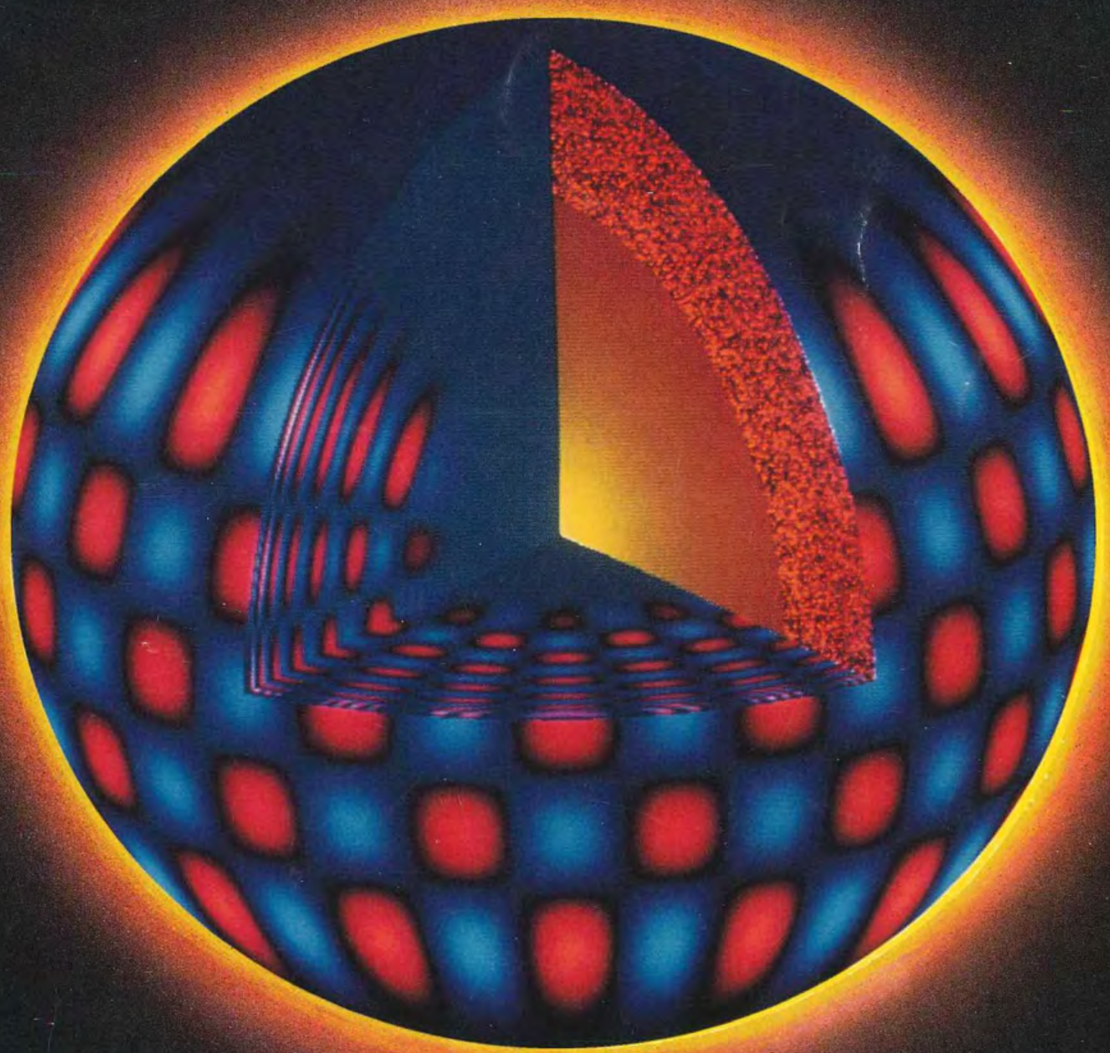
National Science Foundation Annual Report 1990



About the National Science Foundation

The National Science Foundation is an independent federal agency created by the National Science Foundation Act of 1950 (P.L. 81/507). Its aim is to promote and advance scientific progress in the United States. The idea of such a foundation was an outgrowth of the important contributions made by science and technology during World War II. From those first days, NSF has had a unique place in the federal government: it is responsible for the overall health of science and engineering across all disciplines. In contrast, other federal agencies support research focused on specific missions, such as health or defense. The Foundation is also committed to expanding the nation's supply of scientists, engineers, and science educators.

NSF funds research and education in science and engineering. It does this through grants and contracts to more than 2,000 colleges, universities, and other research institutions in all parts of the United States. The Foundation accounts for about 23 percent of federal support to academic institutions for basic research.

NSF receives more than 37,500 proposals each year for research, graduate and postdoctoral fellowships, and math/science/engineering education projects; it makes more than 16,000 awards. These typically go to universities, colleges, academic consortia, nonprofit institutions, and small businesses. The agency operates no laboratories itself but does support National Research Centers, certain oceanographic vessels, and antarctic research stations. The Foundation also supports cooperative research between universities and industry and U.S. participation in international scientific efforts.

The Foundation is run by a presidentially appointed Director and Board of 24 scientists and engineers, including top university and industry officials.

NSF is structured much like a university, with grant-making divisions for the various disciplines and fields of science and engineering. The Foundation staff is helped by advisors, primarily from the scientific community, who serve on formal committees or as ad hoc reviewers of proposals. This advisory system, which focuses on both program direction and specific proposals, involves more than 59,000 scientists and engineers a year. NSF staff members who are experts in a certain field or area make award decisions; applicants get unsigned copies of peer reviews.

Awardees are wholly responsible for doing their research and preparing the results for publication. Thus the Foundation does not assume responsibility for such findings or their interpretation.

* * * *

NSF welcomes proposals on behalf of all qualified scientists and engineers and strongly encourages women, minorities, and persons with disabilities to compete fully in its programs. In accordance with federal statutes and regulations and NSF policies, no person on grounds of race, color, age, sex, national origin, or disability shall be excluded from participation in, denied the benefits of, or be subject to discrimination under any program or activity receiving financial assistance from the National Science Foundation.

Facilitation Awards for Handicapped Scientists and Engineers (FAH) provide funding for special assistance or equipment to enable persons with disabilities (investigators and other staff, including student research assistants) to work on an NSF project. See the FAH announcement or contact the FAH Coordinator at (202) 357-7456.

The National Science Foundation has TDD (Telephonic Device for the Deaf) capability, which enables individuals with hearing impairment to communicate with the Division of Personnel and Management about NSF programs, employment, or general information. This number is (202) 357-7492.

Cover: Computer representation of a solar oscillation, one of the millions of sound vibrations ringing throughout the sun. (Photo courtesy of National Optical Astronomy Observatories)

National Science Foundation (U.S.)

Annual Report, 1990

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

Letter of Transmittal

Washington, D.C.

DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1990 of the National Science Foundation, for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

Walter E. Massey
Director, National Science Foundation

The Honorable
The President of the United States

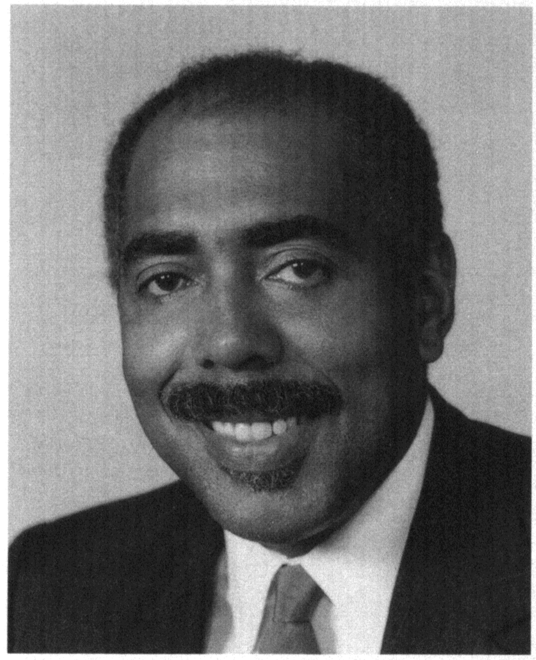
Contents

Appendixes

The important thing is
not to stop questioning.

Albert Einstein

Director's Introduction



Walter E. Massey

The National Science Foundation celebrated its 40th anniversary in 1990 and had good reason to applaud an impressive record of accomplishments. Although a small Federal agency, NSF enters its fifth decade at the center of what is most important to our society. The Foundation's basic mandate, supporting science and engineering research and education, has propelled the agency into a critical role in our Nation's future economic growth and prosperity.

These are times of extraordinary change. Dramatic technological, economic and political changes have occurred in recent years that have underscored a shift in the world economy from a national to an international basis. At a time when virtually no aspect of our lives is untouched by science and technology, American leadership in these areas is something we can no longer arbitrarily take for granted. In a global economy, knowledge, and particularly knowledge produced through science and engineering research, is a critical resource. In addition, our Nation's ability to create and use knowledge to compete in world markets also depends on a technically-trained workforce and a scientifically literate public.

NSF is prepared to assist the Nation in meeting these challenges. This is illustrated by the Foundation's history. Its budget grew from $3.5 million in the early 1950's to almost $2.5 billion in fiscal year 1990. In 1952 the Foundation made 28 research awards; in 1990 there were about 17,000.

The Foundation's mandate has always included supporting education programs in science and engineering, but during the coming decade education and development of our Nation's human resources are clearly among the most important issues this Nation will address. Challenges face us on every level of the educational spectrum, but especially in precollege math and science education. Meeting our national goal of the best math and science students by the year 2000 has brought a greater focus on programs to enhance education and literacy in science and technology. In addition, special attention is being directed toward further development of the talent pool of American researchers.

NSF, within the framework of the Interagency Committee on Education and Human Resources, has a basic responsibility for science and engineering education, and it has taken the lead in creating a range of programs to address these concerns. These programs complement related efforts of other Federal Agencies. They are designed to improve the quality of math and science education from preschool through graduate school, to improve the quality of teaching and develop new learning materials, and to attract more students to science and engineering careers. In the human resources area, the Foundation recognizes the changing demographics of our Nation, and is working to increase the participation in the S&T community of women, minority groups, and people with disabilities. This annual report describes several of the Foundation's recent initiatives in these areas.

NSF remains committed to the support of research by individual investigators in many disciplines, including mathematics, physical sciences, biological, behavioral and social sciences, geosciences, and engineering. NSF also provides the support for research in such key areas as biotechnology, materials research, global change and scientific computing, all of which have significant potential to address areas of national concern. Science and engineering research is more exciting than ever before, but it is also more complex. Thus, NSF has recognized the need for greater cooperation—across disciplines, across international borders, between large and small projects, between groups and individuals, and among Federal agencies, universities and industry. Many of the activities described in the Research News and science Special Focus sections of this report highlight these various types of cooperation.

As a former member of the National Science Board and longtime friend of NSF, I recently arrived at the Foundation in this 41st year with a sense of both appreciation and anticipation.

I am grateful to those who have helped to build this prestigious Federal agency. Isaac Newton said that if he had achieved anything at all, it was by standing on the shoulders of giants. I feel extremely fortunate, as NSF's ninth Director, to be able to benefit from the positive leadership that has preceded me.

I would like to take this opportunity to express the Foundation's appreciation to the many rotator scientists, engineers, and educators whose tours of duty at the Foundation have greatly aided its mission. These individuals continue to provide vital new blood to the organization.

In addition, on behalf of the Foundation's staff, I want to acknowledge the approximately 59,000 persons who serve as panelists and proposal reviewers each year under the merit review process. And I would like to recognize the dedicated work of the Foundation staff. Over the years, NSF has recruited highly-skilled staff members and I look forward to working with them in the coming years.

The combination of opportunities and challenges that the Foundation faces in the coming years gives me a healthy sense of anticipation. NSF has been fortunate to have had the President's support for the doubling of its budget, yet there are more research opportunities than resources can fund. This will require that we set some priorities, seek out additional partners and nurture further cooperation among government, industry and academia. In addition, much work remains to be done to meet the education goals of the Nation, to ensure that there is an adequate human resource base in science and engineering, and to increase the scientific literacy of the public. I believe that the Foundation can continue to build upon the types of activities and accomplishments described in this annual NSF report as it moves forward to meet the new opportunities and challenges of the 1990's.

Walter E. Massey
Director
National Science Foundation

NSF News in Brief

1990 Activities—Research

Plant Genome: To understand more about plant biochemistry, genetics and physiology, many researchers already have adopted as a model the simple weed *Arabidopsis thaliana*.

