circulation, and that this outer motion may be strongly affected by the shape of the Continental Shelf and slope. These findings will provide the basis for planning JOINT-II, scheduled for 1976 and 1977 in the distinctive upwelling region off Peru. Research will also continue in the Seagrass Ecosystem Study, which deals with the biological and environmental processes affecting the growth, reproduction, and distribution of rooted marine grasses. These grasses are important as a nursery for fisheries and as a potential receiver of pollutants released into the marine environment.

OCEAN SEDIMENT CORING PROGRAM

For the past 7 years, the National Science Foundation has sponsored the Deep Sea Drilling Project (DSDP) of the Ocean Sediment Coring Program. The DSDP is a program of reconnaissance drilling and coring in the sediments and uppermost basement rocks of the world's ocean basins to determine their composition, structure, and geologic history. Under an NSF contract, the University of California manages the project, subcontracting with Global Marine, Inc., for its ship *Glomar Challenger* to perform the actual drilling and coring. The Scripps Institution of Oceanography of the university is responsible for meeting the project's scientific objectives.

In August 1975, DSDP completed its third phase of operations since

drilling began in August 1968, with drilling completed at 393 sites in all the major deep water ocean basins and seas of the world. Forty-six of these sites were drilled in the North and South Atlantic Ocean and the Mediterranean and Black Seas in fiscal year 1975.

Drilling in the Atlantic on Legs 38, 39, 40, and 41 was designed to study the early geologic history of the Atlantic Ocean as it first began to form some 150 million years ago when the Americas started to separate from Europe and Africa. This program, which included the

first drilling effort conducted in the far North Atlantic (the Norwegian and Greenland Seas) and in the sediments of the continental margin along the west coast of Africa, has demonstrated that the early Atlantic consisted of a series of freshwater lakes much like the modern-day African Rift System. As these widened, deepened, and became intermittently connected to the sea, conditions in these basins rapidly fluctuated between fresh, brackish, and marine until finally South America slid west of the bulge of Africa and open ocean conditions



On Leg No. 42 of Deep Sea Drilling Project, an international team of scientists determined that the Mediterranean Sea is at least 65 million years old. This photo shows a core bit, part of the drilling equipment, aboard the ship *Glomar Challenger*.

prevailed. A very significant discovery was that conditions during this early period were ideal for the generation and emplacement of hydrocarbons.

During Leg 42, drilling was conducted for the first time in the Black Sea and for the first time since 1970 in the Mediterranean in an attempt to determine the ages of these basins and to clarify the discovery, made on Leg 13, that the Mediterranean was dry only 5 million years ago. From the results of this cruise, it has been found that the Mediterranean is at least 65 million years old and that the Mediterranean and Black Seas have only been intermittently connected. Somewhat unexpectedly, it was found that when the Mediterranean dried up some 5 million years ago, it did so very rapidly, almost catastrophically. A pressure core barrel designed to recover samples and return them to the surface for study under *in situ* pressures was

successfully used for the first time in the Black Sea.

In August 1975, a fourth phase of the DSDP, the International Phase of Ocean Drilling (IPOD), began with expanded international participation. Under an agreement signed with the U.S.S.R. in February 1974, the Soviet Union agreed to contribute \$1.0 million per year to the project for 5 years beginning in calendar year 1974.

The scientific objectives of the International Phase of Ocean Drilling are: (1) to determine, through deep basement penetration, the composition, structure, and geologic history of the oceanic basement beneath the sediments; and (2) through a limited program of continued sediment coring, to study the Earth's paleoenvironment. Scientific planning for the 3-year IPOD program was conducted throughout fiscal year 1975 by the Joint Oceanographic Institutions for Deep Earth Sampling.

Geophysical site surveys were completed in fiscal year 1975 or are currently under way for sites to be drilled during the first year of IPOD.

ARCTIC RESEARCH

The year-long main phase of the Arctic Ice Dynamics Joint Experiment began in March 1975. Four manned stations and eight pairs of unmanned data buoys were deployed over a large area of the Arctic Ocean ice 400 miles northeast of Point Barrow, Alaska, to collect data for study of ice deformation and ocean-atmosphere heat exchange. The objective is to develop predictive mathematical models for interactions of the ice-ocean-atmosphere system. An airlift in March and April established the camps; some 40 persons are conducting experiments through April 1976. In addition to the Foundation, other U.S. and Canadian



Ice deformation and ocean-atmosphere heat exchange are being studied at Big Bear, the main camp of the Arctic Ice Dynamics Joint Experiment (AIDJEX) spread out on the Arctic Ocean ice, 400 miles northeast of Point Barrow, Alaska.

agencies are active in the project, which is coordinated by the University of Washington.

The Greenland Ice Sheet Project is a cooperative effort with Denmark and Switzerland to investigate the chemistry, topography, dynamics, and climatic implications of the ice sheet. Last year surface geophysical and geochemical studies were completed on the southern dome, and a new wireline drill was tested; it will be used to drill through the Ross Ice Shelf in Antarctica in late 1975. A new Swiss drill obtained good ice core to 100 meters depth. The constituents of the core will be analyzed to help establish past climate variations.

Field work in a new project, Research on Arctic Tundra Environments, began in June. The project focuses on manmade stresses on the tundra and deep lakes of Alaska's North Slope. Ten research organizations conducted 15 interdisciplinary projects at and around Point Barrow in fiscal year 1975. Funding agencies include the Environmental Protection Agency and the Energy Research and Development Administration, in addition to the Foundation.

Man-in-the-Arctic, a University of

Alaska study of growth and development in Alaska, concentrated on economic and environmental policies. Particular attention was given to factors subject to policy control. Studies completed in the year included an analysis of economic growth from 1961 to 1972, a forecast of employment, socioeconomic studies of the Bristol Bay and western Gulf of Alaska areas, an examination of the fiscal structure of State and local governments, and a transportation system inventory. In addition, a model was developed of the Alaskan economy.

Geophysicists from St. Louis University and the Polish Academy of Sciences began research in Spitsbergen in which paleomagnetic data were obtained to unravel the tectonic history of the islands and the adjacent Arctic Basin. Seismograms of icequakes and possible microearthquakes were also collected.

The Foundation published a comprehensive statement of fiscal year 1975 Federal arctic research for the Interagency Arctic Research Coordinating Committee of the Federal Council for Science and Technology. The report is available from the Office of Polar Programs.

U.S. ANTARCTIC RESEARCH

A milestone event in Antarctic research occurred in 1975 when a new research station was dedicated and opened for year-round use at the geographic South Pole; it replaced an aging facility built in 1957. Unfortunately, other research capabilities were temporarily set back by the extensive damage to two ski-equipped C-130 airplanes on a research mission in east Antarctica. Nonetheless, 1975 was an extremely productive year, with more than 300 U.S. investigators conducting some 80 research projects in Antarctica and surrounding oceans.

In addition to the South Pole Station, three other year-round research facilities were operated—Palmer, by the Antarctic Peninsula; Siple, in Ellsworth Land; and McMurdo, on Ross Island. During the austral summer, research was also performed at several field camps on the continent, aboard four research ships, and aboard two Coast Guard icebreakers. The Foundation reimbursed the Navy for logistics support provided to the program.

New meteorological projects are in operation at the South Pole to



The new Amundsen-Scott Pole Station, with its 164-foot diameter, 50-foot high geodesic dome and arched structures for scientific research, was dedicated January 1975.

analyze the influence of Antarctica on the world atmosphere and climate. Washington State University researchers found in 1975 that the ice sheet may be cleaning the atmosphere of both manmade and natural pollutants: The snow contains unexpectedly high levels of trace gases normally associated with the atmosphere. Measurements also showed that the atmospheric levels of carbon tetrachloride are the same in Antarctica as in the Northern Hemisphere, implying that the compound may come from natural as well as manmade sources.

University of Maine geologists have been studying the glacial history of the Ross Sea area for a number of years. In the 1974-1975 season they obtained firm evidence that an extensive grounded ice sheet filled much of the Ross Sea as recently as 5,300 years ago. The ice was essentially an expansion of west Antarctic ice. Because ice variations are both a cause and an indicator of climate variations, the finding has significance for studies of past world climates.

Twenty-eight investigators from eight institutions in three countries performed the second year of field work in the Ross Ice Shelf Project. A geophysical survey and a study of surface glaciology were continued from the first year, as was a study of tides beneath the shelf. Snow formation processes were examined to help determine how atmospheric chemical impurities accumulate in snow. Based on findings to date, a site was selected for drilling through the ice shelf in the 1975-1976 season. Detailed radio-echo soundings of ice thickness were made, and a 100-meter ice core was obtained for study of past climates. Project scientists also obtained a 100-meter ice core at the South Pole for comparative analysis.

The fourth season of airborne radio-echo sounding of the ice sheet took place in a cooperative program of the Foundation, the Scott Polar Research Institute of Cambridge

University (England), and the Technical University of Denmark. The soundings revealed ice thickness and internal features as well as sub-ice topography and are considered accurate to 1.5 percent. This basic information is essential for further glaciological studies of mass balance of the ice, flow characteristics, and other processes. To collect the data, a Navy ski-equipped C-130 flew 332 flight-hours (84,000 miles) over east Antarctica, Marie Byrd Land, and the Ross Ice Shelf.

Biologists from DePaul University and other institutions showed that lipid content, oxygen consumption, and carbon dioxide production in antarctic marine animals differ markedly from those processes in lower latitude marine animals. Investigation of biochemical pathways gave strong evidence that polar species make major use of the pentose shunt, a blood sugar conversion process, and that conversion through conventional pathways is minimal. Thus, species now can be defined by the magnitude of organic compounds passing through the shunt: Polar species use the shunt at a phenomenally high rate—about 90 percent—while nonpolar species use it at only about 10 percent. The high usage of the shunt is consistent with the high lipid synthesis, low carbon dioxide production, and low growth rates typical of polar fauna.

A controlled very low frequency (5 kilohertz) wave injection experiment by Stanford University, using a transmitter at Siple Station, has shown that whistler mode echoes of the Siple pulses can suppress wave growth in the magnetosphere. This result, along with earlier findings, implies that an artificial signal, if of very narrow band width, can stimulate wave growth in the magnetosphere. It gives a new clue to the mechanism of what might be called the magnetosphere's coherent wave instability, which is important because it appears to control electron precipitation as well as wave growth. It probably is present in most natural plasmas even though it has not yet

been found in the laboratory or predicted by classical theory. Modification of the ionosphere and the magnetosphere and new communication techniques at very low frequency may be realized through this instability.

The research ship *ARA Islas Orcadas* (formerly *USNS Eltanin*) completed two cruises in fiscal year 1975. The U.S. ship is operated by Argentina, and scientific objectives and uses are shared by the two countries. The first cruise, in January and February, was for study of the physical and chemical properties of the Drake Passage area: Data were collected to estimate the velocities and densities of water layers traveling through the passage and to further comprehend regional circulation and the origin of water masses. In cooperation with the *Islas Orcadas* work, investigators aboard two other ships—the Scripps Institution of Oceanography research ship *Melville* and the Lamont-Doherty Geological Observatory research ship *Conrad*—set out a moored instrument array and obtained data pertaining to density and chemistry. The second *Islas Orcadas* cruise was a food chain study in the South Atlantic.

The Coast Guard icebreaker *Glacier* penetrated far into the ice-packed Weddell Sea to make physical oceanographic measurements aimed at increasing understanding of the formation of antarctic bottom water.

OCEANOGRAPHIC FACILITIES AND SUPPORT

The term "academic fleet" is applied to the group of approximately 30 major oceangoing and coastal research ships operated by academic laboratories in federally supported research projects. Ship-operating and ship-using institutions have joined together in a voluntary association called UNOLS—the University-National Oceanographic Laboratory System—to ensure that

time on federally supported ships is shared equitably by scientists throughout the community.

Foundation support, provided through the Oceanographic Facilities and Support (OFS) program, accounts for nearly 70 percent of the operating budget of the academic research fleet. In fiscal year 1975, OFS awards totaling nearly \$15 million were made for support of ship operations and marine technicians. The Office of Naval Research is the next-largest contributor, providing approximately 20 percent of fleet support, with a number of State and Federal mission agencies accounting for the remaining 10 percent. The distribution of ship support funds, both in aggregate and on an institution-by-institution basis, closely parallels the shiptime needs of the grantees and contractors of the supporting agencies.

The fleet suffered a tragic loss in January 1975. R/V *Gulf Stream*, operated by the Nova University Physical Oceanography Laboratory, was lost at sea with all hands during a storm in the Gulf of Maine. At the time of the accident, *Gulf Stream* was tracking drifting buoys being developed for use in the next phase of the NSF/Navy-supported North Pacific Experiment. Among those lost was William S. Richardson, Director of the Nova Laboratory and Chairman of the UNOLS Advisory Council.

Three ship construction projects funded by NSF reached important milestones during 1975. At a joint ceremony held on May 31, 1975, at the Peterson Builders, Inc., shipyard in Sturgeon Bay, Wis., R/V *Oceanus* and R/V *Wecoma* were christened. The two identical 177-foot-long general-purpose research ships were funded by NSF in 1972 and 1974, but have been built under a single contract under the direction of the Woods Hole Oceanographic Institution. The design for the "Oceanus class" was developed by Woods Hole, and the ship of that name is being operated by the institution as a replacement for R/V *Chain*, a con-

verted World War II salvage ship. Oregon State University (OSU), the operating institution for R/V *Wecoma*, was selected as a result of nationwide competition for assignment of the second ship. *Wecoma* replaces OSU's present flagship, R/V *Yaquina*, a converted freighter built in the early 1940's. Construction of a third ship of the class was funded in fiscal year 1975. In December 1974, a contract was concluded with the University of Rhode Island (URI) for construction of R/V *Endeavor*, which will be operated by URI as a replacement for R/V *Trident*, another converted vessel of World War II vintage. As in the case of OSU, URI was designated as operator institution on the basis of competitive review. Keel laying for *Endeavor*, which is also being built by Peterson Builders, took place in January 1975, and delivery is scheduled for early 1977. Title to all three ships will be retained for the Federal Government by the Foundation, and they will be

assigned to the operating institutions under renewable 5-year Charter Party Agreements.

Another major accomplishment during 1975 was the completion of negotiations resulting in an interagency support agreement for the deep submersible *Alvin*. Under the terms of the agreement, the Foundation, the Department of the Navy, and the National Oceanic and Atmospheric Administration have agreed to provide, in equal shares, support for operation of *Alvin* for 3 years. DSRV *Alvin*, operated by the Woods Hole Oceanographic Institution, is a National Oceanographic Facility. Requests for use of the submersible are evaluated by a special advisory group, appointed by UNOLS, that represents a broad cross section of the oceanographic community. During calendar year 1975, the first operating year under the agreement, chief scientists representing ten academic institutions and Federal laboratories



On May 31, 1975, the 177-foot research vessel *Wecoma* was launched at the Peterson Builders, Inc. shipyard in Sturgeon Bay, Wis. Destined for Oregon State University, *Wecoma* is part of the Nation's academic research fleet.

will direct the use of *Alvin* in biological, geological, and engineering studies. Towards the end of the 3-year period of the interagency support agreement, a full study of both scientific and logistic experience of the users will be undertaken to develop recommendations for the future support of the vessel.

RADIO SPECTRUM MANAGEMENT

Radio techniques for scientific research—remote environmental sensing, radio astronomy, instrumented packages for wildlife studies, and oceanographic data-

gathering buoys—have come into their own in recent years. At the same time, increased use of the spectrum of radio frequencies has required special coordination to protect against that harmful interference from other uses of the radio spectrum, which might delay vital research programs or invalidate their data.

Several Government agencies and the scientific community, particularly radio astronomers, have urged active participation by the National Science Foundation in national-level frequency management affairs. Recognizing the importance of this problem, the NSF established a

position of Radio Spectrum Manager. As a member of the Interdepartment Radio Advisory Committee (IRAC)—which advises the Office of Telecommunications Policy on radio frequency usage, coordination, and policy—the Radio Spectrum Manager represents the NSF and the interests of the National Research Centers and its grantees. He also functions as liaison between the Committee on Radio Frequencies of the National Academies of Sciences and Engineering and the IRAC, and is available to the university community at large for advice on the selection and procurement of radio frequencies for research experiments.

NATIONAL RESEARCH CENTERS

The five National Research Centers supported by NSF provide advanced facilities—available on a competitive basis to visiting scientists—needed for the development of new knowledge in astronomy and atmospheric sciences. Four of the centers are for astronomy: National

Astronomy and Ionosphere Center, Kitt Peak National Observatory, Cerro Tololo Inter-American Observatory, and National Radio Astronomy Observatory; the fifth is the National Center for Atmospheric Research. Scientific and support staffs are maintained at the centers to

provide the necessary expertise to support the research programs of visiting scientists, to develop advanced instrumentation, and to participate in research programs. The centers are operated and managed by nonprofit organizations or universities under contract to the Foundation.

**Table 4
National Research Centers
Fiscal Years 1973, 1974, and 1975**

	Fiscal year 1973			Fiscal year 1974			Fiscal year 1975		
	Capital obligations	Research operations and support services	Total	Capital obligations	Research operations and support services	Total	Capital obligations	Research operations and support services	Total
National Astronomy and Ionosphere Center	\$399,000	\$2,851,000	\$3,250,000	\$590,000	\$2,610,000	\$3,200,000	\$—0—	\$3,200,000	\$3,200,000
Kitt Peak National Observatory	70,000	7,780,000	7,850,000	792,000	7,008,000	7,800,000	22,000	7,653,000	7,675,000
Cerro Tololo Inter-American Observatory	216,000	2,484,000	2,700,000	717,000	1,883,000	2,600,000	150,000	2,800,000	2,950,000
National Radio Astronomy Observatory	3,000,000	6,950,000	9,950,000	4,294,000	7,806,000	12,100,000	12,048,000	7,252,000	19,300,000
National Center for Atmospheric Research	—0—	16,000,000	16,000,000	1,148,000	16,352,000	17,500,000	—0—	17,450,000	17,450,000
TOTAL	\$3,685,000	\$36,065,000	\$39,750,000	\$7,541,000	\$35,659,000	\$43,200,000	\$12,220,000	\$38,355,000	\$50,575,000

NATIONAL ASTRONOMY AND IONOSPHERE CENTER

The National Astronomy and Ionosphere Center (NAIC), operated by Cornell University under contract with the National Science Foundation, provides unique instrumentation and facilities for advanced research in aeronomy and radio and radar astronomy. A fixed, bowl-shaped 1,000-foot-diameter telescope located at a site 12 miles south of the city of Arecibo, P.R., is available to visiting investigators and staff scientists, along with technical and administrative support.

A major project to improve the performance of the instrument culminated on November 16, 1974, when the newly upgraded radio/radar telescope was dedicated. As a result of the upgrading, which took more than 3 years to complete, the planetary ranging and mapping capability of the Arecibo telescope has increased a thousandfold; when final alignment has been completed, the frequency range will be increased by a factor of twelve.

During fiscal year 1975, the NASA-sponsored 450-kilowatt S-band (2,380 MHz—megahertz, or a million cycles per second) planetary radar transmitter, feeds, receivers, and related electronics were installed in a new carriage house mounted on the suspended triangular platform. In January 1975, the first program with the new S-band radar system bounced radar pulses off the rings of the planet Saturn. The return echoes, received by the 210-foot-diameter Goldstone antenna of NASA's Jet Propulsion Laboratory in California, yielded new information on the size, distribution, motions, and chemical makeup of particles forming the rings.

In June 1975, a 100-foot-diameter remote interferometer antenna, with a surface of 290 trapezoidal aluminum panels, was erected. When used in conjunction with the upgraded dish, this antenna permits interferometric radar mapping of



The National Astronomy and Ionosphere Center's upgraded radio-radar telescope near Arecibo, P.R., has a newly panelled surface and upgraded electronics that increase its planetary ranging and mapping capability a thousandfold. [Photo by Cornell University]

planetary surfaces at S-band frequencies. The antenna, located 6 miles north of the main observatory site, can be used separately as a sensitive radio telescope or, in coordination with the main antenna, to make high resolution studies of small radio sources in the sky.

During fiscal year 1975, the NAIC facilities were used by 38 visiting investigators from 17 U.S. and foreign research and educational institutions. Of the 62 percent of the observing time allocated to visitors, 37 percent was assigned to radio astronomy, 23 percent to radar astronomy, and 2 percent to aeronomy research. The NAIC Arecibo observing site was visited by 20,651 persons during the year.

KITT PEAK NATIONAL OBSERVATORY

The Kitt Peak National Observatory (KPNO), operated under contract with the National Science Foundation by the Associa-

tion of Universities for Research in Astronomy, Inc., is located in the Quinlan Mountains approximately 50 miles southwest of Tucson, Ariz. The 6,800-foot-high site is one of the few places in the United States combining the features of dark sky, atmospheric transparency, and relative freedom from manmade pollutants. The observatory headquarters are located in Tucson, providing offices, library, and computing and engineering facilities and services.