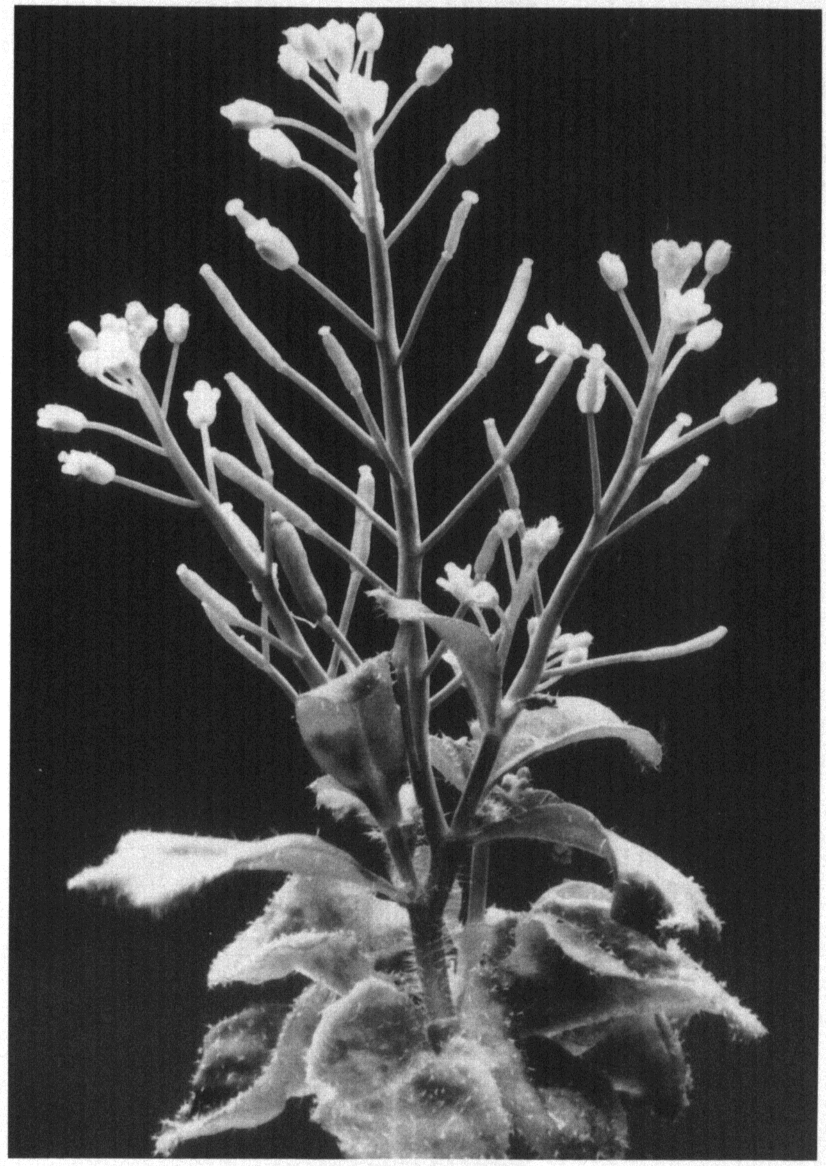
In 1990 NSF—working with the National Institutes of Health, the Department of Agriculture and the Department of Energy—became the lead federal agency in funding research efforts to locate every gene in the plant and determine the sequence of nucleotide building blocks in each. An interagency agreement was signed in June 1990 for the four agencies to collaborate on the project.

Arabidopsis undergoes the same processes of growth, development, flowering and reproduction as do higher plants, including important crop plants. Yet a complete set of *Arabidopsis* genes, known as a genome, has about 30 times less DNA than a corn or human genome has.

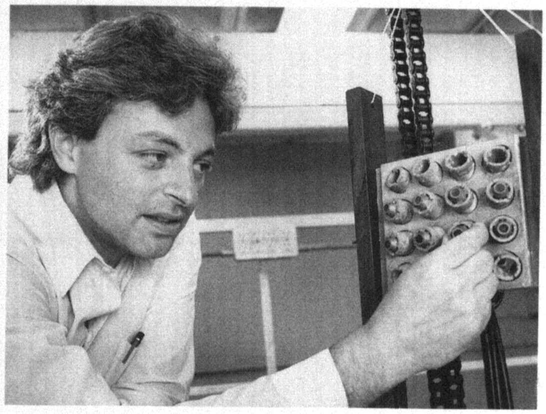
Because *Arabidopsis* has less DNA than other flowering plants, it offers scientists a unique opportunity—the possibility of identifying its complete set of genes. It is small, has a short life cycle and produces many seeds. The weed, which produces a new generation every five to six weeks, can be genetically engineered to incorporate the genes for economically important products made by other plants.

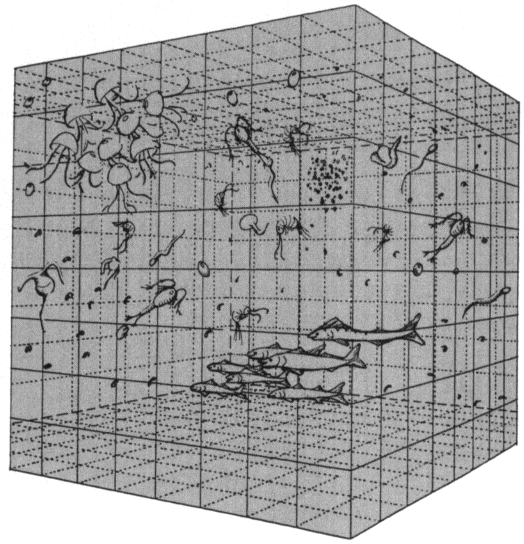
The advantage of *Arabidopsis* genome research is recognized by researchers in many countries, and several nations have established their own initiatives. The international community of these researchers has mounted an informal but coordinated research effort to maximize scientific progress in the field. As a result, a long-range plan for a multinational project is in place. The NSF project is based in part on recommendations in the multinational plan.

Marine Life/Computer Visualization: NSF awarded a research grant to Scripps Institution of Oceanography, University of California at San Diego, to develop a system that uses sound to make computerized pictures of biological activity in the oceans. Research oceanographer *Jules S. Jaffe* received an award to design and test at sea an electronic system for probing the marine environment, combining newly developed sonar (sound navigation and ranging) techniques and advanced computer processing.



Model Plant. ***Because of its relatively simple genome structure,*** **Arabidopsis** ***is being used for genome mapping—in order to understand plant processes more fully.***



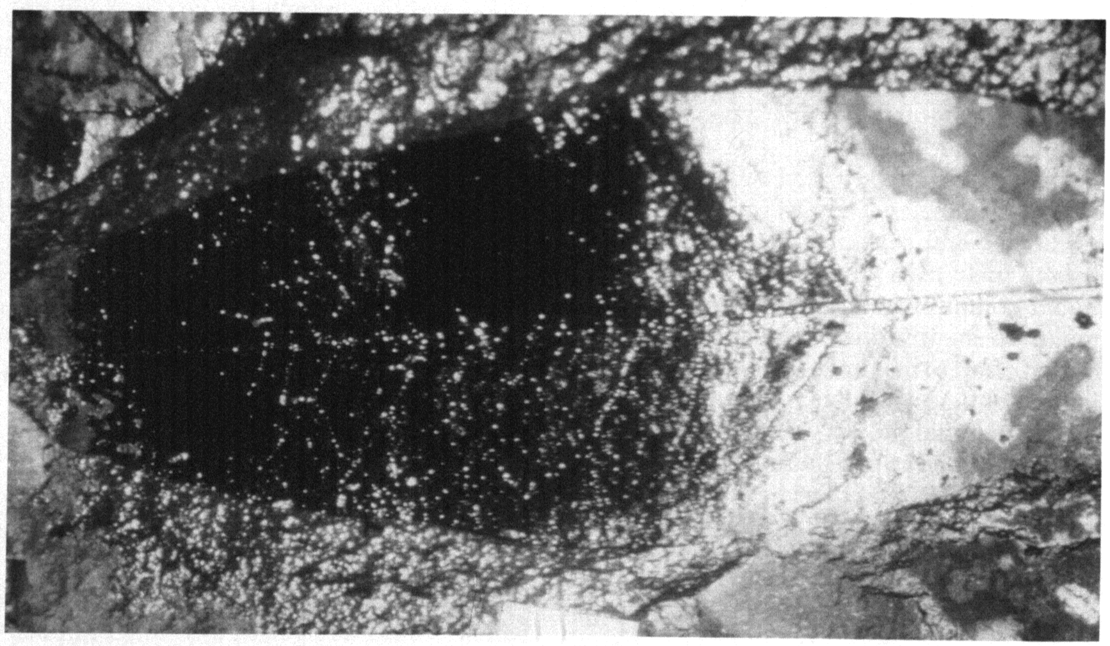


Ocean sonar. ***Oceanographer Jules Jaffe has worked to develop a sonar array to produce three-dimensional computer images of ocean biological activity, shown here in an artist's interpretation. These sonar images are used to evaluate the impact of potential global-environment changes on marine life.***

Such systems will be vital to the success of a new NSF global change initiative called Global Ocean Ecosystem Dynamics (GLOBEC), a large-scale research program to understand ocean ecosystem relationships and how they are influenced by physical processes. Jaffe's system is designed to produce three-dimensional computer pictures of ocean animals, ranging in size from tiny plankton to large fish, in a field of view extensive enough to allow detailed studies of marine populations and behavior.

Genetic Code Discovery: A team of scientists funded by NSF has taken a genetic fingerprint of a magnolia tree that lived millions of years ago. This marks the first time that fragile strands of DNA from such ancient and well-preserved specimens have been recovered and analyzed. The oldest DNA previously analyzed came from a woolly mammoth that lived 40,000 years ago.

The achievement highlights the power of a biochemical technique, developed in recent years, that can be used to make



Michael Clegg

Ancient DNA. ***Millions of years old, a fossilized magnolia leaf from an Idaho river basin contains the earliest strands of DNA yet found.***

billions of gene copies from small—and vanishing—samples.

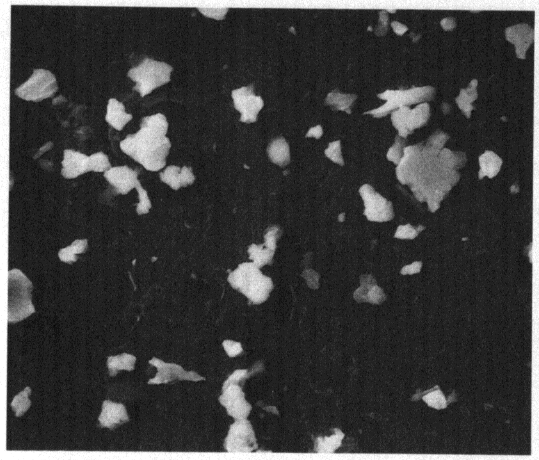
The research team was led by evolutionary biologist Michael Clegg from the University of California-Riverside. The scientists obtained the magnolia DNA from a site called the Miocene Clarkia deposit, in the St. Marie's River valley near Moscow, Idaho. The deposit consists of layers of clay sediments, the remnants of an ancient lakebed. The sample was still green when found embedded in the lakebed, compressed in shale.

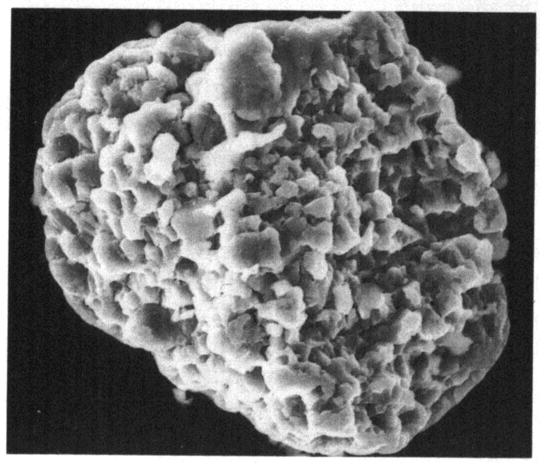
Geologists have used radioisotope dating to determine that the finely layered sediments are between 17 and 20 million years old. Another technique, employing polymerase chain reaction (PCR) technology, helped Clegg's team determine and verify the leaf's DNA sequence.

PCR, a technique developed by researchers at Cetus Corporation in the early 1980s, enables scientists to rapidly reproduce DNA biochemically without cloning it into bacteria. The technique could help scientists understand how often mutations occur in plants or animals, how species evolved from a common ancestor, and how geography might have affected those processes.

Ultrasound: Using sound waves pitched beyond the range of human hearing but more intense than the roar of a jet engine, chemist *Kenneth Suslick* threw metal particles in solution together at speeds of 1,600 kilometers per hour. The collisions produced temperatures of thousands of degrees, melting and fusing the particles. With these high-frequency waves, called ultrasound, the University of Illinois professor was able to speed chemical reactions.

Ultrasound strips metals of unreactive coatings, freeing the pure, elemental metal inside to promote chemical reactions. Once associated with the dog whistle, ultrasound is now used in medical devices to break up kidney stones or to image the body. Its ability to enhance the reactivity of metals used for catalysis also makes ultrasound a potential money-saver in industrial processes.