KPNO provides modern facilities for research in solar, planetary, stellar, and galactic astronomy. The nine stellar and two solar telescopes are available to visiting astronomers 60 percent of all available observing time. The remaining 40 percent is used by KPNO staff scientists.

A major effort during fiscal year 1975 was the fine-tuning and completion of the basic complement of instrumentation for the 4-meter Mayall Telescope, which became fully operational August 1, 1974. During the year, computer systems were integrated with telescope

systems, new image tube systems were designed, and advanced detector systems were developed for the telescopes.

One of the most significant instrumentation developments was the Interactive Picture Processing System (IPPS). Interconnected with the main observatory computer, the IPPS provides a new visual technique for rapid data-reduction and analysis. Astronomers can now accentuate selected areas such as the faint outer regions of distant galaxies. They can visually analyze the full range of information available in a digital picture virtually on the spot. With the IPPS, an astronomer converts a photograph, television picture, or even radio data into a digitally encoded image on magnetic

computer tape. This tape is then processed through the main observatory computer, then through a minicomputer to the digital picture display. Once in the image system, the visual data can be smoothed, further enhanced, or compared instantly with other views of the same scene. Vivid colors can be added or changed for better detail separation. Today, an astronomer may collect as much as one million bits of data in an hour's observing time. Ten years ago, an entire night might yield only 1,000 bits of data.

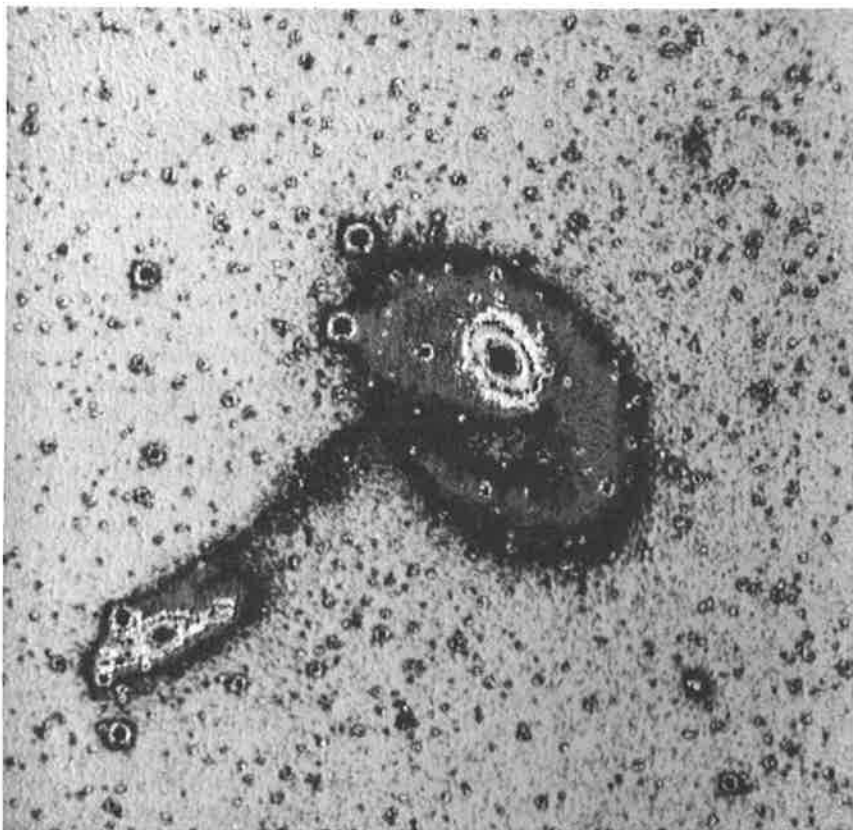
During fiscal year 1975, 281 visiting scientists and graduate students from 71 U.S. and 17 foreign institutions conducted observations at KPNO.

CERRO TOLOLO INTER-AMERICAN OBSERVATORY

The Cerro Tololo Inter-American Observatory (CTIO) is operated under a contract with the National Science Foundation by the Association of Universities for Research in Astronomy, Inc. CTIO provides ground-based telescopes, auxiliary instrumentation, and support facilities for U.S. and foreign astronomers studying stellar and planetary astronomy from a Southern Hemisphere location. Observations can be made of astronomical objects not visible from the Northern Hemisphere, such as our nearest external galaxies, the Magellanic Clouds, and galactic objects in the southern Milky Way.

The primary facilities of the observatory are located on the 7,200-foot-high Cerro Tololo mountain situated in the Chilean Andes at a southern latitude of 30°, approximately 300 miles north of Santiago. The eight stellar telescopes are available to visiting astronomers 60 percent of all available observing time on the telescopes. The remaining 40 percent is used by CTIO staff scientists. Additional facilities are maintained at the coastal city of La Serena—where data reduction, computer services, and engineering and technical support are provided.

The major effort at CTIO during fiscal year 1975 was to bring the 4-meter telescope, largest in the Southern Hemisphere, into operation. The primary mirror was completed in mid-July 1974 at the Kitt Peak National Observatory optical shop in Tucson, Ariz. The finished product concentrated 100 percent of the incident light received to within 0.7 arc seconds, and 94 percent of the light within 0.4 arc seconds. The mirror was shipped to Cerro Tololo and installed in the telescope mounting. The first scientifically usable light was received on October 18, 1974. Since then studies have been undertaken in: broadband photography of Magellanic Cloud



Visual detail of this pair of interacting galaxies has been enhanced by Kitt Peak's new Interactive Picture Processing System. The ring around the larger galaxy is about 180,000 light years across, and is probably composed of young stars recently formed from neutral hydrogen surrounding the galaxy. The star formation may have been triggered by the passage of the smaller galaxy through the larger one.



Primary facilities of the Cerro Tololo Inter-American Observatory are located at an altitude of 7,200 feet in the Chilean Andes. Among the stellar telescopes at the right is the largest telescope (4-meter) in the Southern Hemisphere, which was brought to operation during fiscal year 1975. Visiting scientists' quarters, laboratories, and support facilities are at the lower left. [Photo by Kitt Peak National Observatory]

features and peculiar groups of interacting galaxies; photography of nearby southern galaxies for detection of faint HII regions and other spiral arm traces, cepheid variables, and globular clusters; and limited photographic search for radio sources that have not been identified optically.

The secondary mirror for the 4-meter telescope is now in the final polishing stages at Kitt Peak, with installation in the Cerro Tololo telescope planned for October 1975. The telescope will be available for regularly scheduled programs in early 1976.

During fiscal year 1975, 116 astronomers from 28 U.S. and 16 foreign institutions carried out observational programs at Cerro Tololo.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

The National Center for Atmospheric Research (NCAR) in Boulder, Colo., has two main missions: to plan and conduct, in

cooperation with universities and other institutions, atmospheric research programs that are beyond the scope of individual institutions, and to develop and operate selected research facilities in support of atmospheric research programs. The University Corporation for Atmospheric Research, a nonprofit consortium of 42 U.S. and 2 Canadian universities, operates NCAR under sponsorship of the Foundation.

With the Nimbus 6 satellite, the Tropical Wind, Energy Conversion, and Reference Level Experiment began gathering data from instrumented balloons released in the tropics; and the Limb Radiance Inversion Radiometer began collecting data on ozone and other constituents of the Earth's upper atmosphere. NCAR's National Scientific Balloon Facility recently launched its 1,000th balloon. The 999th balloon, 1.4 million cubic meters in volume, was the largest scientific balloon ever flown. In support of the Global Atmospheric Research Program's Atlantic Tropical Experiment (GATE), the GATE Aircraft Data Management

Program was formed to design the aircraft intercomparison tests during the experiment and to handle U.S. GATE aircraft data. A new solar observation effort with the High Altitude Observatory's Stokes polarimeter at the Sacramento Peak Observatory in New Mexico yielded new information on solar magnetic fields. In recognition of the important role of the ocean in determining the Earth's climate, NCAR initiated a research program in oceanography. A two-layer ocean model has been developed to study the role of mesoscale eddies in the general circulation of the oceans.

The field phase of Project DUSTORM (a major aircraft and ground research program) focused on the influence of duststorms in the West and Southwest on severe weather in the Midwest.

A byproduct of NCAR's third field season of the National Hail Research Experiment was the development of a color radar display that makes wind shears detectable and discloses possible areas of tornado formation. Other new instruments and systems included a windfinding dropsonde

and a fast, high-resolution hygrometer. A new air filtration system, "Samovar," joined the sampling array, and the C-band radar system is nearing completion. Work is proceeding on lidar systems and on the Portable Automated Mesonet, a network of ground-based sensing stations. Expansion of the capabilities of the NCAR Computing Facility is keeping pace with these developments.

NATIONAL RADIO ASTRONOMY OBSERVATORY

The National Radio Astronomy Observatory (NRAO), now in its 19th year of operation, is operated and managed by Associated Universities, Inc., under contract to the Foundation, from headquarters in Charlottesville, Va. The radio telescope systems at the principal Green Bank observing site in West Virginia are a 300-foot meridian transit telescope, a 140-foot fully steerable telescope, and a four-element interferometer. A 36-foot millimeter wave telescope is located on Kitt Peak near Tucson, Ariz.

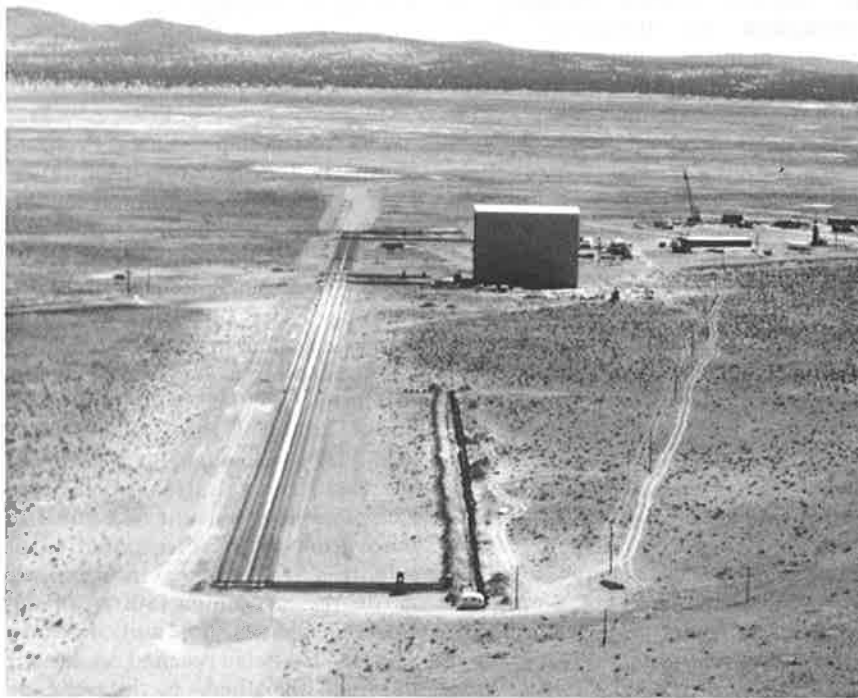
In the past year a Cassegrain system was installed on the 140-foot telescope. Such systems make use of a secondary reflector to fold the path of the collected radiation and direct it to a focus near the surface of the main reflector. This makes possible rapid changes among any of the radiometers (special radio receivers which detect and measure radio energy collected by the antenna) and offers the potential of increased telescope efficiency and lower system temperatures. Four such radiometers are now operating at frequencies of 1,400 to 1,800 MHz, 15 GHz, and 23 GHz. A new Cassegrain radiometer has also been installed on the 36-foot telescope. This radiometer operates (with different klystron tubes) over the range 80 to 120 GHz, which is rich in molecular spectral lines. Since its installation in the fall of 1974, it has been used to detect and measure many molecular

lines emitted from deep space sources, including lines from ethyl alcohol, one of the most complex molecules (nine atoms) yet detected; lines from the first observed polyatomic ion N_2H^+ ; and lines arising from CO in external galaxies.

During the year, a minicomputer was installed at the 140-foot telescope for on-line data analysis. Programs are available for spectral-line processing, and continuum programs are being developed. With these programs the observer can quickly make a first analysis of his data, and thus can better judge, for example, which observations need further integration time. About 25 percent of the observing time on the 140-foot telescope was used for very long baseline (VLB) interferometry, in both line and continuum studies.

A major new radio telescope, the Very Large Array (VLA), under

construction on the Plains of San Augustin, near Socorro, N.Mex., will be an array of 27 antennas, each 82 feet in diameter. The first VLA antenna has been assembled, and final assembly of the second antenna has begun, with delivery of both antennas scheduled for October 1975. The first antenna transporter has been assembled and is being operated on the 0.8 miles of the equiangular "Y" railroad track completed to date. Site facilities including the control building, cafeteria, and central site services and utilities are under construction and scheduled for completion by June 1976. A majority of the electronic modules associated with the first two VLA antennas have been completed. Tests are in progress on the overall operation of a major part of the VLA electronics system, and preliminary results indicate that the performance is essentially as expected.



The Very Large Array radio telescope is now under construction on the Plains of San Augustin near Socorro, N. Mex. The completed antenna assembly building is in the center and the service building to the right. The initial 1.2 kilometers of track have been completed, and the waveguide trench parallel to the track is under construction. Construction of the control building and cafeteria, to right of the service building, has begun. [Photo by National Radio Astronomy Observatory]

SCIENCE INFORMATION ACTIVITIES

The volume of scientific and technical information (STI) is doubling approximately every 10 years and constitutes a valuable national resource. The goal of the Science Information Activities Program is to provide the research, information, and technological bases upon which both users and suppliers of STI can build in order to improve the management, productivity, and utilization of STI. During fiscal year 1975, program activities were carried out under five goal-oriented programs: Research, Access Improvement, User Requirements, Economics of Information, and National/International Coordination.

Research

The Research Program continued to support studies designed to strengthen the theoretical foundations of information science and to provide the technology base for future applications. Two complementary projects, one at New York University and the other at Lehigh University, are attempting to establish bases for new and more effective scientific and technical information systems. These projects are investigating the development of retrieval systems that can present specific facts or quantitative information, in contrast to current systems which are limited to retrieval only of citations to documents. Two other efforts, one at the Institute for Scientific Information and the other at the Illinois Institute of Technology Research Institute, are devoted to the improvement of retrieval effectiveness and automated classification for large information systems. Another two projects are focused on basic problems of facilitating user access to widely distributed information resources. Researchers at the University of Illinois are attempting to identify means for indexing inter-

connections among large data bases so that a user will be able to move readily from one data base to another. The other project, at the Massachusetts Institute of Technology, is seeking to develop a common language which will reconcile the differences among on-line information systems so that a user at a terminal would be unimpeded by such differences in accessing diverse systems.

Research related to networking was continued in cooperation with the Foundation's Computer Research programs. Support was provided for a network simulation and gaming project that involves 16 academic institutions under the auspices of Interuniversity Communications Council, Inc. (EDUCOM). In another project, at Stanford University, the economics of computer communication networks is being analyzed.

Access Improvement

The Access Improvement Program (formerly the National Information Program) sponsors projects to improve the means, both physical and organizational, of transferring information from originators to users. Among the program's accomplishments in fiscal year 1975 were completion and dissemination of design studies of a computer-based Editorial Processing Center (EPC) for small journals, initiation of the first demonstrational test of an EPC, and development of a guide to innovation in the dissemination of scientific and technical information. A degree of compatibility among selected abstracting and indexing services was also reached, making it possible for them to interchange computer data files. Electronic (i.e., "paperless") publication was studied as part of a comprehensive systems analysis of scientific and technical communication in the United States. An inventory of energy-related infor-

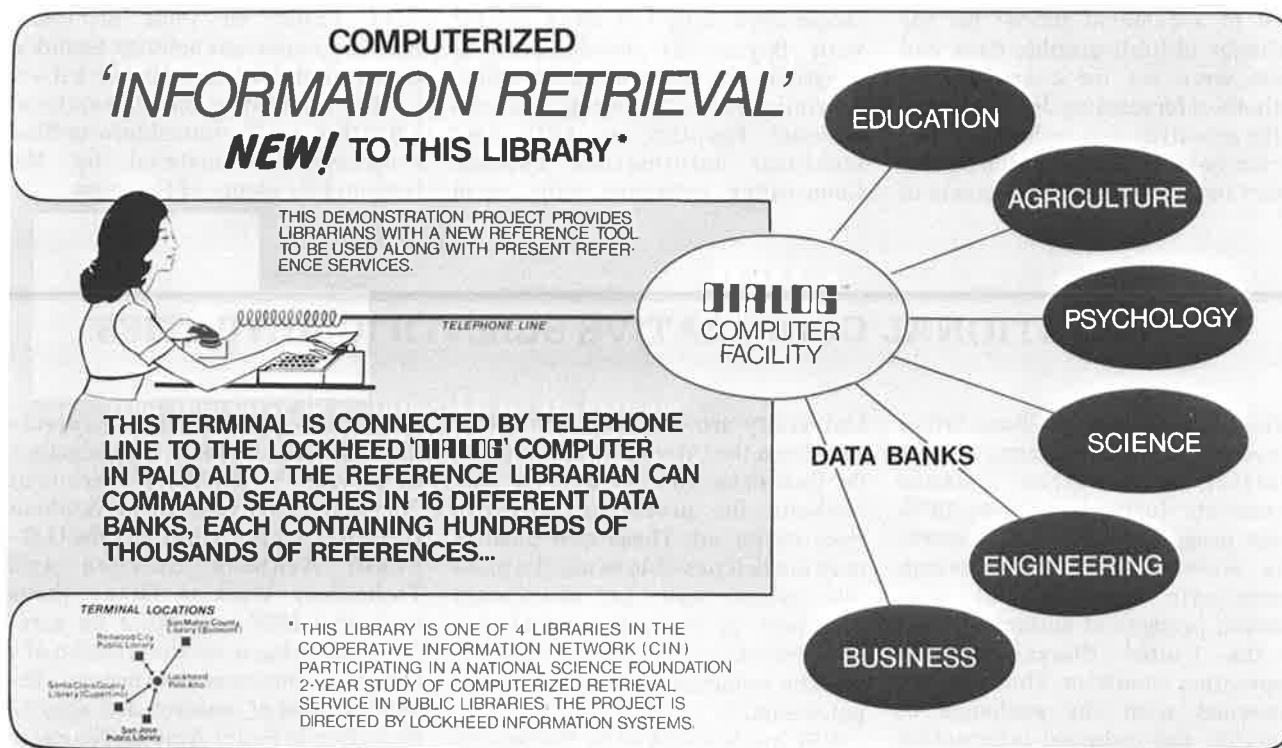
mation resources and a guide to the use of existing indexes to these resources were prepared, and a project to "flag" the presence of factual data in scientific publications was initiated.

User Requirements

The User Requirements Program supported user-oriented assessments of new methods of disseminating scientific and technical information, ways to improve management of scientific and technical information services, barriers to the effective use of such information, and methods of familiarizing users with available information services. The program supported a variety of studies and experiments including application of marketing theory and practices to the dissemination of scientific information, user acceptance of computer-based retrieval of handbook material in place of conventional printed versions, and user acceptance of abbreviated scientific articles.

Several studies were devoted to examining barriers to effective information transfer within large industrial organizations. One study involved practices of providing technical information services to scientists and engineers within approximately 1,000 firms, while another focused on management of information services within one large multifunction firm. Results from both studies will be organized to help R&D managers develop more effective means for utilizing available scientific and technical information.

Education of users received increased emphasis in fiscal year 1975. Projects included development of materials for helping college and university professors to acquaint students with advanced computer-based scientific and technical information services. In addition, the User Requirements Program organized



This diagram represents the results of an operational experiment linking libraries with users of scientific information at the local level.

several national colloquia to help disseminate the early results of newly initiated studies. Colloquia were held, for example, in conjunction with the annual meetings of the American Society for Information Science, the American Association for the Advancement of Science, and the Special Libraries Association.

Economics of Information

Under this program, a systematic study was started on the economics of various information transfer activities. Basic to this effort is the ongoing collection and analysis of data on the generation, transmission, and use of scientific and technical information. Policy-oriented analyses included investigation of the interaction of law, economics, and technology in the use of copyrighted materials, and factors influencing pricing policies for journals and services. Other studies were

directed to development of cost/benefit data for improvement of library operations; cost/benefit analysis of the operation of information analysis centers; assessment of information services designed to reach State and local decision-makers; and cost/benefit assessment of the use of computerized services in place of chemistry journals in the library of a small college.

National/International Coordination

The National/International Coordination Program promotes communication and coordination among U.S. scientific information services and aids the interchange of scientific information with foreign organizations. National coordination activities were carried out through quarterly meetings with managers of Federal scientific and technical information services and through other

meetings, seminars, and colloquia with private organizations. A publication summarizing all fiscal year 1974 awards was distributed, and another, summarizing fiscal year 1975 awards, was prepared for distribution.