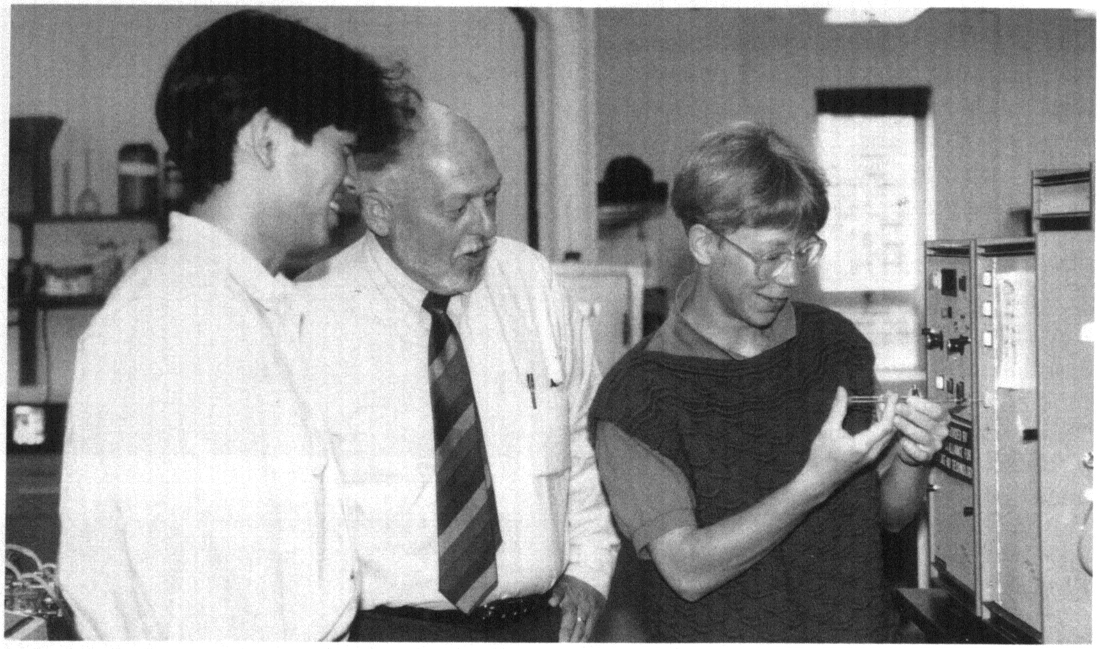
K. Suslick

Speeding chemistry. ***High-frequency waves (ultrasound) fuse metal particles together at 1,600 kilometers per hour, a technique that has wide industrial applications and can also be used to break up kidney stones or image the body.***

News from Science and Technology Centers: The centers program is relatively new. Its proposal competitions have helped universities refocus priorities and encouraged states to make new long-term investments in science and technology in their universities.

Each STC has a strong interdisciplinary mix of science and engineering. Strong partnerships have been forged with several national laboratories and industry. Already this model has resulted in impressive research achievements. Among these are synthesis and growth of new superconducting materials and development of a large field-of-view camera to recognize the ignition of a supernova and measure its luminosity.

The STCs also have a strong commitment to science and engineering education. They reach out to high school teachers and students, as well as faculty and students at

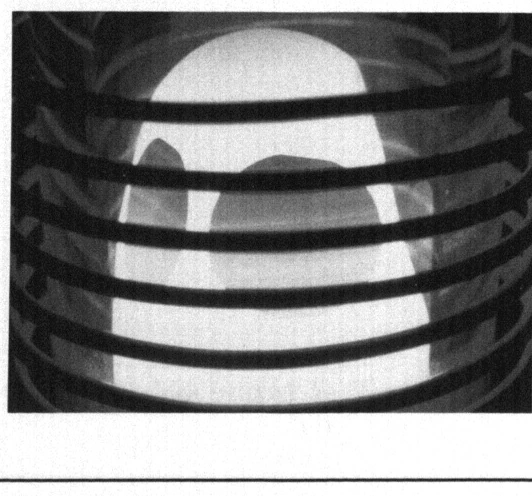


Manipulating microbes. ***Two students at Montana State University work on industrial uses of microbes with a Conoco research scientist. This is one example of work done through Engineering Research Centers supported by NSF.***

local colleges and universities. Those students and teachers get involved in ongoing research. For example, at Rice University in Houston, TX, five minority high school students obtained summer jobs working with center researchers, and both Rice and Caltech held short courses for 66 science and math teachers from high schools with significant minority enrollments.

Engineering Research Center News: MIT's center has taken the lead in an effort called the Interdepartmental Biotechnology Program. This program draws undergraduate and graduate students from biology, chemistry and engineering, training them in key aspects of bioprocess engineering. This program is jointly funded by the center and a grant from the National Institutes of Health.

Two other ERC's have aided the creation of master's level programs at their home institutions. They are Purdue's Center for Intelligent Manufacturing Systems (helped establish a master's program in Manufacturing Engineering), and Duke University Center for Emerging Cardiovascular Technologies (influenced creation of master's in manufacturing systems and engineering).



Small Business Innovation. ***Superconducting film that will increase computer speed is deposited from a heated metal block onto a semiconductor wafer at Spire Corporation, Bedford, MA. Spire is a small high-tech firm supported by NSF's SBIR program.***

Exploratory Research: NSF has begun funding small-scale exploratory investigations in all fields of science, engineering and education supported by the Foundation, using brief proposals without the usual external review. Such work includes preliminary research on untested, novel ideas; emerging-research ventures; work requiring urgent access to special data, facilities or equipment; and similar efforts likely to spark innovative advances.

Small Business Innovation: Since 1977, NSF's Small Business Innovation Research Program has provided early support to small high-technology businesses for research that has led to a variety of commercial products. In 1990 the program emphasized research in biotechnology, scientific instrumentation, supercomputing, manufacturing systems, superconducting materials and high-definition video display.

1990 Activities— Developing Human Resources

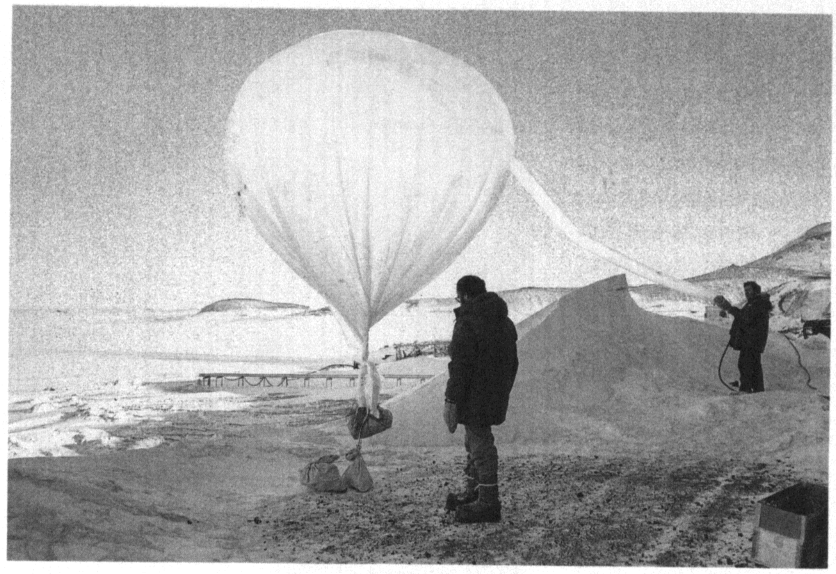
Major Education Reforms: NSF's Scope, Sequence and Coordination program could be the most far-reaching science education reform in the United States since the Sputnik era of the 1950s. The first NSF grants for this initiative were announced in September 1990. Through this program, curricula for more than a million science students in five states will be affected in pilot projects which, if successful, could transform middle level and high school science classes nationwide.

Students may have completely new science class schedules, with time spent in science courses increased by as much as half. Course content will be closely coordinated from one subject to another, and subjects will be offered over three or four years instead of just one year, leading to a more integrated high school science education. (See chapter 3, education section, for more on this initiative.)

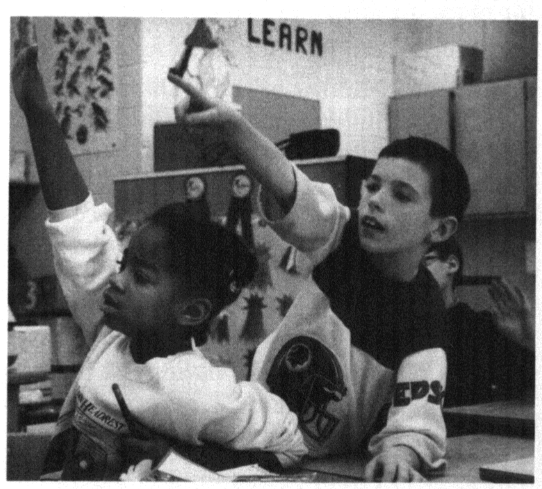
NSF also has announced another major new activity, Statewide Systemic Initiatives in Science, Mathematics and Engineering Education. This large-scale program aims to accelerate the pace of educational improvements by encouraging major changes in state education programs. NSF will provide part of the initial support for up to five years for selected reform efforts. To receive funding under this activity, states must demonstrate plans to revamp the way they recruit, prepare and retain science teachers, along with other systemic changes. (See also chapter 3 for more on this initiative.)

New Minority Program: Every hour of the school day a minority college freshman planning to major in science or engineering changes his or her mind. One of four minority freshmen majoring in science and engineering actually earns a degree in these fields.

To encourage the private sector to support more minority involvement in science and engineering, NSF launched a new program called Alliances for Minority Participation (AMP), and sponsored a National Leadership Forum on this issue. In August 1990, leaders from some of the nation's largest corporations and private foundations met in Washington, D.C., with their government counterparts to pursue the partnerships idea.

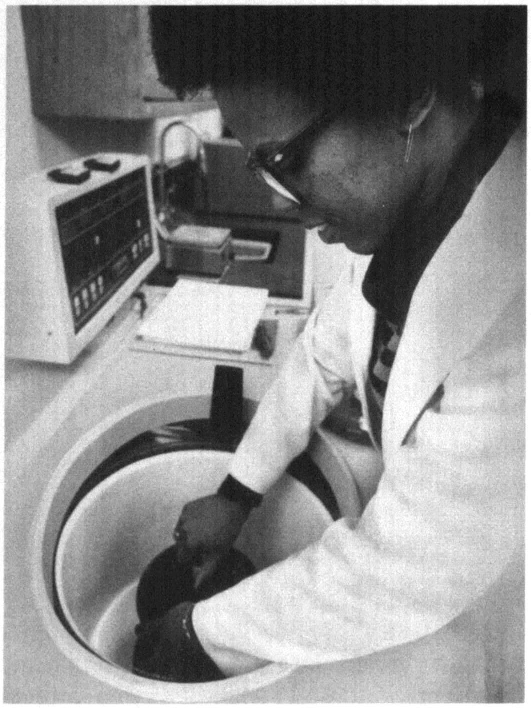


Antarctic News. ***Working out of remote field stations and at three U.S. research bases, 341 researchers and technicians participated in the 1989-1990 U.S. Antarctic Program. They conducted 95 field projects on the coldest continent, a land that was largely unexplored before U.S. scientific activity began there some 35 years ago.***



Revamping education. ***The states are working with NSF to improve math and science teaching in schools nationwide, through such NSF efforts as the Scope, Sequence and Coordination program and Statewide Systemic Initiatives.***

Focus on engineering. ***Three new engineering education programs at NSF aim to boost the number of engineers among women, minorities and disabled persons.***



The AMP program targets key transition points in the educational pipeline: between high school and college, between the freshman year of college and graduation, and between receipt of a bachelor's degree and graduate study. This program represents a new strategy to ensure that there are more minority students earning bachelor's and graduate degrees in science and engineering. AMP is part of NSF's effort to boost minority degrees in those fields to 50,000 baccalaureates and 2,000 doctorates by the year 2000. (See chapter 3, education section, for more on this.)

Women, Minorities and Disabled Persons in Engineering: NSF launched three new engineering education programs in FY 1990. The programs were responses to *Changing America: The New Face of Science and Engineering*, a 1989 report by the federal Task Force on Women, Minorities and the Handicapped in Science and Technology.