International information activities included participation in bilateral cooperative projects; representation in international organizations such as OECD and the UNISIST program of UNESCO; and payment of dues for selected international nongovernmental information organizations such as ICSU's Abstracting Board and the Committee on Data for Science and Technology. Bilateral projects included cooperative activities with the Soviet Union, Egypt, and Japan. With the Soviet Union, a seminar was held in Leningrad on assuring the cost/benefits of information services; work was started toward develop-

ment of a common format for the exchange of bibliographic data; and plans were set for a seminar on methods of forecasting developments in the scientific and technical information field, to be held in the United States in October 1975. Two sets of

cooperative activities were started with Egypt: (1) development of programs for training information specialists; and (2) development of a national Egyptian scientific and technical information system. Cooperative activities with Japan

were based on joint seminars. Another important activity included the assessment activities carried out by the Committee on International Scientific and Technical Information Programs, administered by the National Academy of Sciences.

INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES

The National Science Foundation served as executive agency for 14 bilateral cooperative science agreements during fiscal year 1975. These programs involve U.S. scientists working with their foreign counterparts to carry out joint research projects of mutual interest to the United States and the cooperating countries. They also are concerned with the exchange of scientific and technical information through seminars and visits. This cooperation makes the best use of research talent and facilities by creating the opportunity for scientists to interact in pursuing common scientific and technical objectives.

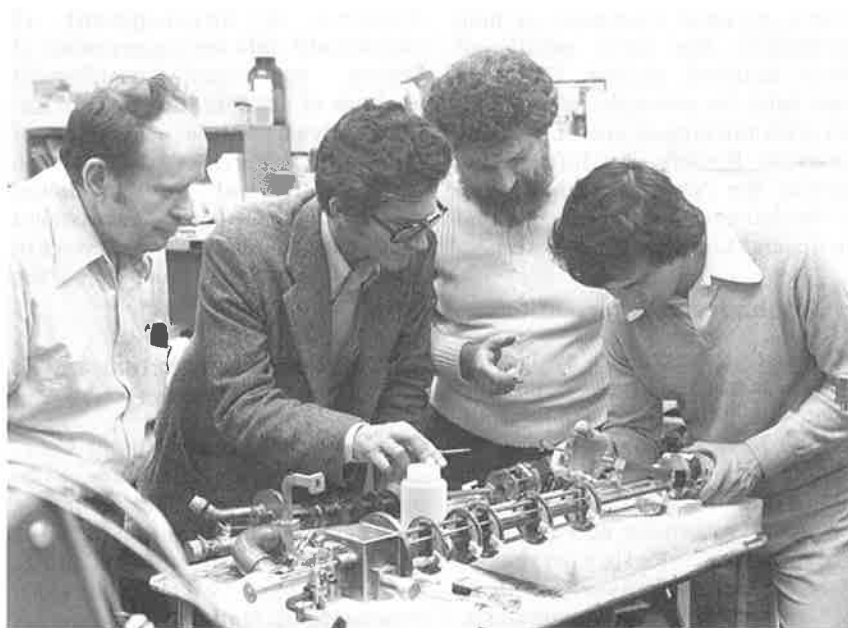
In addition to the formal agreements for cooperative science programs, NSF also supports a number of cooperative projects with foreign scientists from countries where unique research opportunities exist but no formal agreement with the United States has been concluded. This is particularly true in South and Central America, where in addition to the governmental agreements with Brazil, Argentina, and Mexico, the U.S.-Latin America Cooperative Science Program in fiscal year 1975 supported nine new joint research projects and the visits of five U.S. scientists in these countries: Chile, Colombia, Costa Rica, the Dominican Republic, Guatemala, and Venezuela.

An example of joint research on contemporary problems is a project to explore the possibility of producing plastics from sources other than crude oil. Chemical engineers and materials scientists from Lehigh

University are working with scientists from the Universidad Industrial de Santander in Colombia to find methods for producing polymers from castor oil. These new plastics may make it possible to use the plant oils which can be abundantly produced in various tropical and temperate zone countries for plastics, thereby reducing the consumption of petroleum.

NSF has been asked by the Department of State and the Department of the Treasury to assist in developing

cooperative scientific projects through the six Joint Commissions established by the U.S. Government during the past year. Saudi Arabian scientists, working through the U.S.-Saudi Arabian Science and Technology Working Group, have requested NSF assistance on a reimbursable basis for the creation of a central science agency to promote the development of research and science education in Saudi Arabia. They also have requested technical assistance in establishing several national



Under NSF's International Cooperative Scientific Activities Program, U.S. and Brazilian scientists work together on a K-band maser used in one of the world's longest radio astronomy base lines, linking the Haystack Observatory in Massachusetts with the Itapetinga Observatory in Brazil.

Bilateral Science and Technology Agreements
Number of Approved Activities FY 1975

Country	Visiting Scientists		Seminars	Cooperative Research
	U.S.	Foreign		Projects
Argentina ...	1	—	—	1
Australia	13	1	8	5
Brazil	2	—	—	5
Rep. of China	10	2	3	15
France	18	18	—	3
Hungary	6	5	3	2
India	25	14	—	—
Italy	24	*	3	12
Japan	13	2	21	29
Mexico	2	—	2	6
New Zealand	1	—	—	—
Romania	10	24	0	7
Spain	—	—	1	2
USSR	11	4	19	49**
Total	136	70	60	136

* Data unavailable.

** Supported by special budget in SRPS.

Special Foreign Currency Program
Summary of Projects by Country

Country	Research Grant Awards	Travel Grant Awards	Active Translation Projects (Contracts)
Burma	0	0	1
Egypt	5	24	2
India	5	38	2
Pakistan	6	14	1
Poland	7	27	1
Tunisia	1	4	1
Yugoslavia	7	16	0
Total	31	123	8

U.S.-U.S.S.R. and East Europe Academy Exchange Programs

Visits Each Way*

Country	United States		Foreign	
	Scientists	Man-Months	Scientists	Man-Months
USSR	38	96	55	146
Bulgaria	17	28	7	21
Czechoslovakia .	27	54	20	81
Hungary	16	35	15	26
Poland	20	50	11	50
Romania	17	34	7	22
Yugoslavia	19	38	11	30
Total	154	335	126	376

* For the period May 1, 1974 - April 30, 1975.

research centers and for planning cooperative research activities in 18 scientific areas.

NSF has participated in meetings of the U.S.-Egypt Joint Working Group on Technology, Research, and Development in Cairo and Washington. The Foundation has been responsible for joint activities in scientific instrument maintenance, science information systems, and a research management workshop involving U.S. and Egyptian scientists. NSF staff has been involved also in the scientific working groups of the Joint Commissions for India, Iran, and Israel.

The Foundation assisted in further implementation of activities in seven of the 12 research areas of the U.S.-U.S.S.R. Agreement on Scientific and Technical Cooperation: application of computers to management, chemical catalysis, electrometallurgy, microbiology, physics, science policy, and scientific and technical information. More than 100 U.S. scientists have visited the Soviet Union in association with working group meetings and seminars there, and joint work is now under way in 16 of the 28 approved project areas.

NSF continued its support for the exchange programs of the Committee on Scholarly Communication with the People's Republic of China. Six groups of Chinese scientists—in the fields of agriculture, photosynthesis, pharmacology, solid state physics, molecular biology, and communication techniques—visited the United States during fiscal year 1975. Similarly, six delegations of American scientists, chosen in the areas of plant studies, seismology, linguistics, schistosomiasis, paleoanthropology, and rural small-scale industries, traveled for several weeks each in the People's Republic of China.

Exchange of individual scientists for professional visits with their colleagues in the Soviet Union, Bulgaria, Czechoslovakia, Hungary, Poland, Romania, and Yugoslavia continued with NSF funding under a

National Academy of Sciences (NAS) program.

The Foundation supported NAS membership and participation in the International Council of Scientific Unions and other non-governmental scientific organizations. The Academy's membership in and support of the International Institute for Applied Systems Analysis, located in Vienna, continued with funds provided by NSF.

NSF, in cooperation with the Department of State and other U.S. Government agencies, continued a program of fact-finding and cooperative program development visits of U.S. scientists to countries actively engaged in exploring alternative energy sources and technologies.

During fiscal year 1975, an international studies program was initiated to strengthen the Founda-

tion's leadership capability in the development of international science activities. The objective is to develop a more rational strategy for planning future international science projects and programs.

Under a special program funded by the Agency for International Development, the Foundation supported, for the fourth year, problem-oriented research and teaching by individual U.S. scientists and engineers in selected countries receiving assistance from the Agency for International Development.

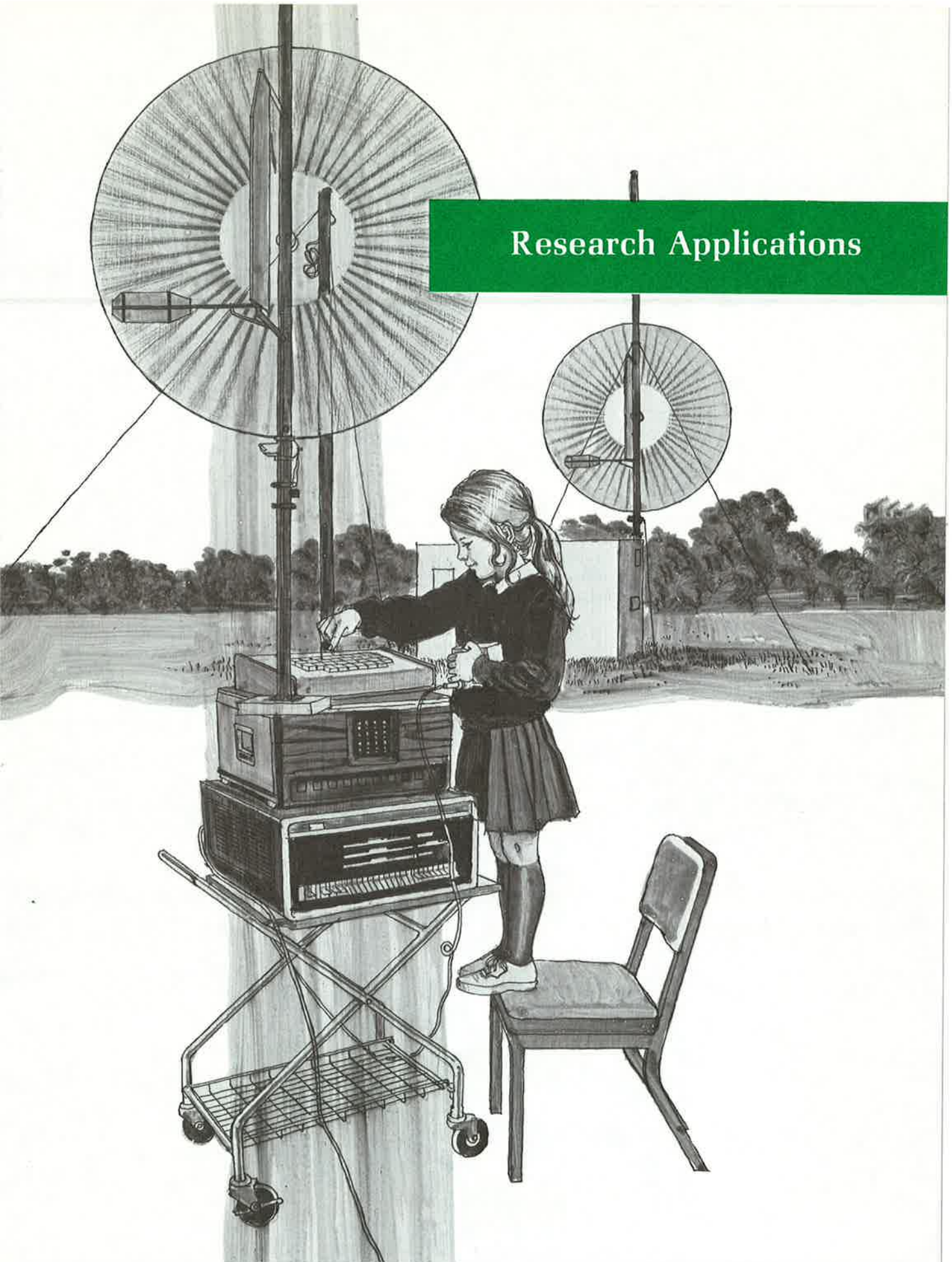
Special Foreign Currency Program for Research and Related Activities

In fiscal year 1975, the Foundation supported 31 research projects in six countries where U.S. scientists work with their foreign colleagues through

the Special Foreign Currency (SFC) Program for Research and Related Activities. The SFC program uses U.S.-owned local currencies in countries where reserves are in excess of requirements. Cooperative research and travel for scientific visits in Yugoslavia are now supported from the Joint Fund, created by the U.S. contribution of its Yugoslav currency reserves and matching funds from the Yugoslav Government.

Contracts with eight translation services in SFC countries provided for the procurement of translations into English of foreign technical publications. The NSF acts as the Government coordinator in obtaining services for the foreign translation of scientific and technical information and is currently the agent for eight U.S. Government agencies in obtaining otherwise inaccessible data for the U.S. scientific community.

Research Applications





Research Applications

NSF established its program of Research Applied to National Needs (RANN) in 1971, with RANN's mission to identify "national needs" that were not being addressed by existing research agencies, to fund both basic and applied research relevant to the identified national needs, and to assure the utilization of the results of the research.

In the past few years the importance of the major problem areas selected by RANN—particularly solar and geothermal energy research—has become apparent. Upon the formation of the new Energy Research and Development Administration (ERDA) about halfway into fiscal year 1975, RANN transferred a comprehensive research program—comprising a scientific and technological base, management, experienced staff, plans, and over 100 operating projects—to the new agency. All were made available to ERDA on its first day of operation and showed how the RANN program could initiate a strong research effort and then turn it over to users for further development, whether the user of the results is industry, State or local government, or in this case, the Federal Government. RANN also continued a strong energy research program in 1975, refocusing it toward longer range, more advanced, high-risk/high-payoff research.

Another important event in fiscal year 1975 was the reorganization of the RANN staff to concentrate more directly on major problem areas. A new program of Advanced Productivity Research and Technology was established by combining programs in social systems with portions of those in advanced technology applications, and other activities

were redirected toward broad interdisciplinary research programs with increased participation on project teams by economists, environmentalists, social scientists, and potential users of the research.

Productivity research was directly targeted on improving the productivity of the public sector, which is one of the most rapidly growing parts of the economy. To enhance utilization and create best practice, large segments of previously conducted related research were evaluated for use of Federal, State, and local decisionmakers. These evaluations are now being used from Federal to local levels in such areas as justice, public safety, health care, waste management, and work satisfaction. Related productivity programs included work in such areas as the effects of regulation on the economy; the development of quantitative, operationally useful measures emphasizing performance output rather than input; and delivery of public services.

In environmental research, techniques developed in 1975 for the seismic safety of dams and nuclear power stations were adopted by the State of California, the Army Corps of Engineers, the U.S. Bureau of Reclamation, and the Nuclear Regulatory Commission. Other achievements occurred in identifying city-caused weather modification (particularly hailstorms), providing guidelines for controlling the environmental release of lead and other trace contaminants, regional planning, land-use management, and fire research.

Programs in Exploratory Research and Problem Assessment continued to selectively evaluate future major problem areas. Program emphasis in

this area in fiscal year 1975 was in renewable and nonrenewable resources research and in a number of technology assessments.

From the beginning of the RANN program there has been strong emphasis on the utilization of RANN-developed research and on obtaining a better domestic payoff from the Nation's research and development investment. In the public sector, the Intergovernmental Science and Research Utilization program emphasized creation of scientific capability at State, local, and regional government levels. Procedures for identifying needs received special emphasis.

The Research and Development Incentives Program supported projects directed at identifying barriers to the solution of public sector problems with high technology content, developing incentive mechanisms to overcome the barriers, and increasing innovation in both private and public sectors of the Nation and its economy.

In May and June 1975, twelve 1-day RANN Regional Seminars were conducted by Foundation staff in key cities throughout the Nation to describe and discuss the objectives of the RANN program, the national problems on which it will concentrate in fiscal year 1976, and the procedures for participation by university, industrial and nonprofit research organizations, and State and local governments. Over 4,000 people attended seminars in Boston, New York, Washington, Atlanta, Cleveland, Milwaukee, St. Louis, Dallas, Denver, Seattle, Palo Alto, and Los Angeles.

Results of many of the projects conducted in Research Applications during fiscal year 1975 are discussed on the following pages.

Table 5
Research Applications
Fiscal Years 1973, 1974, and 1975

(Dollars in millions)

	Fiscal year 1973		Fiscal year 1974		Fiscal year 1975	
	Number	Amount	Number	Amount	Number	Amount
Research Applied to National Needs	552	\$69.88	589	\$75.08	651	\$80.75
Advanced Energy Research and Technology	102	14.23	215	28.11	271	36.44
Advanced Environmental Research and Technology	185	29.27	174	26.80	169	23.68
Advanced Productivity Research and Technology ..	198	21.29	143	16.37	164	17.14
Exploratory Research and Problem Assessment	67	5.09	57	3.80	47	3.49
Intergovernmental Science and Research						
Utilization	33	1.00	26	.96	27	1.00
Experimental Research and Development						
Incentives	22	1.84
Total	585	\$70.88	615	\$76.04	700	\$83.59

* Not included in Research Applications in fiscal years 1973 and 1974.

ENERGY

When impending shortages in the Nation's depletable energy resources became a matter of national concern in late 1973, NSF already had well-developed programs in energy-related research on which new and expanded efforts could be built. As a result, the Foundation was designated the lead Federal agency for solar and geothermal energy research programs, and in fiscal year 1975, the Congress appropriated \$93.4 million for energy research in the RANN program. When the bulk of the Federal energy research efforts was subsequently consolidated under the direction of ERDA in January 1975, NSF transferred the lead responsibility for solar and geothermal energy research, \$51.7 million and 45 staff positions.

This transfer required redirection and refocusing of the RANN energy effort toward very advanced energy concepts and systems having high risk but high payoff. In general, the program seeks to provide a home for highly innovative ideas.

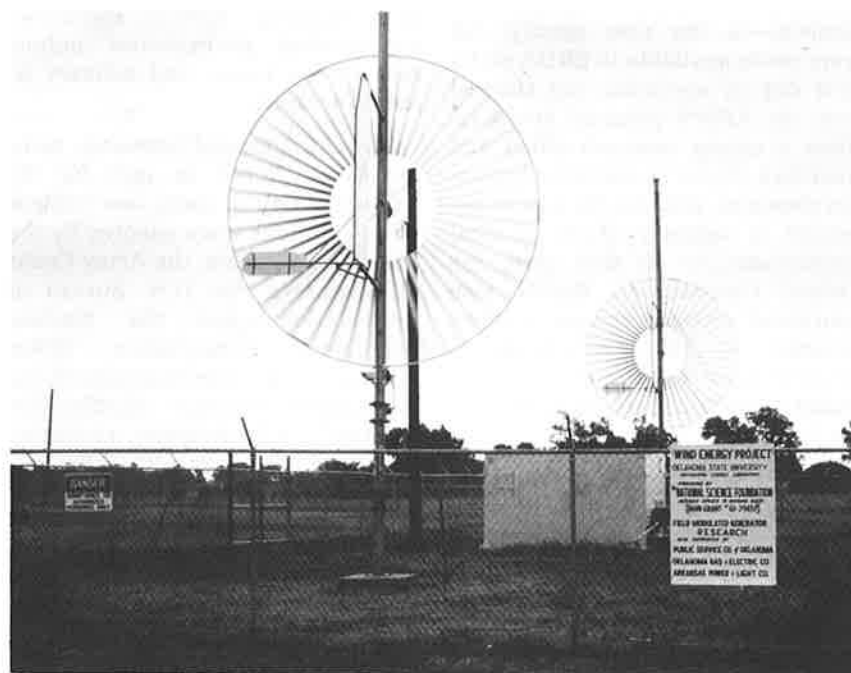
Solar Energy

The objective of the solar energy program is to provide the full technology base for widespread utilization of the Sun's energy in a manner that is environmentally, socially, and economically accept-

able. Major improvements in components and systems have resulted from the 80 projects supported in the heating and cooling of buildings—both homes and schools. In the area of solar thermal (use of the Sun's heat to generate electricity) research, NSF provided the technical background for an ERDA request for a proposal for a 10 MWe proof-of-concept ex-

periment. Similar studies were used to initiate program development plans for a solar thermal conversion system test facility, to be completed and implemented by ERDA.

From the Wind Energy Program has come a realistic assessment of the problems involved in constructing an existing state-of-the-art 100-kilowatt wind turbine generator,



In wind energy research, a priority effort has been to establish a sound data base concerning structure, materials, wind flow, and other factors to aid the design of wind turbines and help in selection of sites.

experience in operating a small system to supply electric power to a grid, and a compilation of wind characteristics and demand data in the State of Alaska. This latter applications study should be useful to other remote areas considering windpower. Additional information on wind characteristics and siting in other areas is becoming available from seven studies initiated in fiscal year 1975.

In the Ocean Thermal Program, results of technical and economic feasibility studies of the closed cycle thermal conversion system indicate a reasonably low technical risk associated with the development of such systems. Additional research has been shown to be required in support of the development of heat exchanger turbines and pumps, but no major problems have been encountered.

In photovoltaic (solar cells) energy conversion, achievements have been made in the understanding of the processes that inhibit improvement in the stability and performance of cadmium sulfide/cuprous sulfide thin film solar cells. Appropriate modifications of material composition and fabrication techniques have resulted in routine preparation of reliable solar cells of conversion efficiency in excess of 5 percent. Accelerated life testing studies indicate that carefully protected cells are stable beyond 20 years.

In the preparation of large-area solar cells, research has led to a one-step process for depositing a thin polycrystalline silicon layer containing a solar cell structure on a low-cost substrate, thus reducing the material cost and simplifying the fabrication process. Solar cells with conversion efficiencies of 3 percent have been prepared on graphite and metallurgical-grade silicon substrates. Improvement of chemical and structural properties of the silicon layer is expected to lead to 6- to 8-percent-efficient solar cells.

Utilization of solar energy research results has been accelerated through a variety of mechanisms. In some

research areas, semi-annual meetings among grantees were held; in others, workshops to bring together investigators and possible users were supported. In all cases, project reports were circulated and, where appropriate, papers presented at professional meetings and prepared for journal publication. A particularly significant activity was the RANN preparation of the Project Independence Blueprint section on Solar Energy.

Geothermal Energy

The objectives of NSF's geothermal energy program have been to investigate the technical feasibility of long-range development of geothermal resources and to investigate the social, economic, legal, and environmental aspects of geothermal developments. During fiscal year 1975 laboratory experiments and computer modeling have provided scientists with new fundamental data on heat and mass transfer of two-phase fluid (water and steam) in permeable media. Laboratory tests also indicate that pumping of geothermal brines is feasible by at least three different downhole pumping concepts: electric motor, hydraulic motor, and in-well heat exchange and steam turbine.

A significant development in the environmental aspects of geothermal research was finding that the radioactive element radon, which is released in the atmosphere by geothermal steam wells, is small and indistinguishable from the radon released by natural emissions from surrounding land masses.

New geological and geophysical field evidence in Nevada and Utah suggests deep-seated, active faults may provide an efficient "plumbing" system for high-grade geothermal reservoirs, which need not be located in association with young volcanics. Topographers have also provided new data on subsidence in California's Imperial Valley, showing that the valley's surface is sinking rapidly

in the vicinity of known but not commercially active geothermal fields.

Research findings in the geothermal program are utilized by resource development companies, electric utilities, exploration service companies, architectural and engineering firms, and State and local regulatory agencies. The RANN-sponsored "Conference on Research for the Development of Geothermal Energy Resources" at Pasadena, Calif., in September 1974, attracted 600 representatives from industry, universities, public interest groups, and government at all levels.

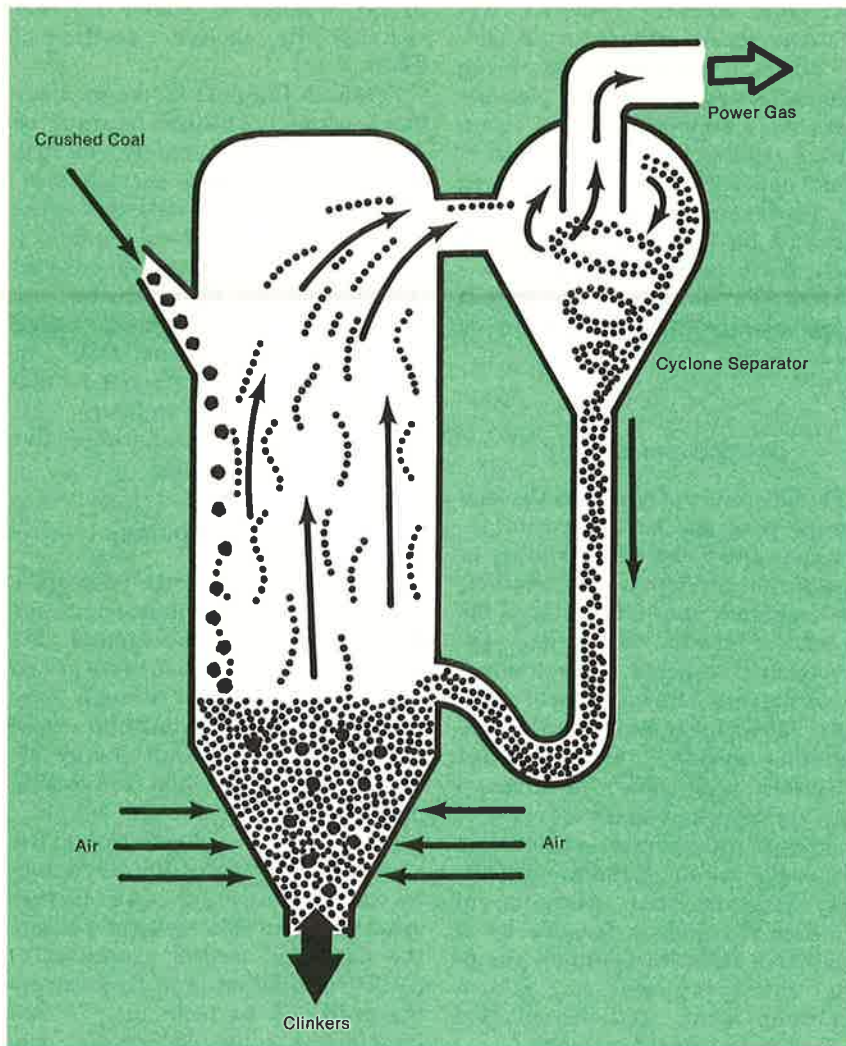
Energy Resources

The objective of this program—aimed at innovative and long-range developments—is to expand the domestic supply of reasonably priced clean fuel products through new fossil fuel production techniques and to increase the overall energy efficiency of fuel-to-fuel conversion processes.

In the area of coal conversion, the concept of fast fluidization as applied to coal gasification was further examined, and this research became the basis for several proposals to ERDA for pilot units to demonstrate the utility of the technique. In coal liquefaction, additional progress was made in the conversion of high-sulfur coals to clean fuels and in the critical area of separation of mineral matter from reacted coal slurry.

Also during the year, a workshop composed of experts from industry, universities, and Government identified the critical technology roadblocks in *in situ* recovery of oil from shale. The results of this conference were incorporated into a comprehensive plan which will be used to initiate a program of research in these recovery techniques.

Results from the Energy Resources Program are expected to be used by the industrial sector, principally petroleum and petrochemical firms, utilities, coal producers, and architectural/engineering companies



Research suggests that large amounts of power gas could be produced by combining an upper fast fluidized bed to gasify fine particles of coal and a lower section to gasify large particles and to remove ashes or clinkers.

engaged in the design of fossil fuel conversion plants. ERDA is a major user of program results in those fields where development programs appear to be feasible.

Energy Conversion and Storage

During fiscal year 1975, research on coal-fueled magnetohydrodynamic (MHD) energy conversion yielded new information on coal slag,

and studies on a non-mechanical conversion of coal to electricity demonstrated a much higher potential efficiency than originally envisioned.

In the area of superconducting magnetic energy storage, optimization studies revealed ways of reducing system costs substantially. Other research on materials fabrication for batteries showed possibilities of reducing costs through use of inexpensive starting materials and less

costly processing techniques.

Varied methods were used this year to assure rapid utilization of research results in this program. Workshops held on materials problems in MHD brought together engineers from the materials community and MHD experts from industry, nonprofit organizations, and universities.

Advanced Automotive Propulsion

Large improvements in the efficiencies of internal combustion engines depend on detailed knowledge of the chemistry and flow properties of fuels and air. This knowledge must then be embodied in mathematical models which can be used in engine design. Advances made during the past year in measurements on fuel droplets undergoing combustion may lead to improvement of combustion efficiency through fuel emulsification. Results of systematic study of problems of multidimensional two-phase models that pertain to automotive combustion should be of considerable usefulness to work in stratified charged engines.

Energy and Fuel Transportation

The primary objective of this program is to create new techniques and advance existing ones for the improvement of energy transmission from production sources to the consumer sites. Research supported in electrical power transmission is focused on electric power system analysis, reliability, security, and control, including interconnected power systems and control methods such as digital and minicomputers. This research also involves superconductivity and electrical insulating materials and physical phenomena associated with circuit breakers. Research in fuel transportation concentrates on novel ap-

proaches to cryogenic slurry transport and some safety aspects of fuel transportation.

Energy Systems

Advances made during the year in the state-of-the-art of power system stability studies are now being applied and utilized as major components in further studies by ERDA

and the Electric Power Research Institute (EPRI). Additional progress was made in solving some of the utilities' dynamic stability problems, and computer applications studies have formed bases for further support by EPRI.

Pattern recognition work and Liapunov analysis for on-line security evaluation has progressed to the point that it is currently being applied to actual power networks.

Some advances in the studies of d.c. high voltage control have also been reported, in particular, a fast multi-terminal control method now under development. Basic experimental data on the flashover process, theoretical modeling, and the application of the results to prevent flashover were obtained. These results contributed significantly to understanding some of the power system breakdown mechanisms.

ENVIRONMENT

The programs of advanced environmental research and technology provide an improved scientific basis for managing environmental resources and for evaluating natural and manmade environmental risks. Ultimately, the results of this research will prevent loss of life, injury, property damage, and ecological, social, and economic disruption. Research supported in the division is directed toward four broad issues:

- Measurement and evaluation of environmental risks and hazards
- Improved mitigation techniques
- Economic and social constraints to environmental risk management
- Risk management strategies

If governments know the physical, biological, and economic dimensions of selected environmental risks and can match that knowledge with innovative and practical mitigation techniques, they are in a position to identify workable options for lessening their adverse consequences. Thus, by developing research programs with input from decisionmakers—public officials and industrial leaders—NSF is able to greatly enhance the probability that the results will find practical applications.

It should be noted that RANN interests lie in environmental risks and hazards across the board—those that originate with man as well as those that arise from the natural environment (such as earthquakes) that directly affect human activities and well-being. Concern is not limited to pollution control, but encompasses the search for ways to enable society to cope with the full array of natural forces.

There are seven advanced environmental research and technology programs: (1) Environmental Aspects of Trace Contaminants; (2) Weather Modification; (3) Environmental Effects of Energy; (4) Regional Environmental Management; (5) Earthquake Engineering; (6) Fire Research; and (7) Societal Response to Natural Hazards and Disasters. Important achievements have been made in each of the program areas in 1975. But more importantly, the work of the programs has collectively contributed to improvements in several important national problems such as air pollution, earthquakes, and techniques for the assessment of secondary environmental impacts.

Environmental Aspects of Trace Contaminants

The Federal Government has been studying air pollution and its effect

on health, weather, and man's habitat since 1970. Research funded by RANN has identified some trace contaminants as a major cause for concern. Heavy metals like lead and cadmium, and some atmospheric pollutants, are known to be toxic, but little information has been available on how they affect the environment or how they are transformed into other substances in the environment. Now, enough has been learned about certain airborne pollutants to contribute to important industrial control programs. For example, industry in the Missouri lead-mining district has made major modifications in operating procedures and plant equipment. Several large firms there have installed bag houses, continuous pollution monitoring equipment to regulate operation, improved waste water discharge systems, improved stack design, and paved work areas.

Other research has revealed that carbon particles, or soot, catalyze the conversion of sulfur dioxide to a sulfate held to the soot particles by surface-chemical attraction. Sulfates are believed to be among the worst air pollutants. Occurring on submicron-sized "respirable" particles that deposit in the lung, the newly recognized form of sulfate may be extremely significant for human health effects. The research suggests the possibility that the control of soot

formation may be as important, or more important, than the control of the sulfur content of fuels.

It has also been shown that the effluent from a municipal incinerator, although small in total amount, can contribute a major proportion of the burden of certain hazardous metallic contaminants in urban air, for example, cadmium. Comparison with the effluent from a coal-fired powerplant shows that municipal incinerators are more likely to contribute major proportions of the respirable fine particles.

Weather Modification

The program continued to emphasize research on weather hazard mitigation, the inadvertent effects of weather modification technology, and the social and economic effects. The major effort continued to be the National Hail Research Experiment where the overall goal is to determine the potential for suppressing hail damage by cloud seeding.

Results of research in weather modification show that air pollution is partially responsible for changes in weather patterns downwind of urban areas. Cities produce particulate matter that rises into clouds (or actually creates them); the particles act as nuclei around which rain and hail form. Preliminary findings indicated, for example, that areas downwind of St. Louis get 25 percent more rain and 200 percent more hail than upwind areas.

Environmental Effects of Energy

One of the new methods advanced by science and industry to meet the increasing need for energy is the multipurpose offshore artificial island, which could serve as a combination port facility, energy park, and site for energy-intensive manufacturing plants. Studies indicate that such islands would be feasible in the Northeast from

Virginia to New England, and that construction is possible and could be carried out in an environmentally acceptable manner with the present level of technology.

Studies in the Philadelphia metropolitan area indicate that storm sewers release an average of almost 8,000 pounds of petroleum each day into the Delaware River. Also, pollution loadings many times the daily average occur several times a year because most of the petroleum influx occurs during storms. Current projects indicate that when planned waste treatment processes become operative, the seven refineries in the Delaware Estuary will discharge an aggregate of about 2,000 pounds of petroleum daily. Although a significant reduction in petroleum pollution will occur with these new treatment processes, petroleum will continue to be a major source of pollution in the Delaware Estuary.

Regional Environmental Management

Development in the United States has all too often been a story of sad surprises for what originally seemed to be sound planning. Case upon case exists where towns seek to attract new industry but fail to consider the cost of new public services, higher housing prices and taxes, social dislocations, and a host of related effects. Recognizing this, RANN supports research to provide practical, useful methods for assessing the severity of the secondary and tertiary environmental effects of particular major regional developments or facilities, such as new powerplants or mining operations.

An example of a potential problem area was Chambers County, Tex., a rural Gulf Coast enclave located between the metropolitan center of Houston-Galveston and Beaumont-Port Arthur. The county was faced with the prospects of having a large steel mill located within its confines, along with several other large industrial facilities. A rather

revolutionary concept was devised for Chambers County by researchers working with local officials—the use of performance standards based on the impact of the land uses and the ability of the environment to support them instead of more arbitrary zoning regulations.

In other research, a set of mathematical models has been developed to predict the land use, environmental, and demographic consequences of major siting decisions. This capability is being adopted and expanded upon by ERDA for use in powerplant and power park siting.

Earthquake Engineering

The Earthquake Engineering Program is designed to develop measures that reduce the vulnerability of structures to damage. They entail research on structural design standards, land use planning, and on human and institutional responses before, during, and after a quake. An important cause of collapse of dams during an earthquake is liquefaction, a situation in which soil saturated with water becomes liquid-like. RANN-supported research has developed a technique for testing soil to predict the probability of liquefaction, and the technique has been used in the subsequent inspection of over 1,100 dams in California. Also, earthquake-resistant design criteria and procedures are now being integrated into manuals of practice for the construction industry and public agencies in a form readily adaptable to building codes in different parts of the country. Partly as a result of RANN-supported research, a high degree of earthquake resistance is now a standard feature of the design and construction of dams and nuclear powerplants. The same is true for many of the newer high-rise buildings.

The program continues to support the National Information Service for Earthquake Engineering at the California Institute of Technology

and the University of California, Berkeley, a one-stop distribution center for people interested in any aspect of earthquakes. The service also provides earthquake-oriented computer programs, many of which have been developed under NSF sponsorship.

Fire Research

RANN's Fire Research Program, now 4 years old, has been in the process of transferring support for projects from NSF to the Department of Commerce; this transfer will be completed during fiscal year 1976. The fire research supported by the Foundation has substantially increased existing knowledge and will provide a broad base of knowledge for continued research by the National Fire Prevention and Control Administration and the Fire Research Center of the National Bureau of Standards.

Pioneering architectural research at the University of California, Berkeley, has provided a technique for the documentation and mapping of fire incidents that gives a clear chronological presentation of events and activities during a fire. The method provides useful information for the architect concerned with fire safety. Another task has shown the importance of furnishing and contents design in relation to fire hazard, particularly that many synthetics should be used with greater caution.

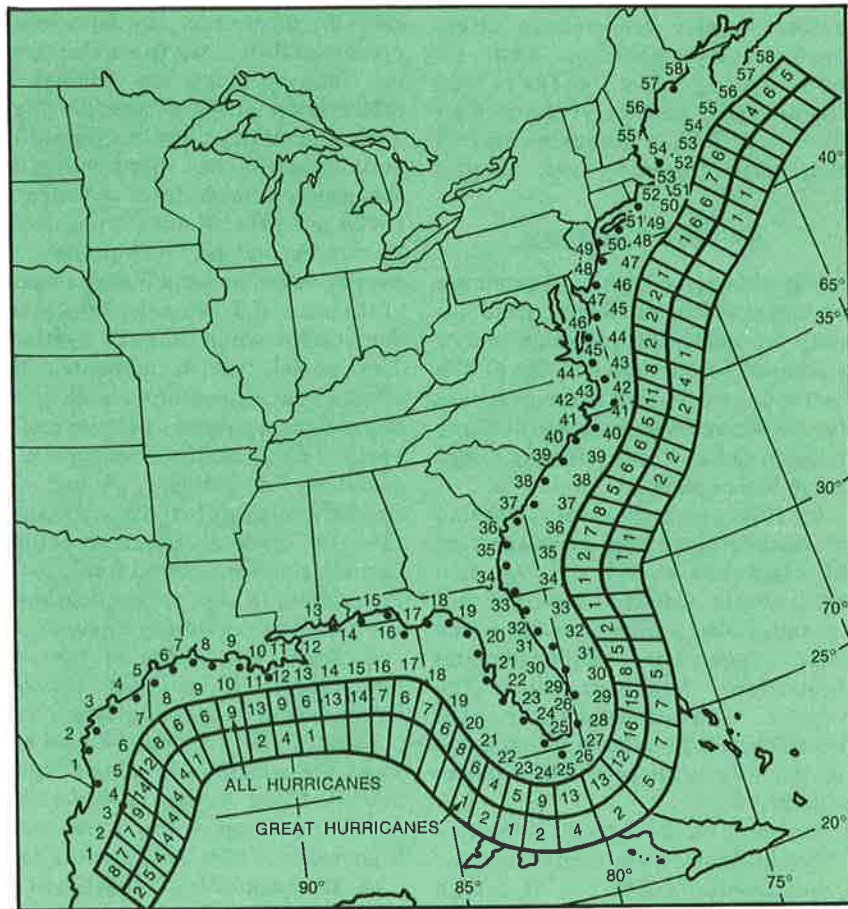
At the University of Utah Flammability Research Center, research has resulted in a model for determining the relative inhalation toxicity under fire stress conditions. The model permits simultaneous evaluation of physiological parameters (blood, central and peripheral nervous system, and respiratory) and behavioral aspects for determining survival response. It is the most advanced model available and could

form the basis of new testing standards.

Societal Response to Natural Hazards and Disasters

In studies on the social impact of natural hazards and disasters, an assessment of research on 15 geophysical hazards has shown that, to date, such research has been largely oriented to technological solutions to problems of natural

hazards. The study recommends a major shift in research to support work on all the important social, economic, and political factors involved in hazard reduction if a balanced approach is to be attained. Based on this completed assessment of research priorities for 15 natural hazards, RANN is developing an expanded research program that will further strengthen its ties with potential users to assure maximum utilization of research results in real-life environmental decisionmaking.



From a study of the social impact of natural hazards and disasters, this map shows estimates of the probability (percent) of a hurricane (with winds exceeding 73 mph) or a great hurricane (with winds exceeding 125 mph) affecting 50-mile segments of the U.S. coastline in any one year. [Drawing after Simpson and Lawrence in White and Haas, *Assessment of Research on Natural Hazards*]

ADVANCED PRODUCTIVITY RESEARCH AND TECHNOLOGY

Advanced Productivity Research and Technology programs are concerned with technological options for increasing productivity and with the social, economic, public service delivery, and regulation of the private sector. In fiscal year 1975, priority was placed on studies to adapt existing technology to increase productivity, on research to assess the benefits and costs of alternative public policies designed to affect productivity growth, and on evaluating the effects of technological and social changes on the use of human resources and on those most affected by such changes.

Public Technology

The objectives of this program are to find ways of increasing productivity by more cost-effective use of advanced technologies in the public sector and to develop a research base for decisionmakers which will allow widespread and cost-effective use of these technologies.

In 1975 researchers at Columbia University completed an evaluation of alternative energy recovery and solid waste disposal methods and recommended a plan of action to the New York City Environmental Protection Administration. The research team estimated that the plan would result in substantial savings to the city with renovation of incinerators.

Research on the impact of high-rise office buildings on municipal service requirements, conducted at Lehigh University, resulted in recommendations that cities require an "impact review" of plans to construct high-rises. The researchers suggest that such reviews should consider factors such as the use of tax incentives to encourage rebuilding of the required utility infrastructure, requirements for fire resistance standards,

provisions for crime control measures in the high-rise office buildings, and possible weather effects.