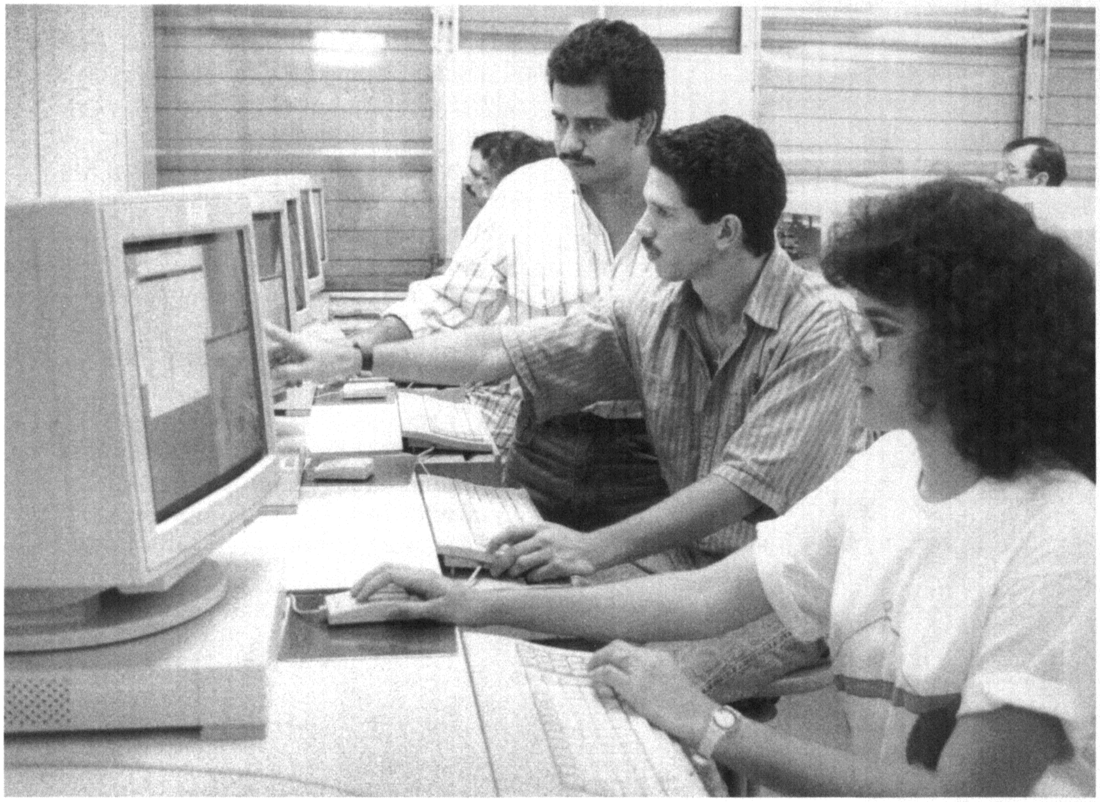
The *Engineering Education Coalitions* program supports innovative, system-wide models for undergraduate engineering education. These models are developed by university coalitions that include both small colleges and major research universities. Another program goal is to boost the number and quality of baccalaureate degrees awarded, especially to women, minorities and people with disabilities.

Faculty Awards for Women Scientists and Engineers will recognize and encourage outstanding female scientists and engineers in academic careers. And *Graduate Engineering Education for Women, Minorities and Persons with Disabilities* is a fiscal 1991 program to encourage those three groups to pursue engineering doctoral degrees and become faculty members.

Life Science Studies for Minorities: While the number of minority Ph.D.'s has grown some over recent years, the number pursuing careers as research scientists has not shown as much progress. To help address this problem, NSF has a program of three-year Postdoctoral Research Fellowships for U.S. minorities who are underrepresented in science. The goal is to produce highly trained minority scientists who will be prepared to assume leadership roles in biological/behavioral/social science research.

This program offers opportunities for postdoctoral training of the highest quality for recent minority Ph.D.'s selected as Fellows. Special provisions address the particular needs of this group. For example, NSF program officers can help candidates identify postdoctoral mentors, and small travel awards are available for visits with those mentors. At the end of a fellowship period, Fellows are eligible to apply for an NSF starter grant to launch an independent academic research program.

Through these approaches, NSF hopes to invest recent minority science Ph.D.'s with the contacts and support they need to become leaders in the science research community.



New computing resources. ***An instructor demonstrates the latest in computer design techniques to students in the Computer Architecture Laboratory at the University of Puerto Rico, Mayaguez.***

University of Puerto Rico

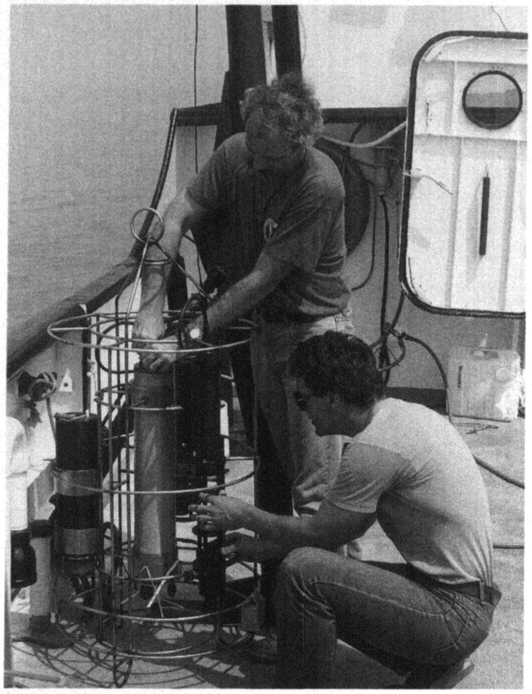
Research Training Group Awards: These NSF grants are for unique training programs in biological, behavioral and social sciences. Under this program, 11 universities are launching 10 new projects to train students in rapidly advancing research areas that require knowledge from many of the traditional academic disciplines.

Research themes include urban poverty, race and social policy; plant cell biology; past climates; animal behavior; the history, philosophy and sociology of science; genes in evolution; development of the nervous system; and mathematical models applied to behavioral sciences. Universities receiving grants are in California, Georgia, Illinois, Indiana, Michigan, Minnesota, Oregon and Pennsylvania.

The new projects, sponsored by NSF's Directorate for Biological, Behavioral and Social Sciences, will promote closer interactions among faculty from different departments. These senior scientists will oversee the multi-disciplinary training of undergraduate and graduate students, and of post-doctoral fellows.

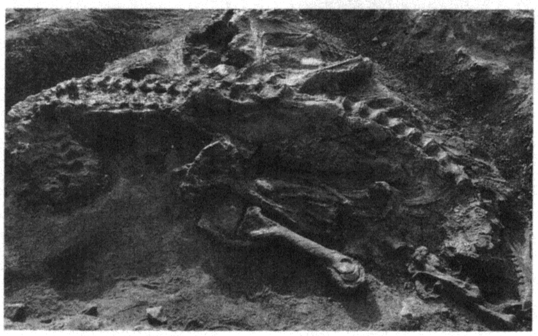
Undergraduate Engineering: In a program to reshape undergraduate engineering education in the United States, new freshman-year engineering courses were developed at the Rose-Hulman Institute of Technology in Terre Haute, Ind., by *Jeffrey E. Froyd*. Ultimately, 12 courses comprising 37 credit hours of mathematics, science and engineering will be replaced nationwide with three courses of 12 hours each.

The project offers a new approach to the freshman experience, in which each course will integrate the relationships among the fundamentals of math, science and engineering. This and 21 other projects were supported by grants under an NSF program called Undergraduate Curriculum Development in Engineering. The grants represent an NSF commitment to 21 universities and organizations in 13 states and the District of Columbia.



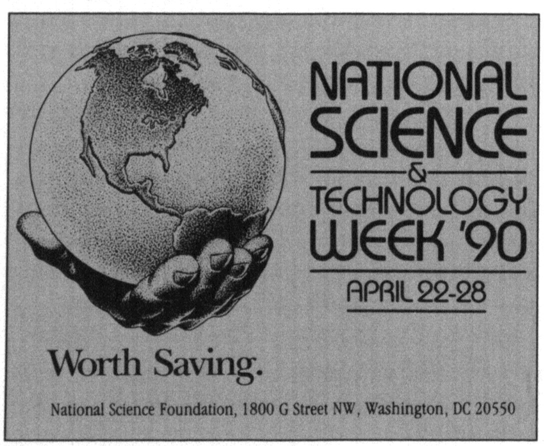
Perry Jones

Ocean profile. ***Under NSF's Experimental Program to Stimulate Competitive Research (EPSCoR), oceanographers prepare a probe to analyze sea salinity, temperatures and depths in Massachusetts Bay.***



Museum of the Rockies

Prehistoric life. ***The first fully complete skeleton of a*** **Tyrannosaurus Rex** ***was found by Montana paleontologist Jack Horner, with past funding from NSF's EPSCoR program.***



National Science and Technology Week. ***The 1990 theme of National S&T Week was "Global Change: Options for Action." The Week is a major educational effort launched by NSF in 1985.***

Minority Computing: Awards from NSF's Directorate for Computer and Information Science and Engineering are helping to establish computer facilities at two predominantly minority universities. These research and education awards are the first installments of five-year grants.

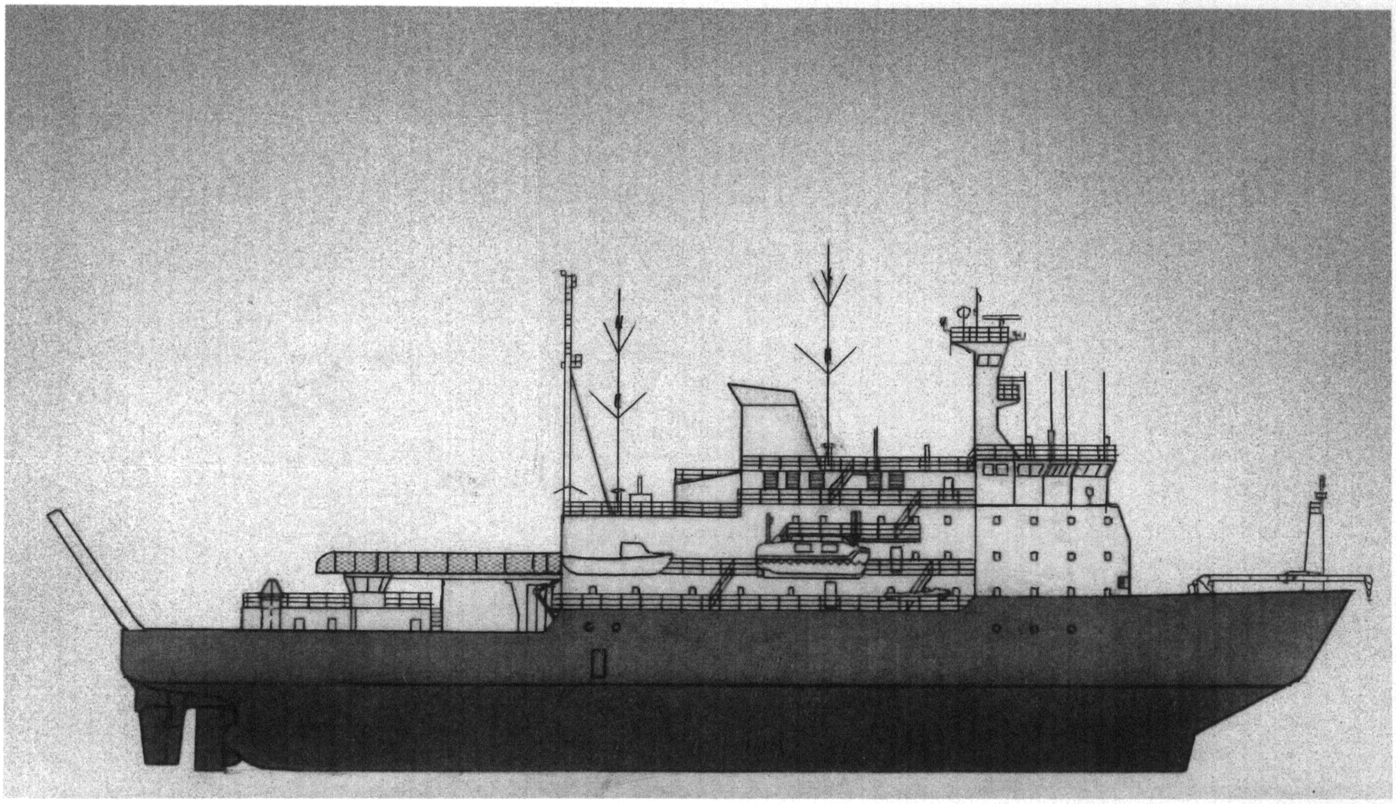
North Carolina A&T State University in Greensboro is receiving funds for computer projects linked with Stanford University, Duke University, the University of Michigan and Michigan State University. The University of Puerto Rico at Mayaguez is acquiring new computing resources, developing a master's program in computer engineering, launching a manufacturing research program with industry, and promoting faculty development and research.

Competitive Research in Key States: Through its Experimental Program to Stimulate Competitive Research (EPSCoR), NSF awarded two-year grants to Arkansas, Maine, Montana, South Carolina and West Virginia to strengthen their research efforts.

At the University of Arkansas, the focus is on expanding opportunities for biological researchers, including programs for undergraduate, high school and minority students. In Maine, a climate research project mounted by the University of Maine and Bigelow Laboratories is also supported by the state's Science and Technology Commission.

The Montana University Systems award, focusing on cellular and developmental neurobiology, potentially could link the state's various commercial biotechnology efforts. The University of South Carolina's project emphasizes research in molecular and cellular biology, and in ecology and evolution. Finally, researchers at West Virginia University are investigating a novel peptide regulator of cellular calcium, among other projects.