Studies initiated in prior years of the feasibility of using telecommunications technology to improve productivity of service delivery led to the support of three field experiments to test the costs and benefits of adopting two-way cable TV for training fire department personnel (Michigan State University), for improving the delivery of information on social services (New York University), and for providing adult education and coordinating the services available from a range of social agencies (Rand Corporation). Researchers at Johns Hopkins University developed and tested a model of the costs of development and of the demand for urban cable TV systems. The model, which estimates the effects on economic viability of alternative regulatory policies and of various applications of a system to social service delivery, proved sufficiently valuable for policy purposes that the Federal Communications Commission transferred funds to the Foundation to support application of the model to regulatory analysis.

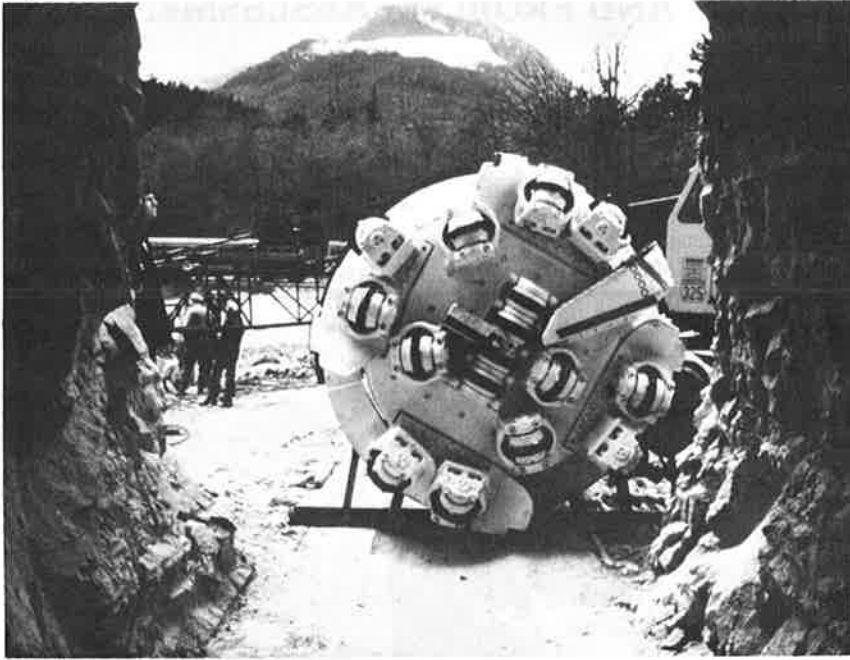
A study of the use of telecommunications to support primary health care delivery in nursing homes concluded that telephone-based services are adequate for this purpose and that the health care delivery system developed could deliver a high level of care at a modest cost. The Massachusetts Department of Public Welfare has contracted to continue the program on an operational basis and is expected to use it as a basis for other such systems in Massachusetts.

In instrumentation technology, Stanford University researchers have developed a computerized X-ray scanner which provides a sub-

stantial increase in information for medical diagnosis over conventional techniques at reduced costs, increased speed, and improved diagnostic capability. Other significant activities in 1975 dealt with an evaluation of recent advances in ultrasonic diagnostic instrumentation. These advances have been so successful that they have outstripped operator training programs as well as the understanding of them and their use by the medical community. Thus, research is planned to produce the new knowledge required to ensure the widespread use of ultrasonic imaging instrumentation.

During fiscal year 1975, considerable progress was made in excavation technology toward increased excavation rates and reduced costs. For example, a water-jet assisted tunnel-boring machine is now being tested under field conditions by the Colorado School of Mines. Research continued on improved materials and environment enhancement by chemicals (Martin-Marietta Laboratories) to provide means for rapid excavation. The successful application of acoustic holography by Holosonics, Inc., in the laboratory has resulted in an accelerated effort to utilize this technology for the prediction of geologic conditions ahead of an advancing excavation face. An instrumentation manual for underground structures has been completed by the University of Illinois and is now being distributed. The completion of a hard rock tunnel-cost model at MIT makes available more reliable methods of cost estimating to owners, engineers, and contractors.

Better contracting procedures for excavation have been recommended by the U.S. National Commission on Tunneling Technology and are presently being implemented with



In cutting a tunnel through rock, this hybrid tunnel boring machine uses high-pressure pulses of water to help shatter rock, which is then more easily removed by the borer.

the expectation that they will remove many of the barriers to technological advancement. After 3 years of support, a data center on geologic materials and underground construction is now available to users on a subscription basis at Purdue University.

Public Policy and Economic Productivity

This area focuses on the management and improvement of government performance and productivity. Research at the University of Oregon on the financing of municipal debt studied the issues involved in how

municipalities could set most advantageous interest rates on municipal bonds. Results were made available to the Oregon State Legislature, which created a Municipal Debt Advisory Commission and which passed legislation requiring municipalities to comply with specific standards when bonds were issued.

A series of assessments of the scientific validity and policy utility of research on municipal systems and human resources has provided a set of state-of-the-art summaries. For example, a review of research on the use of physician assistants and nurse practitioners in health care suggests

that these personnel, in contrast to generally held opinion, are accepted as practitioners by consumers, do perform as well as physicians on low- and mid-level tasks, and can significantly increase physician productivity. They also appear to be profitable to their employers, but there is little evidence of resulting financial benefit to consumers.

Another assessment, this one of innovations in police patrolling, concluded that results of innovations in the allocation of police manpower were generally inconclusive and provided no sound basis for widespread adoption of innovations. Among the more important reasons for these shortcomings were the failure of most interventions to conform to an adequate evaluation design, the difficulty of maintaining innovations in a real-time setting, and the comparatively small scale on which the interventions were conducted.

Studies on intergovernmental structure and service productivity dealt with the impact of general revenue sharing on the operations of local and State governments and with the attitudes and opinions of local governmental officials to the revenue sharing program. Preliminary results indicate that the major effect of revenue sharing to date has been in helping local governments to avoid or minimize tax increases caused by higher costs, particularly increases related to inflation. For the most part, it has not resulted in new or improved services, partly because of the perceived temporary nature of the program. Reports from these research projects were published in a Committee Print by the U.S. Senate Committee on Government Operations.

EXPLORATORY RESEARCH AND PROBLEM ASSESSMENT

Exploratory Research and Problem Assessment programs initiate studies on selected problems that have potential for major national impact. Gaps in the spectrum of existing research relevant to national needs are approached through problem assessment and definition studies, exploratory research projects, and technology assessments.

Technology Assessment

Emphasis continued in fiscal year 1975 on systematic studies of the full range of societal effects that may stem from the introduction, extension, or modification of a technology, and with the overall objective of developing a better information base for policymaking and decision processes at all levels of our society. Efforts carried out this past year included substantive assessment projects in areas of transportation, environmental control, health, and information technologies.

Assessments have been completed covering topics of geothermal resource development, electronic funds transfer, metric conversion, biomedical technologies, and hydrogen energy. Congressional committees have been particularly interested in the electronic funds transfer assessment and there has been considerable demand for the assessment of automotive emission regulation.

Support was also provided for a second regional conference on technology assessment—held in Salt Lake City, Utah—and research was initiated on methodology for technology assessment of retrospective studies of earlier technological innovations.

Results of the Technology Assessment Program indicated that improved techniques for forecasting and analysis are needed for more efficient and effective assessments, and future efforts are planned in

these areas as indicated earlier. This work, as well as selection and evaluation of substantive assessment topics, will be guided by a RANN Interagency Technology Assessment Coordinating Panel composed of representatives of appropriate executive branch agencies.

Exploratory Research

Typical projects conducted in fiscal year 1975 included:

- The development and validation of a tactile-phonetic reading method for children with learning disabilities. The use of tactile informa-



Hugging the tactile device that mechanically traces letters on their stomachs, children learn to decode letters in a tactile-phonetic reading program for aiding certain types of reading disabilities.

tion (letters drawn on the skin) combined with other sensory modalities (sight, sound, kinesthetic) has shown significant promise in the diagnosis and remediation of certain types of reading disabilities. The project, which focused initially on small groups of children in several Philadelphia private schools, has shown sufficient promise to justify a larger scale trial in the Philadelphia public schools.

- Two books of analysis on the Law of the Sea, as it relates to the ocean environment and to the living resources of the sea, were produced by the American Society of International Law. In *Who Protects the Ocean?* an economist, a political scientist, and a chemist teamed with three lawyers to assess what is at stake in the Third Law of the Sea Conference regarding mankind's interest in preserving the integrity of the marine environment. In *The Future of International Fisheries Management*, lawyers and economists analyzed the potential impacts of various institutions and innovations in technology on the fisheries resources of the oceans.

- The Johns Hopkins Ocean Policy Project, in October 1974, sponsored a conference on Conflict and Order in Ocean Relations, involving scholars of ocean affairs as well as policy-makers from the executive branch and the Congress. The proceedings of the conference, which analyze the current situation, alternatives, and future prospects for Law of the Sea, have been printed by the Government Printing Office and distributed to relevant scholars and policy-makers. A new award, to the University of Delaware, will analyze some of the options available for fisheries management in the Northwest Atlantic, given a 200-mile zone of jurisdiction over fisheries resources.

- Research on enzyme technology includes a preliminary economic analysis of several phases of a cell-free enzyme synthesis system (ATP regeneration and enzyme isolation) and shows significant advantages over the classic system for producing antibiotics. Researchers at North Carolina State University have successfully isolated and immobilized an enzyme that catalyzes the oxidation of sulfhydryl-containing substances. The enzyme has been used successfully to treat ultra-high temperature sterilized milk in order to eliminate the associated "heated" flavor. The combination of ultra-high temperature sterilization and immobilized sulfhydryl oxidase could have a dramatic impact on the processing operations and milk distribution in the United States, because the treated milk may not require refrigeration for normal, pre-use storage.

- A beam-bending machine, initially designed with NSF support for ship frame fabrication, has since attracted industrial attention for adaptation to bending techniques for large hydrogen-cooled copper stator coils used on 55 million volt-ampere generators. These coils are presently handcrafted with great difficulty. By utilizing the beam-bending machine, manufacturers expect to obtain precision bends, shortened production times, and significant economic advantages over present methods. Research at the University of Rochester and the Charles S. Draper Laboratory has substantially broadened the knowledge base for automated parts manufacturing and industrial assembly systems during the past year. It is anticipated that much of the modeling that has been done in this area will be applied to actual assembly lines during the coming year.

Resources

The RANN Resources Program was initiated in fiscal year 1975 to carry out research on renewable resources, nonrenewable resources, and resource policy. Renewable resources projects relate to problems with food, fiber, animal feed, and agricultural and forest wasteland. Nonrenewable resources relate to minerals, waste disposal and pollution associated with mining and extraction operations, and the utilization of urban demolition waste. Resource policy questions are concerned with such issues as the vulnerability of agriculture to energy constraints, the need for better nutrition education and standards in the United States, and the evaluation and projection of minerals requirements and shortfalls for the next decade.

While the Resources Program is new, several early accomplishments can be noted. First, in a study carried out by Washington University in St. Louis, the energy cost component for 14 field crops under a variety of conditions was calculated. In most cases, energy price increases have not been higher than other price increases to encourage less energy-intensive agricultural methods.

From a survey of nonconventional and conventional protein resources in the United States, researchers at MIT have concluded that, generally, the U.S. agricultural sector can supply projected U.S. needs through the year 2000 without serious difficulty and at reasonable prices. However, the study suggests that the role of the United States as a major exporter of protein must be considered as an alternative option, and as such it might be worthwhile to carry out an intensive research effort in selected protein areas to improve productivity for export.

INTERGOVERNMENTAL SCIENCE AND RESEARCH UTILIZATION

Intergovernmental Science Program

In fiscal year 1975, the Intergovernmental Science Program addressed two primary needs—the development of State and local capability to use research and technology more effectively, and the mobilization of existing scientific and technological resources to provide better service to State and local governments.

In the State executive assistance area, the National Governors' Conference received NSF funding to assist in the establishment of the Governors' Energy Project. The project has now gone beyond the simple exchange of information and is developing a process to stimulate a national energy program with heavy orientation toward energy conservation measures.

Projects have continued in individual states where activities usually have focused initially on a particular issue but then have evolved into the development of a broader capability for providing research and technological inputs into State government. Additional funding during the year was provided to Hawaii for geothermal energy policy activities and to California for the development of a research and technology policy management capability. An emerging emphasis has been on the role that public interest groups can play in the science assistance program.

In the State legislative area, an NSF-funded Science and Technology Project with a full-time professional staff has been developed with the National Conference of State Legislatures (NCSL). The staff has organized conferences, seminars, and workshops on specific, timely topics such as coal utilization as a response to the energy crisis, and the States' role in radioactive material management.

MISTIC (Model Interstate Scientific and Technical Information Clearinghouse) is an NCSL pilot program to investigate the effectiveness of an information referral system, initially between State legislators in the NCSL Intergovernmental Relations Committee ("users") and five Federal agencies—ERDA, NBS/DOC, NASA, DOT, and NSF. NSF's Intergovernmental Science Program has also supported a number of demonstration programs in State legislatures, notably California, New York, Kentucky, and Illinois, and initiated several more in fiscal year 1975, in such States as Massachusetts, Wisconsin, and North Dakota. Additionally, the program works with legislatures that join together on a regional basis to deal with technology-related problems.

During 1975, the local government science assistance program focused on building networks to meet the widely varying needs of municipal governments. For example, the California Innovation Group is an outgrowth of the successful "Four Cities" project, which linked four California cities with science advisors from aerospace and high technology industry. The Alabama Innovation Group began at Auburn University, where the School of Engineering was used as the backup support for two full-time engineer extension field agents working in rural towns and counties. Results of this program in providing expertise in areas such as land use planning, modern management techniques, and traffic control have led local governments to assume an increasingly significant proportion of the cost.

In addition to the geographically based local government projects, there are projects that have been created to serve specific functions. The Urban Consortium for

Technology Initiatives, a union of the 27 largest U.S. cities and six large urban counties, is conducting a project underwritten by NSF and the U.S. Department of Transportation to help cities organize themselves for maximum receptivity to research and development. The primary purpose of this consortium is to create an urban research and development agenda ranked on a priority basis to encourage Federal and private investment. During this year, the consortium received over 1,200 "needs" statements and is currently making a priority ranking of these needs according to broad categories.

- A Management Innovations Transfer network, operated by the International City Management Association, is collecting and disseminating established information on significant innovations in municipal management techniques, such as LOGIC (a cooperative municipal information system), and in technology, such as fire department use of minipumpers to increase their tactical flexibility. Innovations are disseminated through the project only after they have been evaluated and have demonstrated effectiveness and transferability.

Research Utilization Program

Since the ultimate goal of RANN's activities is the application of research results, RANN's utilization programs are directed to finding out how utilization can best be achieved, when, where, at what cost, and by whom. In the past few years, RANN has increased the emphasis on the inclusion and execution of appropriate utilization plans as part of each research award. At the time, a variety of separate utilization projects were developed to test and disseminate research results from individual projects that appeared to

have the potential for significant impact on the user communities.

A number of projects were started during fiscal year 1975 which were intended to accelerate the application of specific RANN outputs, or to develop mechanisms that would provide delivery and communication systems for various categories of RANN research. Examples of these activities include awards to:

- Kentucky's Office for Local Government to develop a network of communities in that State that would select, apply, and evaluate RANN and other research intended to help solve problems of local governments.

- Oklahoma State University to test the capability of the State's Extension Service in helping local governments solve environmental problems by applying research funded by RANN and other public and private organizations.

- The State of Washington's Department of Natural Resources to test the more general applicability of a previously developed RANN model intended to provide guidance for managing forests, particularly the harvesting of trees with minimal environmental impact.

- Public Technology, Inc., to develop a handbook concerned with improved use of computer technology that would put smaller local governments in a better position to utilize RANN productivity products.

- Harvard University for a workshop to bring State and local employees together with graduate students and faculty to test and learn to apply a regional environmental model developed under a RANN grant.

- Colorado State University to test and, if warranted, disseminate results of a model to apply systems analysis in the management of range land used to raise cattle and sheep. It is projected that the model will make it possible to increase the yield of an average ranch by two to three times and significantly contribute to the availability of reasonably priced beef and lamb.

Another approach is testing several methods for accelerating the application of research and development at the local level. One incentive concept being investigated deals with the question of whether the traditional cooperative extension system, with its network of county agents, can deliver non-agricultural technical assistance by employing specially trained agents within the system. In slightly less than a year of operation, the Center for Local Government Technology at Oklahoma State University has completed or has under way seven "solution packages" for public service problems with six more projected for development.

Another program is testing whether a network of Technology Agents and backup laboratories can accelerate the application of science and technology to the solution of municipal problems in 27 randomly selected cities and, in so doing, aid in the formation of aggregated markets for the requisite technology required by these communities. Already, in Little Rock, Ark., the Agent reorganized the refuse collection system at an expected reduction in operating costs of \$366,000. Energy conservation efforts have yielded an annual savings of \$200,000 in West Hartford, Conn.; \$900,000 in Jersey

City, N.J.; and \$178,000 after only a few months in Nashville, Tenn.

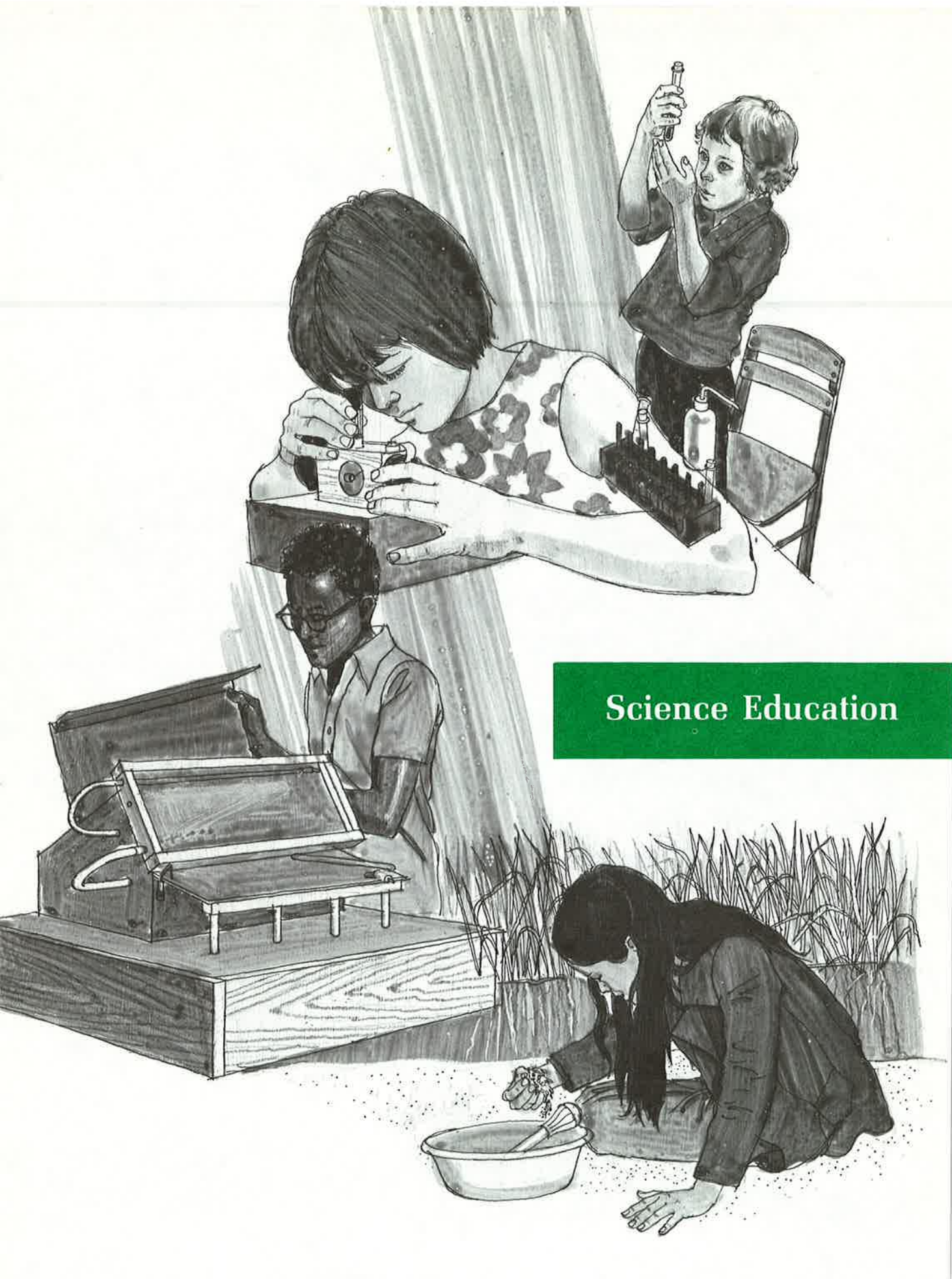
Experimental R&D Incentives

The basic objective of this program is to experiment with incentives to accelerate the use of science and technology by industry and State and local governments and to increase non-Federal investment in research and development. Among the experiments being conducted in 1975, several have already demonstrated significant potential.

The Innovation Centers Experiment is testing whether Government-funded, university-based "innovation centers" can, through project-oriented laboratory approaches, increase the supply and probability of success of technological entrepreneurs, accelerate the commercial introduction of new technology-based products and processes, and become financially self-supporting.

RANN is supporting several experiments whereby Federal or accredited commercial testing laboratories can validate the performance claims advanced by the developers of new products and processes. Three Federal laboratories have conducted tests on a waste purification system for house use, a process for treating sewage, and a limited-range public transit system.

In the medical instrumentation area, a test is being made to determine whether the establishment of performance specifications for an ultrasonic image device to be used for non-invasive diagnosis, coupled with free Government clinical evaluation, will shorten the lead time to market acceptance of newly developed biomedical instrumentation.



Science Education



Science Education

The Foundation has two major responsibilities in the area of science education. One is to assure that education in the sciences at all levels keeps pace with the changing nature and needs of American society; this is the goal of NSF's Science Education Improvement Program. The second is to assure an adequate supply of highly trained young scientists to maintain the strength of the Nation's science research capabilities, and this is done through the program of Graduate Student Support.

A fundamental goal of all of the Foundation's education programs—from elementary school through Ph.D.—is to seek ways to make the most of the Nation's scientific talent, both by upgrading educational processes and by encouraging the participation of people from all parts of society, especially the groups traditionally underrepresented in science—disadvantaged minorities and women.

NSF has used a number of approaches to carry out its science

education improvement activities, paying attention both to the students who may someday be scientists themselves and also to the much larger number of students who, though not engaged in scientific or technical occupations, will nonetheless find themselves living in a world strongly affected by science and technology. So a strong element of NSF's program is to improve science education for a broad range of students; in that way a substantially increased number of people can make effective use of the processes and results of science in their work and personal lives regardless of their occupations, and they will also be better able to understand public issues and participate in policymaking involving science and technology. Major events in 1975 provided a good indication of how many important issues will be interwoven with science and technology from now on; even as mundane an action as reading the newspaper nowadays confronts us with problems of competing energy technologies, conflicts

between our daily needs and long-term environmental effects, uncertainty of world food supplies, and theories and countertheories to explain and solve our social problems.

To meet the country's changing educational needs the Foundation supports many different kinds of projects—development of new curricula and of modern instructional technologies; experiments with new instructional organizations, strategies, and methodologies; and the analysis, development, and evaluation of experimental projects that can focus science education resources on emerging problems on a timely basis. The result is a rich and varied range of educational materials and model projects that the Nation's thousands of educational institutions, public and private, can draw on in upgrading their own evolving programs. Highlights of the Foundation's activities in fiscal year 1975 in support of these goals are reported on the following pages.

GRADUATE STUDENT SUPPORT

The primary objective of the Graduate Student Support activity is to help at least a modest number of the Nation's most talented graduate students in the sciences obtain the education needed to become first-line researchers. Continuing an emphasis begun in fiscal year 1974 to train

scientific and engineering manpower in energy, NSF initiated a new program of postdoctoral energy-related fellowships in fiscal year 1975 to provide experience in energy-related study and research to recent postdoctorals selected on the basis of ability. The fiscal year 1975 energy-

related activities—including both graduate traineeships and postdoctoral components—contributed to both an immediate and a long-term national requirement of strengthening the energy-related science base of the Nation.

Table 6
Graduate Student Support
Fiscal year 1975

	Application		Awards		Individuals Supported
	No.	Amount Requested	No.	Amount	
Graduate Fellowship Program	16,745	\$42,000,000	576	\$9,502,283	2576
Energy-Related Postdoctoral Fellowship Program	332	4,500,000	110	1,296,231	110
Energy-Related Traineeship Program	376	15,400,000	26	2,400,019	107

¹ Includes applications for 26 reinstatements of prior year awards and 946 continuations of prior year awards.

² Includes 26 reinstatements of prior year awards.

³ Proposals, not applications.

Graduate Fellowships

In fiscal year 1975, new 3-year Graduate Fellowships were awarded to 550 students in the sciences, mathematics, and engineering, with selection based upon ability. More than 5,700 students applied for these NSF Fellowships, and the awards represent a success ratio of 9.5 percent. Honorable mention—defined as status which would have rated a fellowship had sufficient funds been available—was accorded to an additional 2,078.

Each fellowship was awarded for 3 years of graduate study to beginning graduate students. Fellowships may be used over a 5-year period, which permits students to fit other scientific and academic experiences into their education programs. Each fellowship carries a stipend of \$3,600 per year for full-time study, and an education allowance of \$3,000 to a

U.S. institution in lieu of tuition and fees.

Fellowship awards were distributed in a variety of fields: 11 percent in mathematics, 12 percent in engineering, 20 percent in physical sciences, 27 percent in social sciences and psychology, and 30 percent in biological sciences.

Energy-Related Graduate Traineeships

To help meet the Nation's future energy research needs, the Foundation awarded grants to 26 institutions, providing for a total of 107 Energy-Related Graduate (ERG) Traineeships. These traineeships will focus on one of two research areas: coal or the environmental effects of non-nuclear energy production. Each traineeship provides 3 years of support for advanced studies leading to doctoral or

masters' degrees. An ERG Traineeship carries a stipend of \$3,000 per year and a \$3,000 per year allowance to the institution in lieu of tuition and fees.

Energy-Related Postdoctoral Fellowships

One hundred and ten young scientists demonstrating special aptitudes for research and interest in energy-related problems were awarded National Science Foundation Energy-Related Postdoctoral Fellowships. The awards, the first under this new program, were made to individuals who have recently received the doctorate degree and who are U.S. citizens or nationals. Selections were made on the basis of merit from among 332 applicants.

Each applicant presented a plan of energy-related study or research. Seventy-one awards were made in the physical sciences, mathematics, and engineering; 18 in the life sciences; 12 in the social sciences and psychology; and 9 in interdisciplinary fields.

The Postdoctoral Fellowships provided a stipend of \$12,000 per year, pro-rated at \$1,000 per month, for full-time study or research, with a tenure period of 6 months to a year. In addition, the fellowships provide an institutional allowance of \$1,200 for educational and research costs for the Fellows attending U.S. institutions of higher education.

IMPROVEMENT OF EDUCATION FOR CAREERS IN SCIENCE

To improve education for individuals contemplating careers in science NSF supports activities both to maintain the quality of instruction in traditional programs and to ex-

periment with new approaches involving prototype materials that promise more effectiveness. Special concern was shown in fiscal year 1975 for the development of new

instructional programs, either single or interdisciplinary, which would lead to a broadening of the scientific and technical career options for the individual student. Also, wherever

Table 7
Science Education Improvement
Improvement of Education for Careers in Science
Fiscal Year 1975

	Proposals		Awards		Individuals Supported
	No.	Amount	No.	Amount	
Secondary School Program					
Materials Development, Testing and Evaluation	4	\$799,083	4	\$628,000	NA
Instructional Improvement					
Implementation	20	1,047,678	9	399,500	483
Student-Oriented Program					
Student Science Training	258	5,369,060	105	1,747,220	3,400
Undergraduate Research					
Participation	415	6,554,529	224	2,873,953	1,794
Student-Originated Studies	206	2,892,160	86	1,150,213	727
Alternatives in Higher Education Program					
Instructional Materials and Modes	63	8,943,670	39	3,993,654	NA
New Degree Programs	4	1,414,312	3	888,505	NA
College Faculty Workshops	32	1,814,624	21	1,193,979	2,375
Faculty Research Participation	119	3,353,131	66	972,080	144
Instructional Scientific Equipment	1,891	19,000,000	552	4,457,459	NA
Faculty Fellowships in Science Applied to Societal Problems	598	9,600,000	93	1,555,536	93
Senior Foreign Energy Scholars	23	500,000	21	428,300	21
Science and Engineering Technician Education	24	4,576,203	13	1,989,150	NA
Continuing Education for Scientists and Engineers	13	3,353,131	4	1,109,330	NA
Ethnic Minorities and Women in Science					
Minority Institutions Science Improvement	37	9,959,240	26	4,958,403	NA
Minorities and Women in Science	33	2,150,000	10	392,248	400
Total, Improvement of Education for Careers in Science	3,740	\$81,326,821	1,276	\$28,737,530	9,437

possible, the Foundation attempted to give emphasis to those activities that were energy-related and, where appropriate, to encourage the academic community to emphasize instructional programs that are responsive to emerging problems in renewable and nonrenewable national resources.

Secondary School Program

Materials, Development, Testing, and Evaluation

Many grants awarded for "careers in science" at the secondary level also could be classified as having a science "literacy" component—that is, material appropriate for students who will not have science careers. The two major awards of this kind were for an Individualized Science Instructional System for high school use and the Human Behavior Curriculum Project, which is preparing a secondary school level

curriculum in psychology. Substantial support was made available for the Biomedical Interdisciplinary Curriculum Project sponsored by the California Committee on Regional Medical Programs; this project has a large "careers" component. A number of smaller career-oriented grants included one to Howard Fehr, Teachers College, Columbia University, for completion of work on the Secondary School Mathematics Curriculum Improvement Study. Among the others are support for the Regional Center in Mathematics under the direction of Ruth Hoffman at the University of Denver; the Teacher's Center at Southern Illinois University, Edwardsville, under Thomas O'Brien; the Federation for Unified Science Education headquartered at Columbus, Ohio, under the direction of Victor Showalter; Exploring Human Nature, being completed under Anita Gil at the Education Development Center; and the Analysis of Operational School

Mathematics Curricula directed by Robert Davis at the University of Illinois.

Instructional Improvement Implementation

Support provided in fiscal year 1975 for the improvement, through curriculum implementation, of secondary school education for students likely to embark on science-related careers was at the same level of funding as in fiscal year 1974. Nine implementation projects provided opportunities for 483 secondary school teachers and other resource personnel—people who must decide on the use of instructional materials in their local school systems—to increase their awareness and familiarity of a variety of new curricular materials in mathematics, chemistry, or the biomedical sciences. Other projects were designed to acquaint State and local supervisory or resource personnel with specific curricula.

Student-Oriented Programs

The three Student-Oriented Programs provide talented students with science learning opportunities that go beyond those offered in the curricula of most of the Nation's schools and colleges. The programs encourage increased independence of the students, stimulate their interest in science, and give the students more responsibility for guiding their own learning.

Student Science Training

Through Student Science Training, secondary school students receive special instruction in science and participate in a college or university research project. In all, some 3,400 student participants were involved in the 105 projects supported in 1975; 44 of the projects, more than a third of the total, were for high-ability secondary school students whose backgrounds have been limited by the facilities and instruction available at their own schools.



A student participating in the Student Science Training program in wildlife biology at Berea College in Kentucky does her outdoor laboratory work in the college forest.

Undergraduate Research Participation

Support provided through Undergraduate Research Participation allowed 1,794 undergraduates who had completed a substantial portion of their science requirements to work full-time with faculty members on research projects. In 1975 this

program was open to proposals in all science disciplines but, where possible, highest priority was given to proposals dealing with energy problems. Among the 224 projects at 273 colleges and universities, one was designed to help undergraduates become acquainted with the research atmosphere of an industrial laboratory.

Student-Originated Studies

Through Student-Originated Studies, undergraduates or combinations of undergraduate and graduate students, who organize their own groups, conceive and write proposals requesting support to carry out their own research activities with minimal faculty supervision. Most projects are designed to provide data to local governmental agencies on planning or administering public programs. In 1975, 86 awards to 70 colleges and universities supported the work of 727 students.

Alternatives in Higher Education

Projects in this category are intended to increase the educational options for people using science and engineering in the solution of today's problems as well as for those people going into academic or industrial research positions. In fiscal year 1975, the program focused on development of experimental course materials or those dealing with new areas of science; new modes of delivering science instruction; development of alternatives to the traditional degree programs; increasing the competence of college teachers regarding national problems; improvement of undergraduate courses through the use of new instructional scientific equipment; and development of prototype programs for technical personnel to assist scientists and engineers.

Instructional Materials and Modes

Development of materials for introductory and core science/technology studies remains an important element of this program. In 1975 it has been supplemented by development of materials aimed at specific national needs and by the exploration of cooperative distribution systems. For example, the Polytechnic Institute of New York is developing approximately 15 modules, each covering a 3-hour laboratory experi-



A Pennsylvania student in the Student Science Training program at Shippensburg State College develops a working model of a solar house as his research project.

ment in polymer chemistry, a field of major industrial importance with a need for up-to-date educational materials. Also, the Georgia Institute of Technology is continuing to produce graduate-level films on traffic signal design and function, using animation, graphs, split-screen photography, and compressed time techniques.

Project Bio-Tech is in the process of completing 160 instructional modules for biological laboratory techniques. The acceptance and demand for these materials may be greater than anticipated. Projects of the American Political Science Association and the International

Studies Association will produce sets of instructional units using analytic tools and concepts from all the social sciences and the results of recent research. The units combine problem solving with course updating.

The field of statistics is undergoing a significant change, and in order to identify the critical aspects of this change, the American Statistical Association carried out an analysis by both statisticians and persons from other fields who make use of statistics. The results are expected to help identify promising areas for the development of curricular materials.

New Degree Programs

In the area of experimental curriculum prototypes to increase career options, a grant was made to Carnegie-Mellon University for an interdisciplinary masters' degree program in building studies. Sponsored jointly by the departments of civil engineering and architecture and the School of Urban and Public Affairs, this project's new courses and materials will stress the incorporation of social and environmental, as well as physical and esthetic, factors in building designs. Clemson University and Washington State University are developing alternative doctoral degrees in the mathematical sciences, designed for mathematicians contemplating careers in business, industry, and Government. These two projects represent coordinated approaches to new career options.

College Faculty Workshops

In these workshops, college faculty contribute their talents as teachers and their knowledge of student needs and capabilities to the work of research scholars in the development and testing of modular instructional materials. In fiscal year 1975 projects were supported to develop: models for applying mathematics and computer simulation techniques to the study of social and environmental problems; teaching materials for courses on population dynamics and comparative politics; and materials for a general physics course for students majoring in the physical sciences and engineering.

In a continuing activity, a Chautauqua-type program has made it possible over the past 5 years for almost 9,000 college and university science faculty to attend short courses designed to bring new scientific knowledge into post-secondary classrooms.

Faculty Research Participation

This program, which gets college teachers directly involved in the ongoing research activities of in-

Table 8
Science Education Improvement
Improvement of Education for Scientific Literacy
Fiscal Year 1975

	Proposals		Awards		Individuals Supported
	No.	Amount	No.	Amount	
Elementary School Program					
Development, Testing and Evaluation of Teaching Materials	18	\$5,374,024	18	\$2,365,817	NA
Instructional Improvement Implementation	257	13,838,922	154	5,684,541	22,000
Secondary School Program					
Development, Testing and Evaluation of Teaching Materials	30	5,784,149	25	4,386,020	NA
Instructional Improvement Implementation	353	17,000,727	153	6,227,076	19,000
Public Understanding of Science Program	64	3,651,221	57	1,689,284	NA
Total, Improvement of Education for Scientific Literacy	722	\$45,649,043	407	\$20,352,738	41,000



Elementary school children exhibit an intense curiosity about the natural world. Science Curriculum Improvement Study materials build on this curiosity and assist children in development of confidence in their own ideas. The curriculum focuses on laboratory experiences and provides continuous interplay of observation and interpretation throughout the course of instruction from kindergarten through 6th grade.

sity, Edwardsville; an evaluation by Mary Shann at Boston University of a large-scale mathematics and science program; and a general evaluation of teachers' centers and resource centers, including those devoted primarily to mathematics, by David Butts of the University of Georgia. Funds were also made available for the study of mathematics teaching and learning at the University of Georgia under the direction of Leslie Steffe.

A major grant was made to the Education Development Center for development of a unified program on mathematics and science under the direction of Earle Lomon. Smaller awards were made to the University of Colorado for an elementary science teachers' center under the direction of David Hawkins, to Ohio State University to assess the usefulness of electronic hand-held calculators at the elementary level, and to San Francisco's Palace of Arts and Science Foundation for continued exhibit development by Frank Oppenheimer at the Exploratorium. Two biology projects, one concerning Outdoor Biology Instructional Strategies at the University of California, Berkeley, under the direction of Watson Laetsch, and a multiyear Human Sciences Program conducted by the Biological Sciences Curriculum Study (BSCS) group under the direction of Jack Carter, received major funding. The program also supported several conferences, including one, conducted at the University of Maryland by David Lockard, on NSF's impact on school science curricula.

Instructional Improvement Implementation

Fiscal year 1974 launched an effort to increase the use at the pre-college level of curricular materials that stress a "hands-on," inquiry-oriented approach. During the past year this effort was continued, with emphasis on the support of highly visible model projects intended to catalyze school improvement in a variety of



Activities designed in the Outdoor Biology Instructional Strategies project at the University of California, Berkeley, are primarily intended for youth programs outside the school—such as scout troops, community recreation programs, and camps—but can also be used in school programs. In this case, a student gathers materials from a pond for further study. [Photo by Herbert Thier]



Using inexpensive instruments, such as this microscope developed in the Elementary Science Study project, elementary school children can extend their range of observations while keeping instructional costs down. [Photo by Educational Services Inc.]

learning situations. The projects are designed to disseminate information about the materials, to train school personnel in their effective use, or both.

Dissemination is usually achieved through information to provide school decisionmakers with an overview of new curricula available for particular educational situations, and through the training of resource personnel, who assist schools in bringing about the curricular changes they have planned. Teacher training in the effective use of new materials is carried out by colleges and universities in conjunction with school systems, in school system projects, or with individual teachers in teacher-centered projects. During the past fiscal year, through 154 projects, training opportunities were provided for some 22,000 elementary teachers, supervisors, administrators, and other resource personnel.

Secondary School Program

Development, Testing, and Evaluation of Teaching Materials

Many awards made for elementary school projects also have a secondary school level component. This was the case with the award for Outdoor Biology Instructional Strategies at the University of California, Berkeley, and the Human Sciences Program at BSCS, as well as the Mathematics Resource Center at the University of Denver, and a number of smaller grants.

Awards were made to the American Political Science Association for the development of secondary school level curriculum materials under the direction of Howard Mehlinger, to the American Psychological Association for a curriculum in human behavior under the direction of John Bare, and to the Social Science Education Consortium in Boulder, Colo., under the direction of Irving Morrissett. Awards also went to the Education Development Center for the comple-

tion of Exploring Human Nature directed by Anita Gil, and to Pacific Lutheran University for a conference to consider possible curriculum materials in economics under the direction of Donald Wentworth. Also receiving additional funding were the Individualized Science Instructional System project under the direction of Ernest Burkman of Florida State University, and the Technology & People—Environment project being directed by John Truxal and Joseph Piel at the State University of New York at Stony Brook—both interdisciplinary. Funding was also made available to the Boston University 7th and 8th Grade Mathematics Development project under the direction of Uri Haber-Schaim, and to the Mathematics Resource Center at the University of Denver for work at the secondary school level. An award to the University of Oregon provided continued funding for the Mathematics Teaching Resources Project initiated there previously under the direction of Alan Hoffer.

A number of evaluation studies were funded in fiscal year 1975. These included the evaluation of Unified Science and Mathematics for Elementary Schools carried out by Mary Shann at Boston University; an evaluation of teachers' centers and resource centers under the direction of David Butts at the University of Georgia; and an evaluation of selected projects in mathematics education carried out by Francis Archambault of Boston University.

Instructional Improvement Implementation

Support for the implementation of new materials at the secondary school level was structured in essentially the same way as in the Elementary School Program. Some 19,000 training opportunities in 153 projects were provided for secondary school and other resource personnel.

Public Understanding of Science Program

Since World War II, science and technology have enriched our lives

and made them more complex. Because of the rapid pace of scientific development, it is no longer possible even for scientists themselves to remain completely abreast of current discoveries. The layman's task is far more difficult, and yet some level of scientific comprehension is essential if the public is to make sound judgments on those many public policy issues heavily permeated with scientific and technical elements. Recognizing this need, the National Science Foundation established the Public Understanding of Science Program in 1959 to provide modest support for projects across the country directed at improving public knowledge of the potential and limitations of science.

During fiscal year 1975, the program, continuing the trend of recent years, concentrated much of this support on the interrelationships of science with public policy issues. Experience has shown that science becomes less mysterious and more personal when it is related to problems facing the individual, either personally or through his family, community, or nation. Therefore, many public understanding of science projects dealt with the scientific and technical elements of such major questions as energy resources, growth and the environment, food, and similar subjects.

As in previous years, projects were supported at a variety of institutions and utilized a wide range of communication channels, including print and broadcast mass media, museums and other community-based educational institutions, and public forums and workshops at the regional, State, and local level. A strong research component was built into the program this year to complement and support ongoing projects.