The EPSCoR program, launched in 1978, is one way that NSF supports states that traditionally have not received a large share of federal funds for S&T research.



Icebreaker. ***This new research ship will go into service in the Antarctic in 1992.***

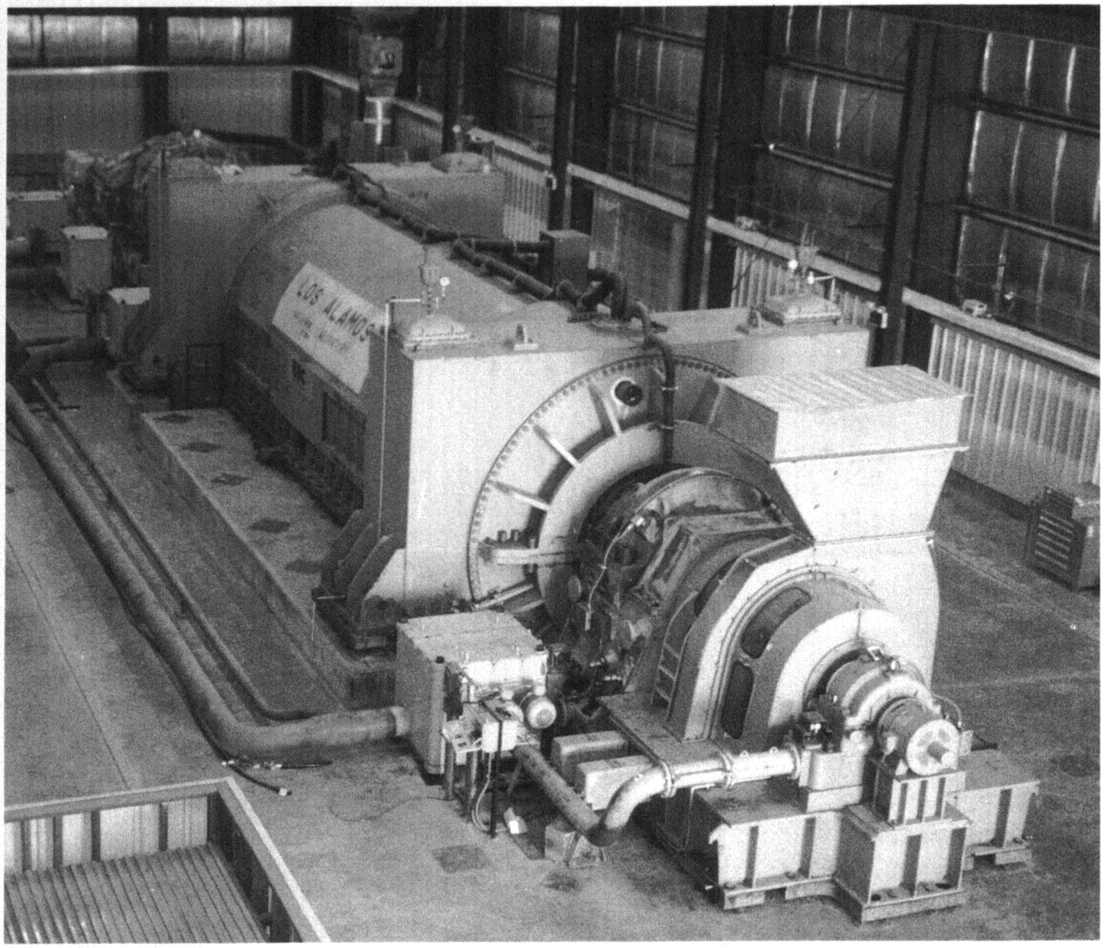
1990 Activities—Instrumentation, Facilities

New Oceanographic Facility, New Research Ship: Ocean scientists are benefitting from a new, NSF-backed, national site for round-the-clock analysis of ocean samples. In 1990 the National Science Board approved creation of the Accelerator Mass Spectrometer facility at the Woods Hole Oceanographic Institution in Woods Hole, Mass.

By serving as a sink for industrial gases emitted into the atmosphere, the world's oceans temper global warming caused by the intensified greenhouse effect. But scientists don't know how much of the emitted greenhouse gases end up in the oceans, nor do they fully understand how ocean organisms transport and recycle carbon from carbon dioxide and other molecules, or the processes governing ocean currents.

At the new site, researchers can trace climatic and oceanic processes over longer time periods and with greater precision. The facility features an accelerator mass spectrometer, a state-of-the-art instrument that is about 1,000 times more sensitive than conventional technology in detecting slowly decaying radioisotopes.

NSF also has signed a contract for the construction and 10-year leasing of a 90-meter icebreaking research ship for use in the U.S. Antarctic Program. (NSF is the lead federal agency in Antarctica.) The ship, scheduled to enter service early in 1992, will be the first U.S. flag vessel with icebreaking capability that is fully dedicated to research and capable of operating year-round on the world's coldest continent.



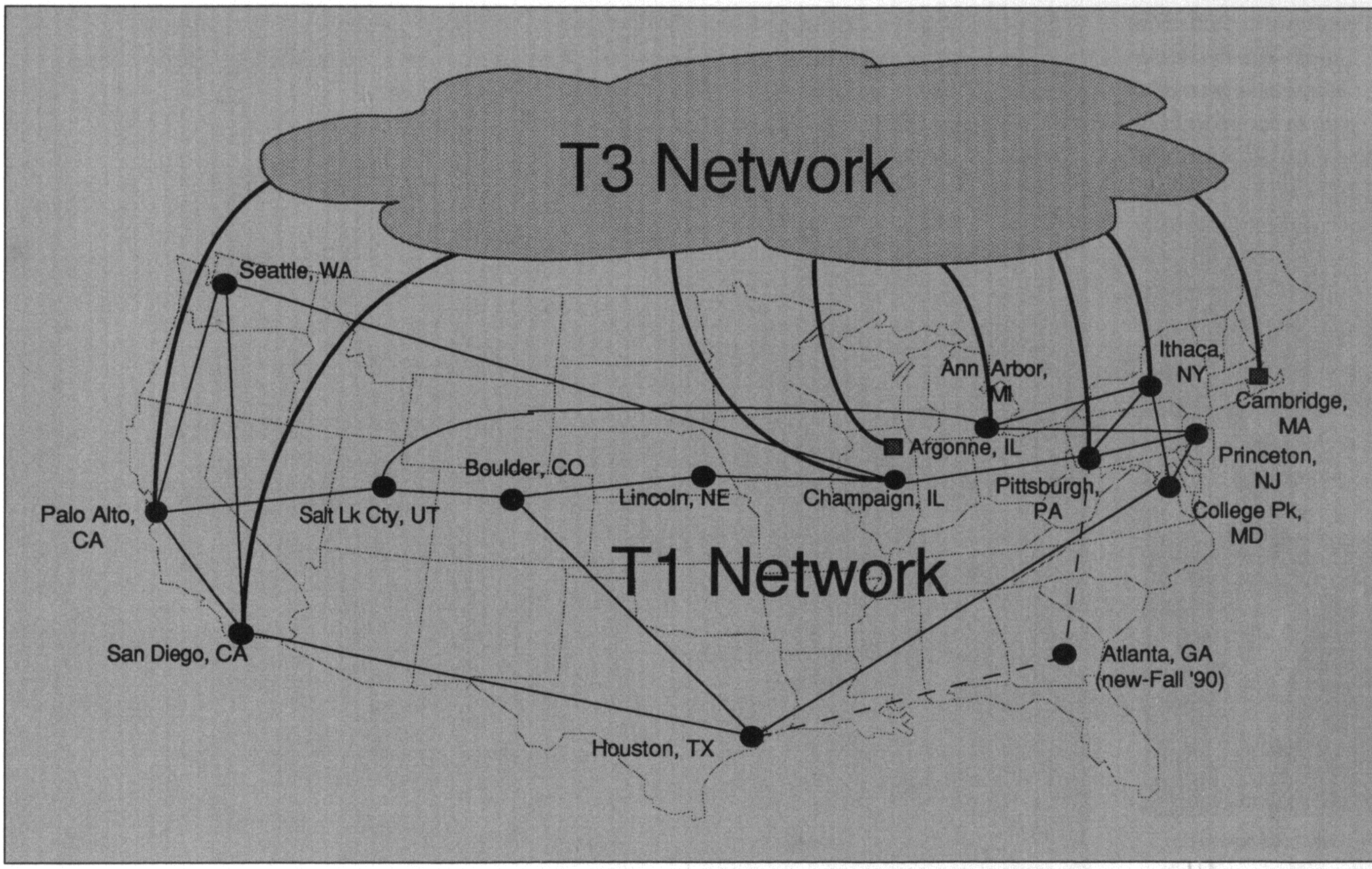
Power magnets. ***This 1430 megawatt electric generator—unique in the world—will be used to power long-pulse quasi static magnets at Los Alamos National Laboratory, as part of the new National High Magnetic Field Laboratory. The very intense magnetic fields generated by such magnets will be used to carry out basic research, such as studies of high-temperature superconductors.***

High Magnetic Field Lab: In 1990 NSF requested proposals to establish a new National High Magnetic Field Laboratory; its development will be guided by the July 1988 report of an NSF Panel on Large Magnetic Fields. A five-year award went to a consortium led by Florida State University. Other partners are the University of Florida and Los Alamos National Laboratory in New Mexico.

NSF and the state of Florida will share the cost of establishing and operating the facility. The lab, which will boast powerful magnets creating unprecedented magnetic field strengths, should contribute to basic discoveries in many areas, including materials research, physics, chemistry, biology and engineering. The success of this lab is expected to boost U.S. competitiveness in high-magnetic field research for decades to come.

NSFNet Expansion: In expanding its nationwide computer network, NSFNet, NSF has created the world's fastest openly available computer network for research and education. Three new nodes are being added to the NSFNet backbone, increasing data transmission speed on several key links to 45 million bits of information per second.

Sites linked by the new connections are Cambridge, Mass., Argonne, Ill., and Atlanta, Ga. These sites augment 13 nodes that connect mid-level networks—which link computers in hundreds of university, government and industrial research institutions worldwide—to the network backbone.



Network improvements. ***In addition to its three new stations (Atlanta, Houston and Pittsburgh), NSF's nationwide research network is being upgraded with faster data transmission between several key links for a newer T3 network.***

Gigabit Network: NSF and the Defense Advanced Research Projects Agency (DARPA, part of the U.S. Department of Defense) have made a three-year award for research on very high-speed communication networks. The award went to the Corporation for National Research Initiatives (CNRI), a non-profit organization in Reston, Va.

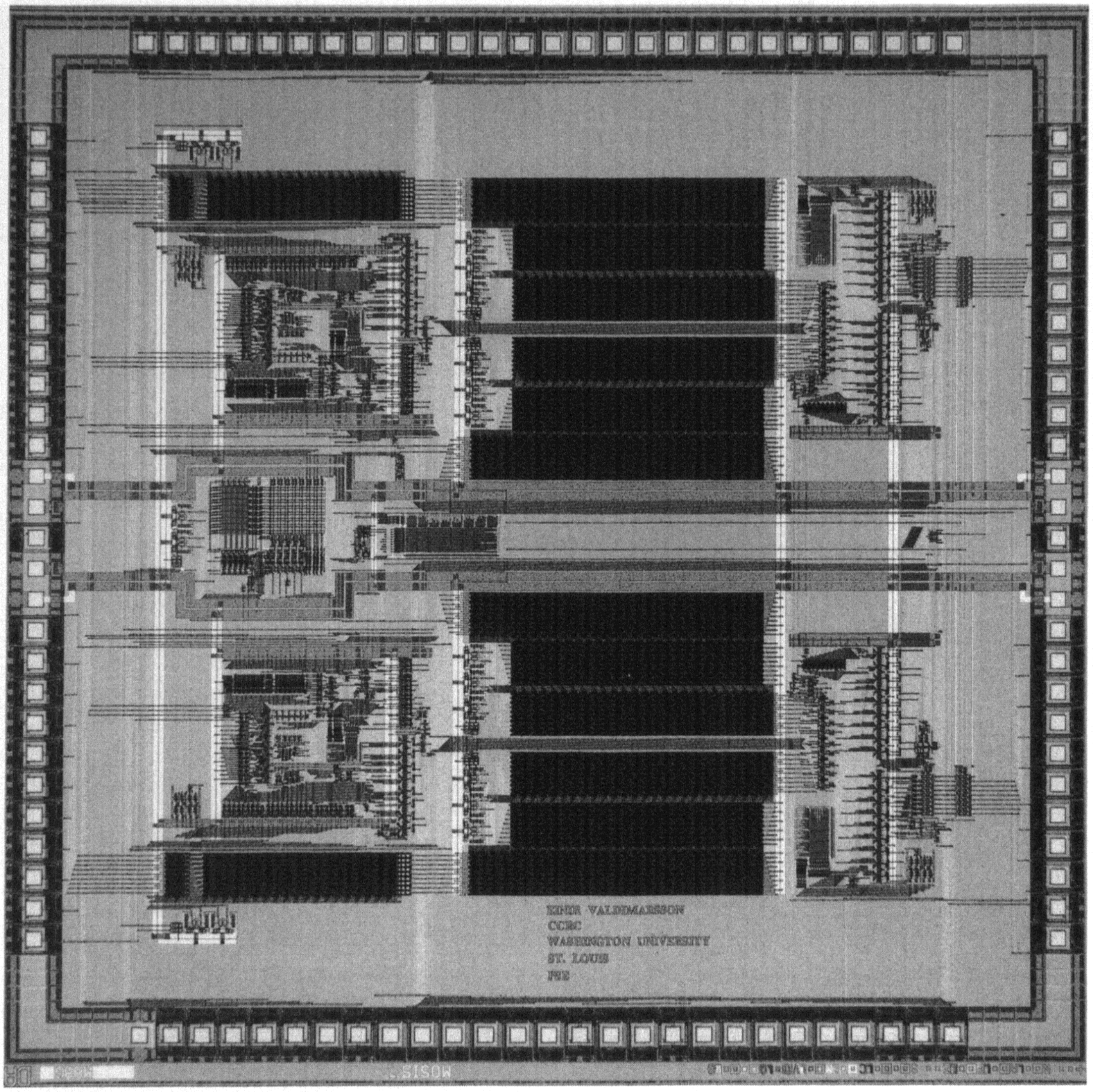
Communications networks operating at speeds of about a billion bits per second or more (called gigabit networks) will enhance the ability of end users to access remote facilities and collaborate with colleagues in other parts of the country and the world. The networks will enable researchers to access and connect supercomputers, workstations, graphic processors and large data bases. The researchers will also be able to use advanced collaboration techniques.