In television, this was a banner year as the NOVA science series (supported by NSF, the Carnegie Corporation, Polaroid, and The Corporation for Public Broadcasting) continued its excellent coverage of many areas of basic and applied science. In all, 23 programs were

produced, and the year culminated in receipt of the prestigious Peabody Award by NOVA producers. A major research study was completed by Educational Expeditions, Inc., in Boston during fiscal year 1975 for the development of a television series on Indian migration and history, "The Peopling of the New World." The series, to consist of nine programs, has involved many archaeologists, anthropologists, and historians in the preliminary research and script drafting. Finally, a promising statewide program was initiated with the Montana Academy of Science, which will produce a series of television programs highlighting areas of science of direct interest to citizens of that State. This project, if successful, could be a prototype for other statewide programs in the future.

Museums received support in fiscal year 1975 for both cooperative science exhibition programs and for the development of special traveling exhibits on science-related subjects. The Field Museum of Natural History is completing work on a traveling exhibit, "Man and His Environment." The University of Colorado, Denver, is now entering the fabrication stage of a traveling exhibition on the potential of solar energy. This exhibit will be completed by the spring of 1976. Michigan Technical University, with support from the Foundation and private industry, inaugurated a traveling science and technology program which brought special exhibits and demonstrations on energy, space, and the environment to communities throughout rural upstate Michigan. A major bicentennial-related museum program has premiered at the Boston Museum of Science with a large exhibition, "Yankee Ingenuity," which focuses on the inventive propensity of Americans throughout our first 200 years. The first of four environment-related traveling exhibits has been completed by the Smithsonian Institution's Traveling Exhibition Service. This first exhibit deals with the



As a Public Understanding of Science project, a traveling demonstration program has been developed by Michigan Technological University to reach residents of rural communities. [Photo by Michigan Technological University]

problem of population and is currently booked in museums around the country for the next 2 years.

In addition to the mass media programs, a large number of "dialogue" projects were supported, including workshops, seminars, and public forums. These included a series of lectures on the basic sciences sponsored by the University of Florida, and a series of citizen workshops on energy and on food developed and sponsored by the

American Association for the Advancement of Science in various cities across the country. An attempt to reach the blue collar audience was inaugurated by faculty at Tulane University in New Orleans, with the cooperation of State and local AFL-CIO. The Tulane group organized and conducted a series of special workshops for union officials on the impact of technology on the work force—both today and as forecast into the future. These workshops will

be continued next year and may form the basis for similar programs with other union groups across the country.

Much attention was paid this year to the development of a research focus for the program. A major national survey on public understanding of science and public attitudes towards science is under development at the Center for Policy Research in New York. Preliminary planning meetings have been held, and a series of open ended oral interviews have been conducted with citizens in the New York area. The survey itself will be concluded by the summer of 1976. Gerald Holton at Harvard University has continued his analysis of the intellectual challenges to science literacy, and this year, with support from the program, has undertaken an analysis of the interrelationships between the public understanding of science and concern about the ethical uses and implications of science. A series of similar research projects was initiated during fiscal year 1975 to analyze the effectiveness of various ways of communicating science to the general public. An evaluation of the impact of television on science communications was conducted in San Diego, and other experiments are planned for next year.

INCREASING EFFECTIVENESS OF EDUCATIONAL PROCESSES

The unfavorable financial outlook for schools and colleges caught between inflated costs and declining enrollments in recent years gives added impetus to problems of cost effectiveness in educational processes. With this in mind, NSF supports two major approaches to attain a better balance between cost and educational productivity. One, Technological Innovation in Education, involves the application in education of technological devices

such as computers and television. The second, Educational Program Restructuring, focuses on a few major models of new approaches to the organization, management, and delivery of education.

Technological Innovation in Education

Computing technology makes possible a degree of individualization, instrumentation, and control

unequaled except by human tutoring. Because of its potential for improving both the quality and efficiency of instruction at all levels, this program has concentrated support on projects of computer-based education. Generally speaking, the hardware cost for computing continued to decline throughout fiscal year 1975, and it is hoped that the future cost for computation (which recently seemed prohibitive) will be further reduced.

Some of the projects supported by

Table 9
Science Education Improvement
Increasing the Effectiveness of Educational Processes
Fiscal Year 1975

	Proposals		Awards	
	No.	Amount	No.	Amount
Technological Innovation in Education	72	\$25,500,000	22	\$5,997,130
Educational Program Restructuring				
Restructuring the Undergraduate Learning Environment	32	2,815,738	13	2,090,970
Pre-Service Teacher Education	15	2,416,600	10	1,457,805
State, Regional or Urban Systems of Science Education	3	1,963,384	2	958,216
Total, Increasing the Effectiveness of Educational Processes	122	\$32,695,722	47	\$10,504,121

the program work primarily upon improving quality; others seek to lower cost. Some focus on a single discipline or level of education, while others concentrate upon the development or application of systems and techniques designed to improve the quality at many levels of education.

For example, the PLATO (Programmed Logic for Automatic Teaching Operations) system of computer-based instruction (CBI) can now provide more than 4,000 lessons of instruction in approximately 100 subject areas in-

tended for students in kindergarten through graduate school. The field-test of this system began in the fall of 1974, in elementary, community college, and university classrooms. By January of 1975, over 5,000 students were using the system for accredited instruction each week. A single system, located in Urbana, Ill., provided over 4,000 hours of CAI (computer-assisted instruction) service each day to its network of 70 educational campuses.

Another project, undertaken by Educational Testing Service,

provides highly sophisticated computer-based interactive guidance and planning for students in a virtually self-contained system. Utilizing data banks of occupational, educational, and student information, it also seeks to provide each student with skills in making decisions. A successful pilot study of a prototype of this system was completed in fiscal year 1973, and an extensive field test at five widely scattered community colleges was commissioned in fiscal year 1975.

Other projects are attempting to improve instruction not by "conventional" CBI, but by the introduction of dramatically different instructional content and pedagogy made possible by computing technology. For example, in projects at the Massachusetts Institute of Technology and the University of Pittsburgh, elementary mathematics and science are not so much taught as discovered by each student in a computer-based laboratory. Students are encouraged to design their own computer programs to control physical devices such as robots and music boxes, in the belief



Seymour Papert, project director of the Computational Geometrics project at the MIT Artificial Intelligence Laboratory, explains the workings of the "Turtle"—a computer-controlled robot which students can program to move and draw geometrical designs with a felt-tipped pen (left). Students observe the moving "Turtle" at close range (right). [Photos by MIT News Office]

that they will learn mathematics and science as well.

The use of computers to change the content of instruction is not limited to elementary/secondary levels; it also occurs at a number of colleges and universities. Project Conduit, a consortium of over 100 colleges and universities, is promoting lesson-sharing by locating, documenting, testing, and certifying a large number of computer-based curriculum packages.

The full impact of these systems is not yet clear. However, fiscal year 1975 yielded continuing evidence not only of declining hardware cost and growing appreciation for instructional computing, but also of some significant improvements in student performance. For example, students using Stanford's CBI programs in elementary reading and mathematics showed consistent gains in achievement over those who did not use the programs. Coupled with consistently favorable acceptance of CBI by students and teachers, this has long-term implications for productivity in education.

Educational Program Restructuring

Educational Program Restructuring encourages changes in the organization, management, delivery, and content of science education through use of a very limited number of major models. Principal efforts include restructuring the un-

dergraduate learning environment, pre-service teacher education, and State, regional, or urban systems of science education.

The Restructuring the Undergraduate Learning Environment (RULE) program has supported unconventional instructional approaches to undergraduate science instruction. Four such projects were initiated, and one was provided additional support in fiscal year 1975. For example, major new support was provided to the Utah State Board of Regents for a plan involving cooperation between most of the State's colleges and universities and the major technical industry of the State. The purpose is to obtain a uniform modularized program of undergraduate instruction in the basic sciences across the State, accessible to working people, and with minimal loss of credit by students because of relocation.

Under a second RULE Program component, conducted on a trial basis in fiscal year 1975, seven small awards for highly focused restructuring efforts by individual or small groups of faculty totaled \$99,500. These awards constitute a pilot study of the effectiveness of small grants in disseminating new scientific and educational developments and for ensuring the continued validity of undergraduate science teaching. One such award will permit Coe College (Cedar Rapids, Iowa) faculty from the social sciences and biology to develop a course with a

biologically oriented approach to human behavior.

In the area of pre-service teacher education, the Foundation began shifting its support from development of new models to installation of tested models on other campuses. These trials include carefully controlled evaluations, carried out under actual conditions, to provide a performance test of the transferability of models. Seven developmental projects received final funding and three field test projects were initiated in 1975.

A field test at the University of Southern Mississippi involves modification of the entire program of science and mathematics instruction for prospective elementary school teachers. It utilizes models developed at Indiana University (mathematics), at the College of St. Teresa (natural science), and at Purdue University (biology).

Through its program of support for State, regional, or urban systems of science education, the Foundation concentrates relatively large sums of money in a very few large-scale projects that involve several layers in the educational apparatus. The aim is to help ensure a coordinated attack on complex problems in science education. "Project City Science" in New York City's middle schools is being monitored through an ongoing third party evaluation which provides suggestions for in-course corrections and collects data on which decisions regarding further Foundation support can be based.

PROBLEM ASSESSMENT AND EXPERIMENTAL PROJECTS

The Problem Assessment and Experimental Projects program's aims are to study problems in science education and sift options on program strategies; formulate and test remedial strategies; and analyze the impact of programs and major individual projects. In 1975 the

program was modified to increase the evaluation of the Foundation's own education programs and projects. These aims are carried out through two activities: studies that collect, analyze, and interpret independently generated information; and experimental projects that also

generate information. While analyses of this type have been carried out by other NSF education programs as part of their normal responsibilities, this program (a) coordinates similar activities throughout the Education Directorate; (b) upgrades their quality and utility; and (c) increases their

reliability, validity, and objectivity.

Problem assessments initiated in fiscal year 1975 by means of proposal solicitations include:

- ° A study of the current state of continuing education for non-academic scientists and engineers in the United States.

- ° An analysis of the results of approximately 20 previously funded experimental projects designed to test ways of increasing the number of women and ethnic minorities in science and technology.

A number of assessments were initiated through unsolicited proposals. These include:

- ° Development of a plan for measuring the impact of continuing education on work performance, productivity, or job attainment of engineers.

- ° An analysis of school-based programs of in-service education for school mathematics teachers with a view toward identifying exemplary programs.

Among the experimental projects supported in 1975 are:

- ° Documentation by the Human Resource Research Organization, working with four secondary schools in the District of Columbia, of the factors involved in adopting instructional computing in secondary school

curricula.

- ° Development by the University of Arkansas of a system for rapidly integrating new results of energy research into instruction for undergraduates, using media kits.

Table 10
Science Education Improvement
Problem Assessment and Experimental Projects
Fiscal Year 1975

	Proposals		Awards	
	No.	Amount	No.	Amount
Problem Assessment and Experimental Projects—Total	52	\$2,100,000	14	\$1,240,296

A new effort, the Ethical and Human Value Implications of Science and Technology Program (EHVIST), aims at increasing public discussion of ethical and value issues related to science and technology. During fiscal year 1975, its first year of operation with program status in the Education Directorate, the EHVIST Program devoted most of its resources to the identification of more than 1,000 researchers and

teachers involved in projects dealing with these issues; the stimulation of communication among individuals by the publication of several bibliographies; and the support of a broad diversity of interdisciplinary research projects on which to base future decisions concerning program priorities. A number of these projects were jointly funded with the National Endowment for the Humanities.

Science Assessment, Policy and Advisory Activities





Science Assessment, Policy, and Advisory Activities

The interrelationships of today's growing problems seem to demonstrate an increasing need for a more holistic national science policy. Economic, environmental, and energy concerns emphasize that the various facets and disciplines of science and technology now form an ecology of forces that must be dealt with in a more knowledgeable and organized manner. Hence, 1975 has seen more attention focused on how the Nation is planning and guiding its scientific and technological affairs.

At the Foundation a number of functions and programs contribute to the formation of improved science policy. Central to all policymaking is adequate, accurate information. Sufficient data must continually be supplied and analyzed to provide a fund of information and knowledge upon which judgments can be made and new plans drawn up and acted on. NSF's Science Resources Studies provide this kind of information and analysis on the Nation's scientific assets—its research resources and manpower.

A program designed to evaluate the effect of the policies and practices of the Federal Government on research and development and technological innovation is the National R&D Assessment Program. The emphasis of this Foundation activity is on gaining a better understanding of what stimulates or stifles scientific and technological advances.

NSF also conducts a program that supports various science policy studies. These studies, conducted by prestigious scientific groups, such as the committees of the National Academy of Sciences, produce well-documented reports that make important policy recommendations on national and global problems.

Other offices established to assist the Director in his role as Science

Adviser to the President provide additional policy guidance; these are the Science and Technology Policy supporting studies and the Energy R&D Policy Research. Both draw on NSF staff expertise and on the advice

and studies of other Government and non-Government organizations to provide the Science Adviser with the background and ideas for science policymaking within the executive branch.

Table 11
Science Assessment, Policy, and Advisory Activities
Fiscal Year 1975

(Dollars in millions)

	Number	Amount
Planning and Policy Studies	37	\$2.94
Science Advisory Activities	122	6.17
National R&D Assessment	26	2.46
TOTAL	185	\$11.57

NATIONAL R&D ASSESSMENT PROGRAM

Through the National R&D Assessment Program, the Foundation analyzes the processes of research and development and technological innovation; the incentives and decisions that underlie the processes; and the effect that Government policy options have in shaping future patterns of research and development and technological innovation.

Work under this program can be roughly categorized in three broad areas. The first area examines past, present, and alternate future policies and practices of governments as they impact on the processes of technological innovation. Emphasis is placed on Government policies manifested through expenditures, the tax system, and the legal framework. In addition, the experience of other industrialized nations in the area of science and technology policy as it relates to R&D/innovation is studied to determine implications for U.S. policy options. In fiscal year 1975, work was undertaken on:

- The role of Government in allocation of resources to technological innovation.
- Government policy toward joint ventures as a mechanism affecting research and development.
- The impact of regulation on innovation.
- Technological diffusion in the hospital sector.
- Diffusion of technological innovations among privately owned electric utilities.
- A comparison of technological innovation and Government regulation of pharmaceuticals between the United States and Great Britain.

The second area in this program is the study of socioeconomic consequences of technological innovation, with the aim of establishing methodologies and estimates to measure and analyze the effects of technological changes. Specific studies started in fiscal year 1975 in this category are:

- Technology transfer as a motivation for U.S. investment by foreign firms.

- The relationship between international technology transfer and R&D expenditures by U.S. firms.

- Assessment of the impact of mechanisms used to aid worker adjustment to technological change.

- The impact of technological change on time use and household production.

- A more effective framework for governmental and industrial evaluations of changes in technology.

- Impact of technological change in the financial sector.

The third area explores innovation for a better understanding of the processes and decisions involved. An understanding of how the innovation process works is necessary to ascertain Federal options. Included in this area are the processes of innovation that may pertain to the private and public sector. In fiscal year 1975, the following studies were started:

- A longitudinal study of the diffusion of innovation in the shoe industry.

- An exploratory study on the

comparison of innovation in public and private sectors.

- An exploratory study of the coordinating mechanism between research and development and marketing as an influence on the innovation process.

- A study of decisionmaking in the adoption and utilization of urban technology.

- An assessment of modeling capability related to the process of organized technological innovation within the firm.

- The use of new technology to deliver local services.

PLANNING AND POLICY STUDIES

SCIENCE RESOURCES STUDIES

The Foundation's program of Science Resources Studies encompasses the collection, interpretation, analysis, and dissemination of data relating to the Nation's scientific and technological resources and activities. The primary objective of the program is the development of factual and analytical information to provide a basis for national planning and policy formulation in the area of science and technology resources. The information developed through these studies is made available to a wide audience through the publication of reports and summaries. These are supplemented by numerous reports published by contractors. Several representative examples of science resources studies carried out during the year are summarized below.

Periodic R&D Funding Studies

Expenditures for research and development in the United States are estimated at \$34.3 billion in 1975, a 7-percent increase over 1974. When adjusted for an 11-percent in-

flationary factor, however, this increase becomes a 3-percent decrease. Since 1967, total U.S. expenditures for research and development, in constant dollars, have dropped to about the 1965 level; Federal funding has declined at an average rate of 3 percent since 1967, while continuing to grow in current dollars. These and other data are published in the report *National Patterns of R&D Resources; Funds and Manpower in the United States, 1953-1975*, which contains analyses of the national R&D effort in terms of types of research and development, performer, and source of funds.

Preliminary data on 1974 industrial R&D funding showed that total industrial R&D spending increased by 7 percent between 1973 and 1974. However, when measured in constant dollars, there was a 3-percent decrease between the two years. The Federal Government funded one-third of the total, with four-fifths of the Federal share being concentrated in two industries—aircraft and electrical equipment. Industry employed the full-time-equivalent of 360,000 scientists and engineers in January 1975, about the same number as a year earlier.

Periodic Manpower Studies

The first results from the 1974 survey of a National Sample of Scientists and Engineers were released. This sample of 50,000 persons represents 1.3 million individuals identified from the 1970 Census, on the basis of a set of criteria developed by the Foundation. This is the first of a series of biennial surveys which the Bureau of the Census will carry out for NSF as a part of the Manpower Characteristics System. The 1974 survey revealed an unemployment rate of 1.1 percent in that year (about the same level as in 1970) compared to 1.9 percent in 1972.

The third in a series of projections of science and engineering doctorate supply and utilization was published; previous studies had been carried out in 1969 and 1971. The new analysis reexamined and revised not only the methodological techniques but also the underlying assumptions in the light of recent changes in enrollment, funding, and utilization patterns. Its projections indicate that between 375,000 and 400,000 science and engineering doctorates may be available in 1985, compared to about 295,000 available positions in

science- and engineering-related activities. Thus, the analyses indicate an increasing trend away from traditional doctorate activities such as research and development and academic teaching with the result that by 1985 perhaps a third of all science and engineering doctorates might neither be employed in academic institutions nor engaged in non-academic research and development.

Special Studies

Three major energy-related studies were carried out during the year. One of these, a study prepared for the Foundation by the National Planning

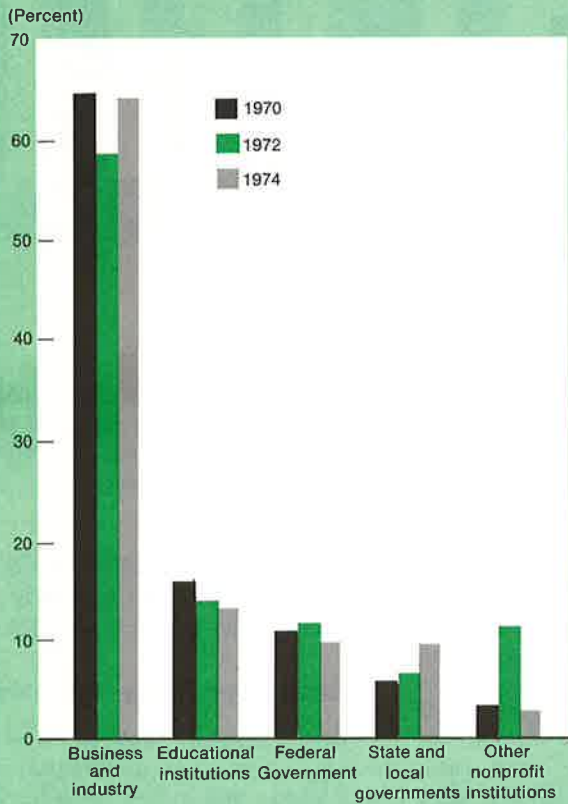
Association, developed a methodology and manpower coefficients to estimate scientific and technical manpower resources required for domestic production of energy for any future energy mix. Application of the data and techniques indicated that requirements for scientists and engineers for energy production in 1985 might be more than double those of 1970, if dependence on foreign sources of energy were reduced to about 9 percent.

Two other studies were carried out by Foundation staff. One of these made available for the first time statistics on industrial R&D spending in the area of energy. The data showed that industrial firms ex-

pected to spend in excess of \$1 billion on energy-related projects during 1974, an increase of 18 percent over the 1973 level. The other study revealed the Federal obligations for intramural energy research and development in fiscal year 1975 were expected to reach \$140 million, approximately twice the 1974 level. Despite such large increases, intramural energy research and development accounts for less than 10 percent of the total Federal energy R&D effort for 1975.

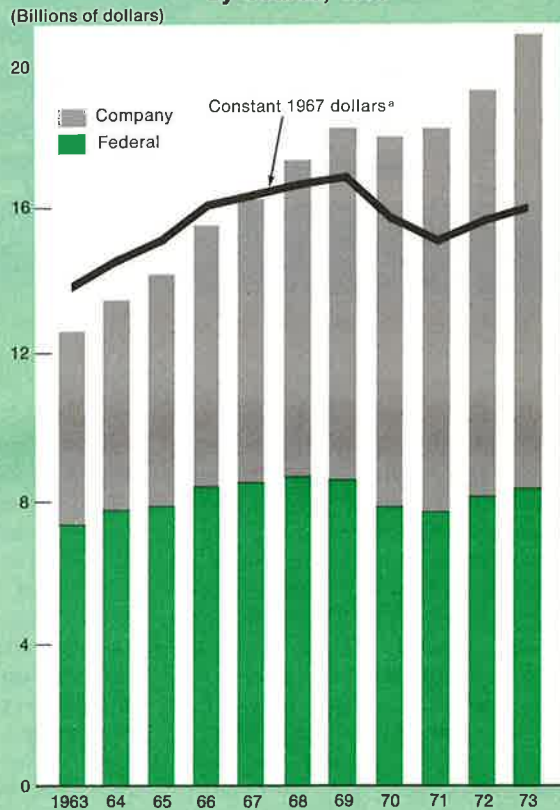
A special study of the research activities of full-time faculty in 1,366 doctorate-level science and engineering departments at 160 colleges and universities was com-

Distribution of the 1970 science and engineering labor force by type of employer, 1970, 1972, and 1974



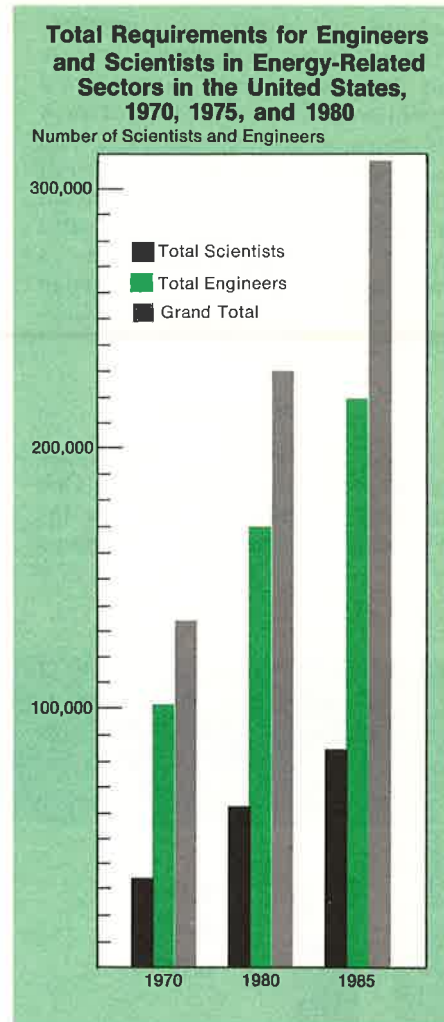
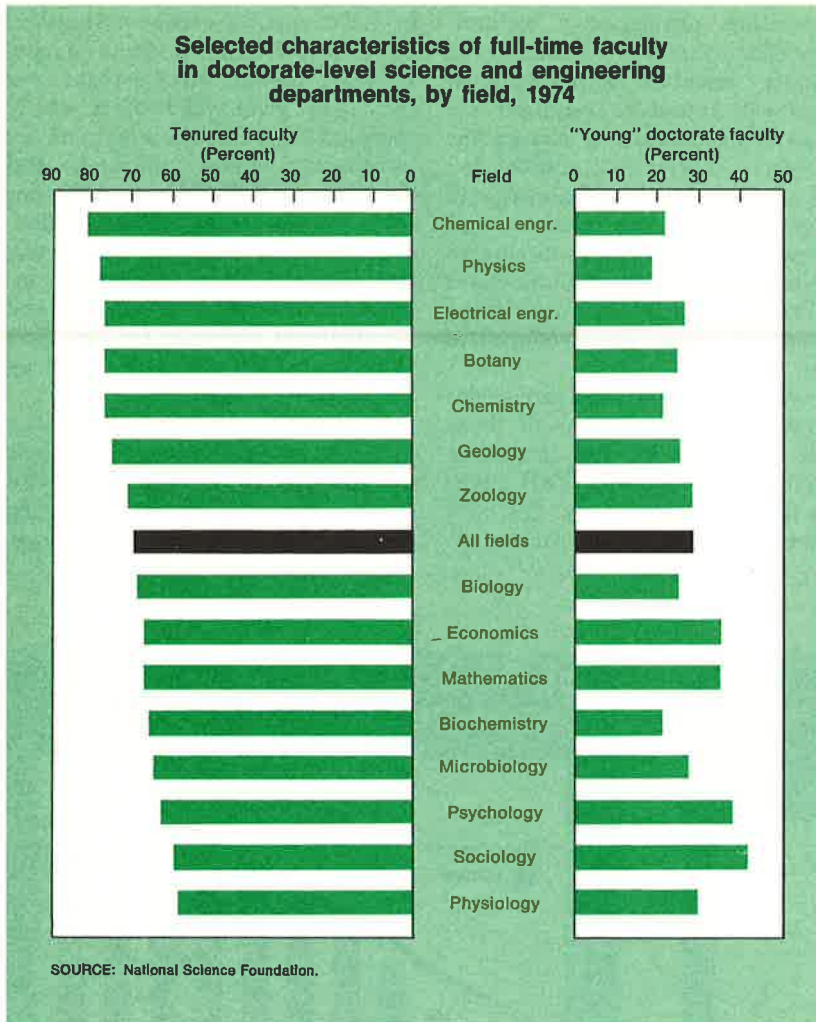
SOURCE: National Science Foundation.

Total Industrial R&D Expenditures, by Source, 1973



*The GNP implicit price deflator has been used to convert from current to constant dollars.

SOURCE: National Science Foundation.



pleted and published during the year. *Young and Senior Science and Engineering Faculty, 1974: Support, Research Participation, and Tenure* shows that of the faculty active in research, only about one-half are involved in research directly funded by the Federal Government, a proportion substantially below the nearly two-thirds 1968 level. The data also indicate that fully 70 percent of the faculty in these departments were tenured. Further, the overall proportion of young doctorate faculty (i.e., those who had held doctorates for 7 years or less) in these departments had decreased

from 39 percent of full-time faculty in 1968 to 28 percent in 1974.

Two special analytical reports were released during the year. One, entitled *The Federal Role in the Support of Graduate Science and Engineering Education*, analyzed shifting patterns of graduate enrollment during a 7-year period when federally supported fellowships and traineeships were drastically reduced. The second report, *R&D Expenditures of State Public Institutions, Fiscal Year 1973*, combined data on State agency R&D funding and manpower with similar statistics on State universities and

colleges, showing that these combined expenditures for research and development amounted to \$1,990 million—or 6.5 percent of the national R&D total.

SCIENCE PLANNING AND POLICY ANALYSIS AND PROGRAM EVALUATION

Planning and Policy Activities

These science policy studies provide information on Foundation-wide issues and policy concerns for the use of the Director and the National Science Board in fulfilling

their responsibilities for strategic planning and policymaking. During the past year, some of these studies have been carried out by the staff while others are being conducted extramurally.

Staff studies have included an extensive, internal review of the Foundation's basic social science and applied social research programs as well as an examination of some of the factors affecting the costs of performing research in universities. In the case of the social sciences review, a task group examined the rationale and justification of the research programs, identified some opportunities for increasing the focus and relevance of the research, and suggested several specific steps for realizing these opportunities. The Foundation has now funded a study by the National Academy of Sciences to further analyze the social science research programs.

With respect to cost factors in research performance, the staff has established a liaison with a number of university associations, including the Committee on Government Relations of the National Association of College and University Business Officers and the National Association of State Universities and Land Grant Colleges. They have participated in meetings with these and other groups with a view to identifying issues bearing on the costs of performing research.

During the year there has been a series of policy discussions regarding the present and future health of research institutions in the United States. Two extramural awards have been made to assess the current status of two of these research sectors—the university and Federal R&D laboratories. The first of these, focusing on the future research role of universities, is being conducted by the American Association of Universities. An advisory committee which is widely representative of the academic community has been appointed to assist in identifying issues and reviewing the results of the analysis. An assessment of the status

and research role of Federal in-house laboratories is being conducted by Henry Lambright, Syracuse University, and Albert Teich of the Institute for Policy Studies of the State University of New York. The results from these two studies plus additional in-house reviews, will provide a framework for considering policies which may affect the future research roles of different institutions.

The National Science Foundation continued to support and utilize the advisory services of the National Academy of Sciences' Committee on Science and Public Policy (COSPOP). The committee's activities included a survey of materials science and engineering, the last major survey of scientific disciplines to be conducted by the committee. The summary report and recommendations were published in April 1974 under the title, *Materials and Man's Needs*. The technical material developed by the panels during the course of the survey was published in 1975.

In 1974, the National Academy of Sciences sponsored the first in a series of "mini-studies." These are designed to replace the major scientific surveys with more limited ones that can identify priorities and current research frontiers of more narrowly defined fields and sub-fields of a science in a shorter time and with a greatly reduced investment of money and manpower.

The astronomy manpower mini-study examined problems created by the recent rapid growth in this field. These problems include the lack of employment opportunities for young astronomers, the possibility of limiting graduate enrollment in the field, and the consideration of research opportunities for talented scientific investigators trained during the past 10 to 15 years. The available data on manpower in astronomy was reviewed and it was concluded that the field does indeed have an impending manpower and funding crisis. Detailed recommendations for possible action are con-

tained in the report, released by COSPOP in spring of 1975.

Also under the aegis of COSPOP is a study of the use of science in the determination of safety of consumer items. The final report was completed and is now in press.

In cooperation with the Department of the Interior and the Population Council, the Foundation supported the work of the Academy's Commission on Mineral Resources and the Environment, funding a workshop and report on how technology can contribute to conservation of the Earth's resources of materials and energy and maintain its environment.

The Foundation also continued its liaison with the National Academy of Engineering's Committee on Public Engineering Policy (COPEP). The committee currently consists of 20 members, distinguished in engineering, research, or administration. COPEP identifies, develops, and undertakes studies of emerging issues of technology and related public policy and provides advice on the utilization of science and technology to achieve public purposes. COPEP conducted a seminar and prepared a report on *World Hunger: Approaches to Engineering Actions*. The report reviews opportunities and limitations for feeding a hungry, crowded world. It focuses on ways in which engineering resources and techniques could be applied to improve food production, processing, storage, and distribution.

Evaluation Activities

Evaluation activities provide independent, objective analyses of the effectiveness, impact, and adequacy of the Foundation's programs and plans. An evaluation of the NSF Science Development Program was carried out in cooperation with the National Board on Graduate Education. This program, now completed, was aimed at upgrading the science capabilities of second-tier universities and providing a broader geographical distribution of scien-

Appendix A

National Science Board, NSF Staff Advisory Committees and Panels

NATIONAL SCIENCE BOARD

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 ROBERT H. DICKE, Cytus Fogg Brackett Professor of Physics, Department of Physics, Princeton University, Princeton, N.J.
 DAVID M. GATES, Professor of Botany and Director, Biological Station, Department of Botany, University of Michigan, Ann Arbor, Mich.
 ROGER W. HEYNS, President, American Council on Education, Washington, D.C.
 *FRANK PRESS, Chairman, Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Mass.
 F. P. THIEME, Special Consultant to the Board of Regents and Professor of Anthropology, University of Colorado, Boulder, Colo.

Terms Expire May 10, 1978

- W. GLENN CAMPBELL, Director, Hoover Institution on War, Revolution and Peace, Stanford University, Stanford, Calif.
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 *RUSSELL D. O'NEAL (Vice Chairman, National Science Board), Executive Vice President, KMS Fusion, Inc., Ann Arbor, Mich.
 JOSEPH M. REYNOLDS, Boyd Professor of Physics and Vice President for Instruction and Research, Louisiana State University, Baton Rouge, La.

Terms Expire May 10, 1980

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 SAUNDERS MAC LANE, Max Mason Distinguished Service Professor of Mathematics, University of Chicago, Chicago, Ill.

* Member, Executive Committee

** Deceased, April 1, 1975

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 L. DONALD SHIELDS, President, California State University at Fullerton, Fullerton, Calif.
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 VERNICE ANDERSON, Executive Secretary, National Science Board, National Science Foundation, Washington, D.C.

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Appendix B

Patents and Inventions Resulting from Activities Supported by the National Science Foundation

During fiscal year 1975 the Foundation received 157 invention disclosures and made rights determinations in 40 inventions, some of which were submitted in previous fiscal years. The determinations made in accordance with the NSF Patent Regulations which became effective December 4, 1974, include decisions to dedicate the inventions to the public through publication in 18 cases, and to transfer NSF's rights to other interested Government agencies in eight cases. At the end of the fiscal year, NSF had entered into Institutional Patent Agreements with 11 universities, under which 20 inventions were selected for exploitation. Licenses were received by the Foundation under 40 patent applications filed by grantees and contractors who had been allowed to retain principal rights in their inventions.

The following patents which issued from research which it sponsored:

U.S. PATENT 3,766,048 entitled "Analysis of Polymer Mixtures in Solution Utilizing Electrophoretic Light Scattering Apparatus" which issued on October 16, 1973, in the names of William H. Flygare and Bennie R. Ware, arising from research supported by a grant to the University of Illinois.

U.S. PATENT 3,775,560 entitled "Infrared Light Beam X-Y Position Encoder for Display Devices" which issued on November 27, 1973, in the names of Frederick A. Ebeling and Richard S. Goldhor, arising from research supported by a grant to the University of Illinois. The primary use of this invention is as auxiliary input device for the PLATO terminal.

U.S. PATENT 3,777,549 entitled "Measurements of Hole Pressure Differentials and Protuberance Pressure Differentials in Non-Newtonian Liquids or the Like" which issued on December 11, 1973, in the name of Arthur S. Lodge, arising from research supported by a grant to the University of Wisconsin. This device measures the degree of polymerization of resinous plastic liquids which are undergoing polymerization.

U.S. PATENT 3,815,995 entitled "Method and Apparatus for Spark Spectroscopy by Deriving Light from Limited Portions of the Spark Discharge" which issued on June 11, 1974, in the names of John P. Walters, Steven A. Goldstein, and William S. Eaton, arising from research supported by a grant to the University of Wisconsin. According to the invention, the stabilized spark discharge may be used for analytical spectroscopy by deriving the light for such spectroscopy from the luminous wings of the spark discharge outside the defined spark channel.

U.S. PATENT No. 3,822,381 entitled "Multimode Oscillators for Pattern Recognition" issued on July 2, 1974, in the name of Alwyn C. Scott, arising from research supported by a grant to the University of Wisconsin. The patent discloses improved multimode oscillators which can be used to provide electronic data for recognizing or characterizing a pattern produced by visible light, infrared or ultraviolet light, X-rays, sound waves, or other forms of radiation.

U.S. PATENT No. 3,849,254 entitled "Process for Effecting Enzymatic Reactions in Aerosols" in the names of Donald J. Kirwan and John L. Gainer arising from research supported by a grant to the University of Virginia. The patent discloses a process of purifying air by use of an immobilized hydroelectric enzyme.

U.S. PATENT No. 3,872,218 entitled "Synthesis of Alkali Metal Tetracarbonyl Ferrates" issued in the names of James P. Collman and Stanley R. Winter, arising from research supported by a grant to Stanford University. According to the patent, sodium and potassium tetracarbonyl ferrates are prepared at relatively low cost in high yield and good purity by reacting metallic sodium or potassium with an iron carbonyl in the presence of an electron carrier.

U.S. PATENT No. 3,850,109 entitled "Transportation System Employing Magnetic Levitation, Guidance and Propulsion" issued on November 26, 1974, in the name of Richard D. Thornton, arising from research supported by a grant to the Massachusetts Institute of Technology.

U.S. PATENT No. 3,860,483 entitled "Novel Method of Diagnosis of Schistosomiasis and Reagents Therefor" issued on January 14, 1975, in the name of Alfred W. Senft, arising from research supported by a grant to Brown University. This invention relates to a test for "snail fever."

U.S. PATENT 3,892,839 entitled "Process for Forming Nitrosyl Tetrafluoroborate" issued in the names of James L. Adcock and Richard J. Sagow, arising from research supported by a grant to the Massachusetts Institute of Technology. The invention is based on the discovery that nitrosyl tetrafluoroborate can be formed from boron nitride, fluorine gas, and oxygen gas in the absence of water while employing heat or ultraviolet radiation as a source of energy for the reactor.

Appendix C

Financial Report for Fiscal Year 1975

(In Thousands of Dollars)

Salaries and Expenses Appropriation	
	Fund Availability
Fiscal year 1975 appropriation	\$763,300
Unobligated balance carried forward from fiscal year 1974	655
Adjustments of prior year costs	2,218
Fiscal year 1975 availability	<u>\$766,173</u>
Obligations	
Scientific research project support:	
Atmospheric sciences	\$13,814
Earth sciences	12,972
Oceanography	15,284
Biochemistry & physiology	37,460
Cellular biology	14,314
Ecology & population biology	26,104
Physics	42,198
Chemistry	32,728
Astronomy	10,930
Mathematical sciences	16,463
Social sciences	26,297
Engineering	34,263
Materials research	43,525
Computer research	11,784
Subtotal, scientific research project support	<u>\$338,136</u>
National and special research programs:	
Global atmospheric research program	\$4,040
Climate dynamics	1,000
International decade of oceanographic exploration	14,779
Ocean sediment coring program	10,497
Arctic research program	3,635
U.S. Antarctic research program	25,898
Oceanographic facilities and support	20,637
Solar eclipse support	2
Science information activities	5,378
National R&D assessment	2,463
Subtotal, national and special research programs	<u>\$88,329</u>
National research centers:	
National Astronomy and Ionosphere Center	3,200
Kitt Peak National Observatory	7,675
Cerro Tololo Inter-American Observatory	2,950
National Radio Astronomy Observatory	19,300
National Center for Atmospheric Research	17,450
Subtotal, national research centers	<u>\$50,575</u>
International cooperative scientific activities	<u>7,935</u>
Research applied to national needs	<u>81,009</u>
Intergovernmental science and research utilization	<u>2,580</u>
Graduate student support	<u>13,199</u>
Science education improvement	<u>60,835</u>
Planning and policy studies	<u>2,938</u>
Science advisory activities	<u>6,172</u>
Program development and management	<u>37,867</u>
Subtotal	<u>\$689,575</u>
Transfer to ERDA	\$51,730
Administration deferrals	20,000
Unobligated balance carried forward to fiscal year 1976	4,868
Total	<u>\$766,173</u>

Appendix C

Special Foreign Currency Appropriation		
Fund Availability		
Fiscal year 1975 appropriation	\$4,850	
Unobligated balance carried forward from fiscal year 1974	5	
Fiscal year 1975 availability		<u>\$4,855</u>
Obligations		
Total obligations for fiscal year 1975		\$3,552
Unobligated balance lapsing from 1975 appropriation		5
Unobligated balance carried forward to fiscal year 1976		<u>1,298</u>
Total		<u>\$4,855</u>
Trust Fund		
Fund Availability		
Unobligated balance brought forward from fiscal year 1974	\$956	
Receipts from non-Federal sources	3,193	
Fiscal year 1975 availability		<u>\$4,149</u>
Obligations		
National and special research programs:		
Ocean sediment coring program	\$1,252	
Graduate student support:		
NATO fellowship program	319	
Gifts and donations	9	
Subtotal		<u>\$1,580</u>
Unobligated balance carried forward to fiscal year 1976		<u>2,569</u>
Total		<u>\$4,149</u>

*Appendix D**National Research Centers Contractors*

Associated Universities, Inc. (AUI)
Gerald F. Tape, President

National Radio Astronomy Observatory
David S. Heesch, Director

AUI Member Universities:
Columbia University
Cornell University
Harvard University
The Johns Hopkins University
Massachusetts Institute of Technology
University of Pennsylvania
Princeton University
University of Rochester
Yale University

*Association of Universities for Research in
Astronomy, Inc., (AURA)*
Gilbert Lee, President

Cerro Tololo Inter-American Observatory
Victor M. Blanco, Director
Kitt Peak National Observatory
Leo Goldberg, Director

AURA Member Universities:
University of Arizona
California Institute of Technology
University of California
University of Chicago
Harvard University
Indiana University
University of Michigan
Ohio State University
Princeton University
University of Texas at Austin
University of Wisconsin
Yale University

Cornell University
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National Astronomy and Ionosphere Center
Frank D. Drake, Director, Ithaca, N.Y.
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University Corporation for Atmospheric Research (UCAR)
Francis P. Bretherton, President

National Center for Atmospheric Research
Francis P. Bretherton, Director

UCAR Member Universities:
University of Alaska
University of Arizona
California Institute of Technology
University of California
The Catholic University of America
University of Chicago
Colorado State University
University of Colorado
Cornell University
University of Denver
Drexel University
Florida State University
Harvard University
University of Hawaii
Iowa State University
The Johns Hopkins University
University of Illinois at Urbana—Champaign
University of Maryland
Massachusetts Institute of Technology
McGill University
University of Miami
University of Michigan
University of Minnesota
University of Missouri
University of Nevada
New Mexico Institute of Mining and Technology
New York University
State University of New York at Albany
Ohio State University
University of Oklahoma
Oregon State University
Pennsylvania State University
Purdue University
The Rice University
Saint Louis University
Stanford University
Texas A&M University
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