CNRI will lead research focusing on gigabit testbeds. Research participants include universities, national labs and supercomputer centers, and industrial organizations. Industry will contribute switching, interface, and computer and fiber-optic transmission capacity. Research applications include weather and storm modeling, geologic mapping, chemical dynamics, real-time sensor data analysis and biomedical imaging.

In another joint project, NSF and DARPA began to support research projects on formal methods technology and software engineering. The goals here are to strengthen the scientific basis for formal methods applied to specifying, analyzing, verifying, testing and adapting programs; improve the engineering basis of experimentation; and, through joint awards, promote collaboration between academic and industrial partners.

Radio Telescope: The National Science Board approved an award to Associated Universities, Inc., for the design of a new

Prototype switch. *The high-speed switch element is part of a system for switching data among hundreds of fiber optic data links. Applications include storm modeling and biomedical imaging.*



100-meter radio telescope at the National Radio Astronomy Observatory (NRAO), Green Bank, West Virginia. The fully steerable instrument will be the world's most advanced radio telescope, replacing a partially steerable, 90-meter instrument that collapsed at Green Bank in November 1988. The new telescope, projected to become operational in 1995, will detect energy emitted at radio wavelengths by objects in space, much as optical telescopes detect energy emitted at visible light wavelengths. It will be particularly valuable for Very Long Baseline Interferometry, a type of radio astronomy using antennas that are thousands of kilometers apart.

Research Facilities Modernization: NSF has a new program to support the repair, renovation and replacement of existing research and research training facilities at nonprofit research institutions. Initial awards in 1991 went to 78 colleges, universities, and nonprofit institutions in 37 states. Award recipients include 26 institutions that grant baccalaureate and master's degrees, 43 that grant doctorates, 3 museums, 1 consortium, and other nonprofits.

Awards, New Top Staff

Distinguished Public Service Awardees: *Rep. George E. Brown, Jr.* (D-Calif.), chairman of the House Science, Space and Technology Committee

Retired Congressman *Emilio Q. Daddario* (D-Conn.), chairman of the House Science, Research and Development Subcommittee 1963-1970

John A. Young, president and chief executive, Hewlett-Packard Co., Palo Alto, Calif.

This award is given periodically to those who have distinguished themselves through their leadership, public service and dedication to the support of American science, engineering and education in those fields.

Alan T. Waterman Awardee: *Mark E. Davis*, professor of chemical engineering at Virginia Polytechnic Institute and State University. Davis is the first engineer to receive this major NSF award, which is presented to an outstanding young researcher each year.

New NSF Director: *Walter E. Massey*, Vice President of The University of Chicago for Research and for Argonne National Laboratory, became NSF's ninth director in March 1991. Massey, a physicist, has an extensive background in teaching, research and administration. He is a former member of the National Science Board and a past president of the American Association for the Advancement of Science.

New Deputy Director: In March 1990, *Frederick M. Bernthal* was sworn in as NSF's deputy director. From September 1990 until March 1991, he served as acting director of the Foundation. Bernthal, a chemist, previously had been assistant secretary for oceans and international environmental and scientific affairs at the U.S. State Department.

New Assistant Directors: Mathematician *David A. Sanchez* was named assistant director for Mathematical and Physical Sciences. Formerly he was vice president and provost at Lehigh University, Bethlehem, Pa.

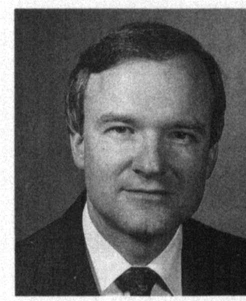
NSF Senior Science Adviser *Luther Williams* became assistant director of NSF's new Directorate for Education and Human Resources—previously called Science and Engineering Education (SEE). Williams is a past president of Atlanta University. The new directorate he heads includes all of the old SEE programs, along with some of the human resources activities formerly lodged in the Directorate for Scientific, Technological and International Affairs.

National Science Board News

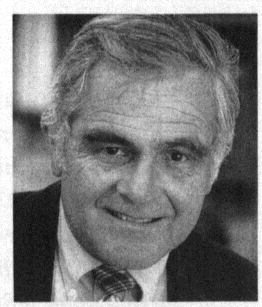
American science and engineering are vibrant and productive, but the United States is no longer dominant in these fields, according to a 1990 statement by the National Science Board. In The State of U.S. Science and Engineering, the Board also reiterated the need for better science and math education (both precollege and undergraduate) and stronger support for university research.

These findings were based on *Science and Engineering Indicators—1989*, a statistical report prepared biennially in NSF's Division of Science Resources Studies and issued by the National Science Board. The report provides a broad base of data about U.S. science and technology, including information on research and development, education, employment, expenditures and public attitudes.

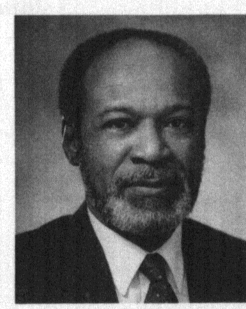
Walter E. Massey, ***new NSF Director***



Frederick M. Bernthal, ***NSF Deputy Director***



David A. Sanchez



Luther Williams

International News

EXIRPTS: In 1987, NSF joined the Exchange of Information on Research Projects (EXIRPTS), which involves science agencies from Great Britain, the United States, Japan, France, Sweden, West Germany and Canada. EXIRPTS provides a forum for exchanging information about research activities sponsored by member organizations. During FY 1990, the group developed a prototype of an electronic catalog that allows science administrators and researchers to obtain study summaries and information on principal investigators in each country. EXIRPTS members believe the on-line catalog will increase knowledge-sharing and encourage research collaborations.

Interns: Twenty-five U.S. science and engineering graduate students have had first-hand experience in Japan's science research labs, thanks to a program sponsored by the U.S. and Japanese governments. Students attending the NSF Summer Institute gained not only lab experience but an introduction to both the Japanese language and the science policy infrastructure there.

NSF selected interns through a national competition, and the Science and Technology Agency of Japan arranged for their placement in Japanese government labs. The students, from 21 universities in 15 states, represented a broad cross-section of disciplines, including the physical, biological and computer sciences, geology, oceanography and several engineering fields.

Japanese Databases: Through a new NSF program, U.S. scientists and engineers may now access—at no charge—computer-searchable, bibliographic databases in Japan. The databases are compiled and updated by Japan's National Center for Science Information Systems (NACSIS), a component of the Ministry of Education.

The databases include information about research projects sponsored by the Ministries of Education, Science and Culture; papers presented at electronics and chemistry society conferences; doctoral theses; and both Japanese- and foreign-language holdings of periodicals and books in the libraries of 1,100 Japanese universities.

Under this NSF-Ministry of Education collaboration, the Ministry provides access to a trans-Pacific telephone link and supplies bilingual workstations.

Japan interns. *White House science advisor D. Allan Bromley meets with 25 U.S. science and engineering graduate students as they prepare for NSF's Summer Institute in Japan.*

Special Focus Sections

Special Focus: Redirecting S&T Education

> By the year 2000, U.S. students will be first in the world in mathematics and science achievement—*Statement from education summit meeting of President George Bush and the nation's governors, February 1990*

Over the years, most education reform programs, including those supported by the National Science Foundation, have resulted in important but often incremental changes. In 1990, NSF's new Education and Human Resources Directorate (EHR, formerly Science and Engineering Education) began structuring its programs toward more fundamental change, seeking a major redirection in science/mathematics/engineering education. Supplementing its traditional activities, NSF has created more comprehensive projects that spring from broad collaborations among schools, industry and various levels of government.

One sweeping change in education is called *Scope, Sequence and Coordination* (SS&C). This is perhaps the most far-reaching science education reform in the United States since the Sputnik era of the 1950s. Curricula for more than a million science students in five states will be affected in pilot projects which could transform middle and high school science classes nationwide. Students may have completely new class schedules, with time spent in science courses increased by as much as half.

One objective of this program, which is supported by $8.6 million in NSF grants, is to spread the teaching of science over several years, progressing from basic concepts to more abstract theories. Course content will be closely coordinated from one subject to another, and subjects will be offered over three or four years instead of just one year, leading to a more integrated science education. For instance, concepts of chemistry and biology might be integrated into a more general multi-disciplinary module on aquatic ecosystems.

The first SS&C grants went to the National Science Teachers Association (the overall project coordinator); the University of North Carolina at Wilmington/East Carolina University in Greenville; the Puerto Rico Center for Science and Engineering; the University of Iowa; the California Department of Education; and the Baylor College of Medicine.

The *Statewide Systemic Initiative* (SSI) is another example of far-reaching change. This initiative has three aims: to *extend the impact, accelerate the pace and increase the effectiveness* of statewide, and systemwide, improvements in science and technology (S&T) education. The focus here is on both precollege and undergraduate students.

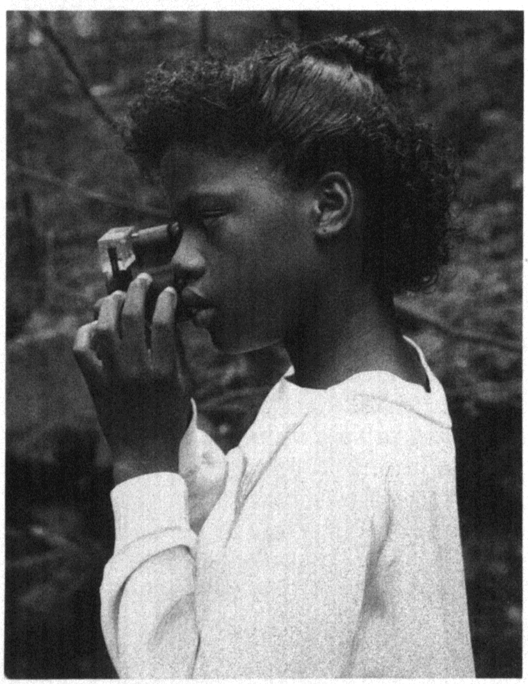
The first SSI proposals were submitted by the governors of each state in late 1990. The programs funded will address major elements of science and math education, such as training teachers, developing materials and curricula and assessing student progress. NSF's portion of the cost-shared programs can reach $2 million a year per proposal, for up to five years. This contribution is expected to leverage considerable financial commitments from state governments and private industry.

A continuing program in 1990 was the 60-project *Private Sector Partnerships*, which tap the private sector's intellectual resources and involve industry cost sharing. Some two-thirds of U.S. research scientists, engineers and mathematicians work in industry, and NSF backs projects that draw upon a company's scientific expertise (see box next page).

Creative Robotics. ***Catherine Cooper, a science teacher from Sharon, MA, builds a robot car at the Thames Science Center in Connecticut.***

Robert Houser

Hands on. ***Ebony Cole, of New London, Conn., learns to use a stream sampler kit designed by the Thames Science Center to help students monitor their environment by testing water quality.***



Lisa Brownwell

Private Sector Partnerships

- At the Thames Science Center in New London, Conn., through Project RobotACTS, K-12 teachers develop both skills and classroom materials—including robot constructions, electronic assembly, computer operations, applied mathematics and engineering design. The hardware and software developed are designed for classroom use and could be marketed nationally by at least one private partner.
- In a Missouri project, the Cooperating School Districts of St. Louis collaborated with scientists from Monsanto and other area companies to establish the Mathematics and Science Education Center. This center will develop—and help biology teachers introduce—biotechnology units into their classes. All materials eventually will be available for national marketing.

Another NSF program, the *Engineering Education Coalitions,* aims to improve undergraduate education in various engineering fields by bringing together a cluster of two- and four-year schools to develop new curricula. Among the requirements: together the colleges must produce 2,000 engineers per year, 600 of whom must be women and minorities.

A math project of this type is the *Core Calculus Consortium* based at Harvard University. Here a national cluster of institutions is developing an innovative calculus curriculum that will be both practical for, and attractive to, many kinds of institutions.

Sustained Focus on Minorities and Women: In 1990, NSF continued its special focus on attracting—and keeping—women and minorities in science, mathematics and engineering. Old and new NSF programs, some of them described below, target specific groups of students at one or more educational levels—from precollege through graduate level and beyond.

Career Access Opportunities operates at the precollege level to channel more minority students into the career pipeline of science and engineering. Typical activities include Saturday academies, research collaborations with scientists, museum trips and special seminars.

Alliances for Minority Participation, or AMP, is a new, large-scale program for minority undergraduates that stresses cost-sharing partnerships among academic institutions, private companies and the National Science Foundation. AMP will operate through regionally based alliances of K-12 school districts, community colleges, four-year colleges, universities and local businesses.

AMP projects typically involve up to 500 students, and NSF's portion of the funding can reach $1 million a year for five years. Projects address one or more transition points in the educational pipeline where students tend to drop out of science—between high school and college, between undergraduate and graduate programs, or between graduate programs and science careers.

In the fall of 1990, NSF awarded the first AMP planning grants to 12 universities, among them Mississippi State, the University of Puerto Rico, Howard University in Washington, D.C., Arizona State University, and Oklahoma State University.

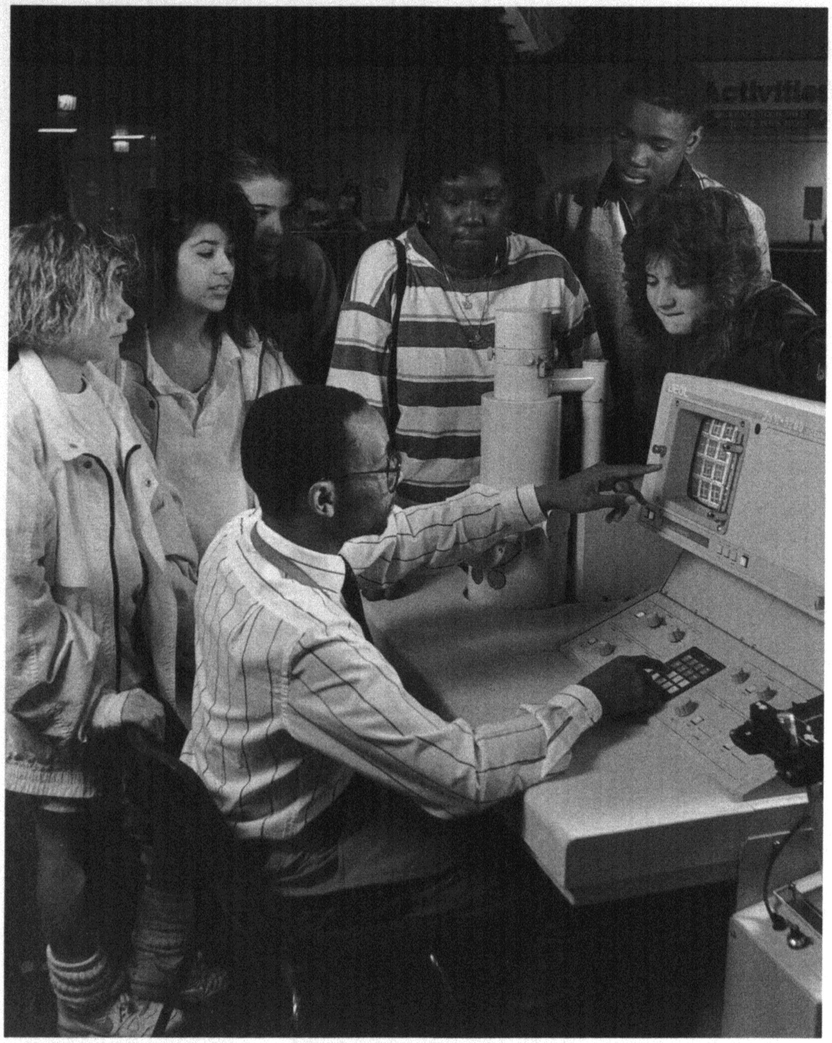
Research Careers for Minority Scholars is designed to attract undergraduate students with a B average or above into science and engineering. Students in this program have access to mentoring services, interaction with research faculty, special seminars and research assignments and summer jobs in research laboratories. The program helps students with tuition and books and offers peer counseling and study sessions.

The *Minority Research Initiation* program helps talented minority faculty members get started in research careers; there they help train our future researchers and serve as mentors and role models to those interested in science and engineering.

Another activity, *Research Improvement in Minority Institutions,* seeks to enhance research and training by funding faculty research, student involvement in that work and research equipment. This program also fosters cooperative research with industry. Last year, 15 grants went to colleges and universities with substantial minority enrollments. With one of these grants, biologists at Clark/Atlanta University in Georgia are establishing a resource center for electron microscopy. This center will serve several local academic institutions in the Atlanta area, including Morehouse and Spelman, two of the nation's historically Black colleges.

Environmental engineers at New Mexico State University in Las Cruces are examining the effect of tailoring soil and clay mineral properties to produce specific absorption characteristics. This research will lead to methods for removing organic pollutants from aqueous and gaseous streams, and to better management techniques for hazardous waste materials.

NSF is only one of many players in this vital drama. Ultimately, all who have responsibility for education in any place, at any level, must play their roles if we are to achieve the improvements in science and mathematics education demanded by the national interest . . . *Luther S. Williams, Assistant Director for Education and Human Resources, NSF*



Ken Howard (Copyright 1990)

"Informal" science. ***Demonstration of a scanning electron microscope gets student attention at the New York Hall of Science's exhibit "Hidden Kingdoms: The World of Microbes."***

Curricula: During the year NSF funded two large projects to develop comprehensive *math curricula* (including geometry and data analysis) for grades K-6; the Foundation also approved several middle school math proposals that will build on the elementary materials. These projects will add to the supply of K-9 materials that meet national standards and engage children in considerably more demanding math. The goal is to create a curriculum that presents more than arithmetic, focuses on problem-solving and uses computing support, is available to all school children (regardless of ability) and includes scientific applications.

In *curricula for the sciences*, 11 projects form the core of NSF efforts for elementary and middle school educational materials. The projects were funded under the *Publishers Initiative* and are sometimes called the Triad Projects. (All proposals had to show a three-way collaboration among a curriculum development team, a publisher and a set of schools.)

The proposals covered a variety of instructional materials, from textbooks to supplemental information such as a biweekly science magazine for children. An example is the National Geographic Kids Network Project, *KidsNet*, a series of exciting and flexible elementary science units. They feature cooperative experiments in which young students (grades 4-6) share data nationwide, via telecommunications.

These projects involve the students in issues of everyday scientific, social and geographic significance, such as testing water quality in different parts of the country and storing the information in a central database. Combining content from school curricula and an approach known as guided inquiry learning, KidsNet supplements textbooks and other classroom materials.

The National Geographic Society and a network of professional organizations, state education agencies and museums are publicizing this project. Eventually it will include computer bulletin boards and other forms of electronic mail that will encourage children and teachers to develop their own experiments.

Undergirding these efforts is the NSF program called *Research in Teaching and Learning*. Here scientists study the way people learn scientific concepts and how to communicate these concepts most effectively; studies range from basic cognitive science to the way a classroom is arranged for teaching hands-on science. Some researchers also examine the misconceptions students have about the principles of science and math, seeking ways to turn those misconceptions into understanding.

Also within the EHR Directorate is a small research and development effort through which scientists study the applications of advanced technologies—computers, video disks, television, telecommunications—to see how technology can be used in education. KidsNet came out of this NSF program, and researchers have been investigating an expanded role in education for NSFNet (the computer network linking NSF and research institutions).

Informal Science: Science taught outside the classroom is another way to attract people of all ages. Last year, NSF continued informal education efforts such as alliances with museums, also fostering links with community organizations (such as the YMCA) to deliver programs at sites outside the museums.

NSF also continues its support for instructional television in science and math, including the Children's Television Workshop programs *3-2-1 Contact* and *Square One TV*. When the year's production schedule for *3-2-1 Contact* ended, the segments were repackaged into units for use by schools. The programs also were indexed on computer disk and packaged with supplemental written materials developed for classroom as well as day-care and after-school use.

All of these programs, as explained by one NSF division director, are in the spirit of getting people linked . . . so they are not working in isolation.

Coordinating the Federal Role: In May 1990, D. Allan Bromley, Assistant to the President for Science and Technology, convened a Committee on Education and Human Resources under the Federal Coordinating Council for Science, Engineering and Technology, located in Bromley's Office of Science and Technology Policy. The Committee's purpose is to guide all federal activities in S&T education.

Besides NSF, these federal agencies are also on the Committee: NASA, the Environmental Protection Agency, and the Departments of Energy, Education, Defense, Interior, Commerce, Health & Human Services, and Agriculture.

In early 1991 the Committee published a report called *By the Year 2000*, which describes current federal efforts in S&T education, along with plans for future activities.

CTW/A. & S. Shevett

Iguana kiss. ***Stephanie Yu, host of the science series 3-2-1 Contact, meets a new friend in the rainforests of Costa Rica and explains the importance of these forests in the earth's ecosystem.***

Special Focus: Biological Diversity and Ecological Restoration

> If the Lord Almighty had consulted me before embarking on the Creation, I would have recommended something simpler.
> —*Alfonso X of Castile*

Facing a Loss: Although 1.4 million of the earth's plant and animal species have been given scientific names, the actual number of species could range from 5 million to 80 million. Human existence depends on such biological diversity—the variety of life forms, their ecological roles and their genetic diversity.

While knowledge of some groups of organisms is extensive, the vast majority is unknown. Nor is there an inventory of earth's plant and animal life forms. Even in the scientifically sophisticated United States, Harvard University's E.O. Wilson has estimated, a handful of soil from anywhere in the nation contains many organisms entirely new to scientists. The rate of disappearance for some of the earth's most precious animal and plant life is accelerating—from

Endangered life. ***Development and introduction of exotic plant species threaten the fiddlehead fern, indigenous to Hawaii.***

Tom Ranker

Hawaiian ferns to Olive Ridley sea turtles to African elephants. Relentless human activity is destroying or degrading entire ecosystems, speeding the loss of species from communities or ecosystems, and selectively inducing the loss of genetically distinct segments of animal and plant populations. Not all regions of the planet are equally affected, but the problem is global.

This wave of extinction is destroying both known life forms and those yet to be discovered. Unless reversed, over the next few decades the extinction rate could rise to 1,000 times the normal rate. A quarter of earth's species ultimately could be lost.

All things by immortal power
Near or far
Hiddenly
To each other linked are,
That thou canst not stir a flower
Without troubling a star.
—*Francis Thompson*

In an August 1989 report to the National Science Board, the Board's Committee on International Science's Task Force on Global Diversity recommended that NSF spearhead the funding of a research effort to inventory biological diversity and identify areas under particular stress.

The report, *Loss of Biological Diversity: A Global Crisis Requiring International Solutions,* also recommended more funds for efforts in conservation biology and restoration ecology. Researchers in these fields develop ways to conserve biodiversity and determine what information is needed about organisms that require help to survive. And they study how plants and animals respond to environmental change—both natural and human-induced.

Other report recommendations:

—A strengthened scientific basis for conservation biology and restoration ecology;

—Better education on biological diversity (including K-12 and informal science education);

—More research into the socio-economic bases of the causes, consequences and solutions to the biodiversity crisis; and

—New ways to support biodiversity science in developing countries.

NSF responded to the report's challenge in 1990. The Foundation's effort, funded through its Directorate for Biological, Behavioral and Social Sciences (BBS), is interdisciplinary, international, complex and long term. The project involves not only biologists but researchers from the social and economic sciences and the behavioral and neural sciences. Their goal is no less than understanding natural systems and their organisms—and how both change over time.

The far-ranging research topics and the sheer number of disciplines involved illustrate the stunning complexity of biological diversity. All this involves thinking about questions in new ways, as scientists supported by NSF continue to do.

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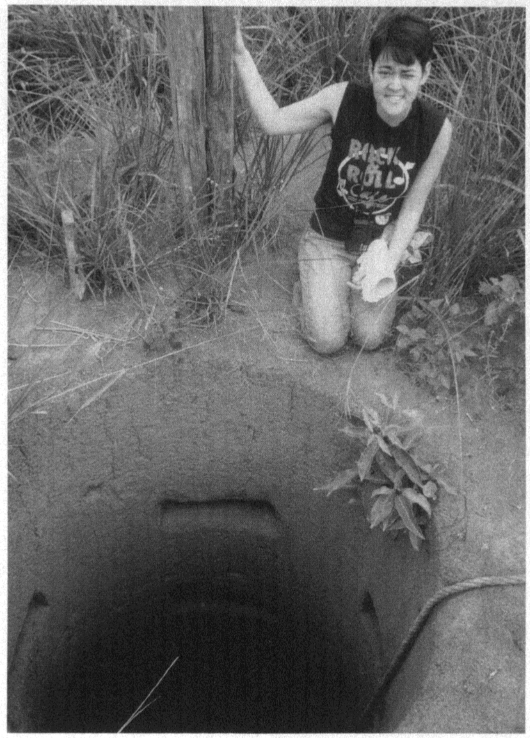
For years NSF's BBS directorate has funded biological diversity research within the *Systematic Biology Program*, focusing on surveys of organisms or habitats in different parts of the world. A scientist, for example, might study spiders in Chile, or the plants and animals of a piece of rainforest in Brazil. To highlight NSF's interest in biological diversity, the directorate agreed in 1990 to concentrate such proposals into a single review panel. The directorate is also fostering collaborative biodiversity research involving database experts, social scientists, ecologists and biologists (both molecular and cellular).

To advance knowledge of ecosystems and species under pressure, the Foundation launched a special grants competition in conservation biology and restoration ecology. The competition highlights activities funded through several BBS programs and encourages collaborations among many disciplines. Seventeen research projects were funded in 1990. Reflecting the complexity of the conservation issue, topics have ranged from molecular biology, animal behavior, ecosystem studies, international economics and changing people's perception of conservation in developing countries.

Another collaboration has been forged between NSF and the U.S. Agency for International Development (AID), to support biodiversity research in Africa, South and Central America and other areas. Some examples:

—One study seeks to understand how the use of religious water temples and other irrigation systems in Bali affects the economic and ecological regulation of irrigated rice terraces. To fine-tune and test a computer model (developed with prior NSF funding) of the temples' role in managing water in irrigated rice growing, and to determine effects on biological diversity in irrigated lands, researchers are measuring water flow, pest levels, production and other critical variables.

—Another is a pilot study to determine how legal, social and other changes have affected the physical landscape of part of the Amazon River in Brazil.



Scott E. Subler

Ground down. ***Taking a soil core from the Amazon rainforest floor helps scientists determine changes in the physical landscape of the area.***

Temple wisdom. ***Scientists use computer models to help them understand how religious water temples regulate the economic and ecological function of irrigated rice terraces.***

Water management. ***In Bali, researchers measure water flow and other factors in irrigated terraces, to determine the effects of irrigation practices on biological diversity.***

J. Stephen Lansing

Native knowledge. ***In Chiapas, Mexico, NSF funds research on contemporary Mayan ethnobotany—to help understand and preserve that culture's knowledge about biodiversity.***

—In Chiapas, Mexico, a third project addresses medical ethnobotany, ethnomedicine and ethnopharmacology of the native Tzeltal and Tzoltil populations. The project continues previous NSF-funded research on contemporary Mayan Indian medical ethnobotany. The results will include an encyclopedia of plants and their medicinal properties and local customary uses. Documenting native knowledge of the environment, according to the researchers, builds and preserves the cultural store of knowledge on biodiversity.

Special Focus: Earth System History

The earth has been changing naturally for millions of years. But now there is evidence that human activities are causing changes of their own: levels of the gases carbon-dioxide and methane are rising (which may lead to climate warming), while synthetic chlorofluorocarbons threaten the stratospheric ozone layer.

Concerns about these and other recent changes are driving the U.S. Global Change Research Program, a multiagency effort to reduce scientific uncertainties and produce more reliable predictions for devising policy strategies. Joining NSF in this work are NASA, the Environmental Protection Agency, the Smithsonian Institution, and the Departments of Commerce (National Oceanic and Atmospheric Administration), Defense, Energy, Agriculture and Interior.

The objectives of this federal program are to understand, monitor and ultimately predict global change through research into climate and hydrologic systems, biogeochemical dynamics, ecological systems and dynamics, earth system history, human interactions, solid earth processes and solar influences.

One of these research areas, earth system history, addresses several questions that are central to understanding global change: What is the degree of natural variability in global climate and environmental systems? What are the causes and consequences of global change? How can predictions from general circulation and other numerical models be tested?

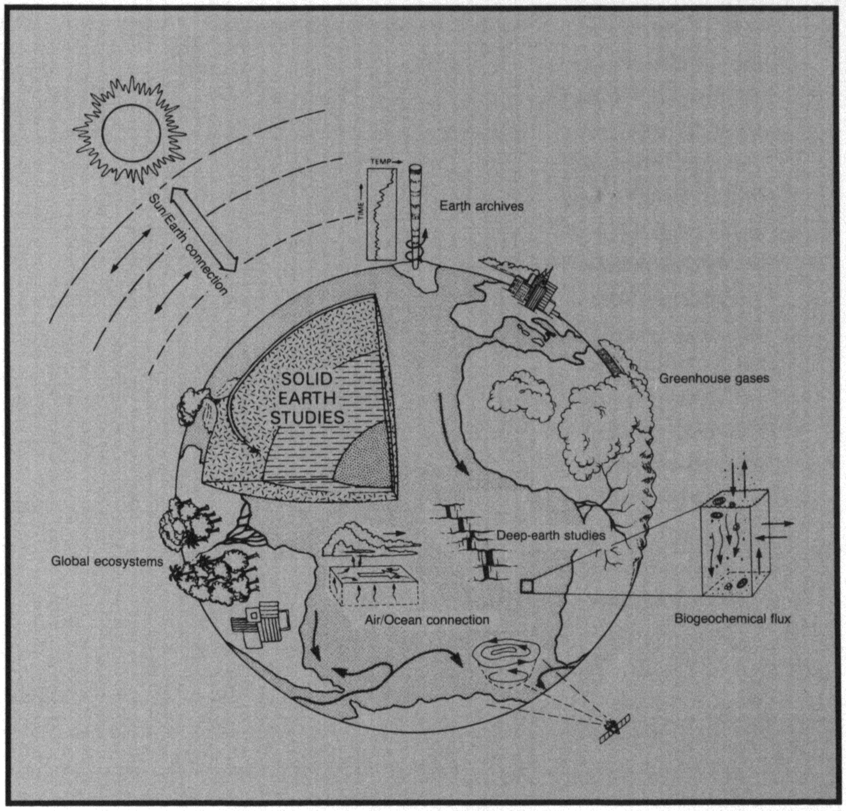
To separate human from natural causes in global change, scientists must know the planet's natural mode of variability. The goal of those studying earth system history is to look at environmental records—in tree rings, glacier ice cores, terrestrial and marine fossils, sediments and elsewhere—to paint a picture of the planet's normal behavior.

Geologic Record of Global Change: This NSF program is helping researchers gather some of those clues. Scientists use proxy parameters from the geologic record—among them carbon-14, oxygen and sulphur isotopes, organic material and grain sizes—to reconstruct past climate and environmental history. Oxygen isotopic chemistry, for instance, is used as a proxy for ice volume or global temperature.

NSF-funded research involving Barbados coral has revealed unexpectedly large errors in the carbon-14 dating method, developed in the late 1940's. One team used coral to calibrate the carbon-14 scale over the past 30,000 years. The results suggested that carbon-14 produces dates as much as 3,500 years too young for material from 20,000 years ago. This work will change the estimated dates of prehistorical events and help researchers better understand how the earth warmed after the last Ice Age—an issue important to predictions of future climate change.

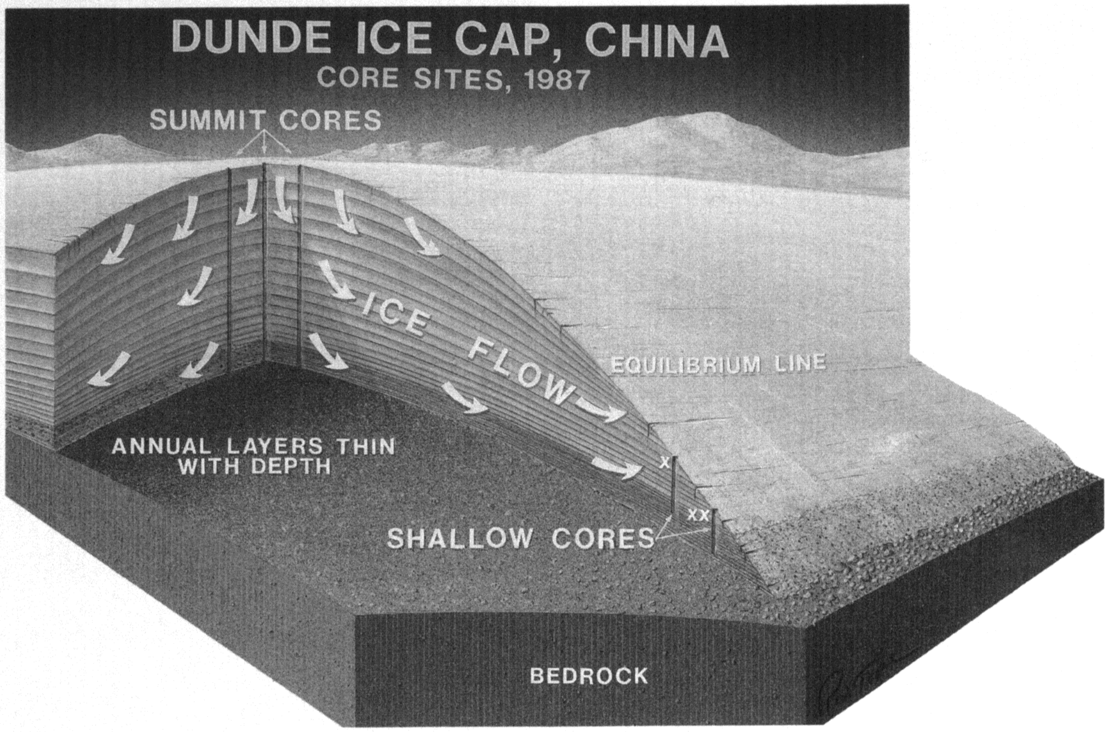
This team included Edouard Bard at the Center for Weak Radioactivity in Gif-sur-Yvette, France, and Richard Fairbanks at the Lamont-Doherty Geological Observatory in Palisades, N.Y.

In other research, seismic profiling and drilling in the sediments of New York's Finger Lakes gave a detailed record of continental climate change over the past 14,000 years. Studies on the sedimentary history of the Estancia Lake Basin in New Mexico aided development of a hydrologic climate record for the area. And scientists drilled in the Newark, NJ basin through Jurassic-Triassic sediments that are 150 to 220 million years old. The sediments, deposited



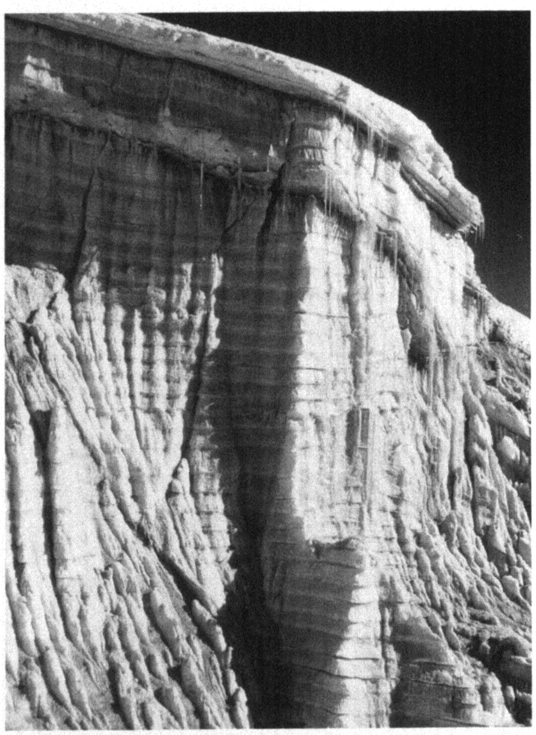
Integrated studies. ***Many disciplines and interdisciplines are required in studying global change. NSF participates in such whole-earth investigations, represented here schematically.***

40,000-year record. ***Drilling of the Dunde Ice Cap in China contributes to data on past climatic events, producing information that is essential in predicting future climate changes.***



Robert Tope

El Niño clues. ***The Quelccaya Ice Cap in the Peruvian Andes may provide a record of major El Niño events, a record scientists hope to use in predicting future occurrences that may alter global weather patterns.***

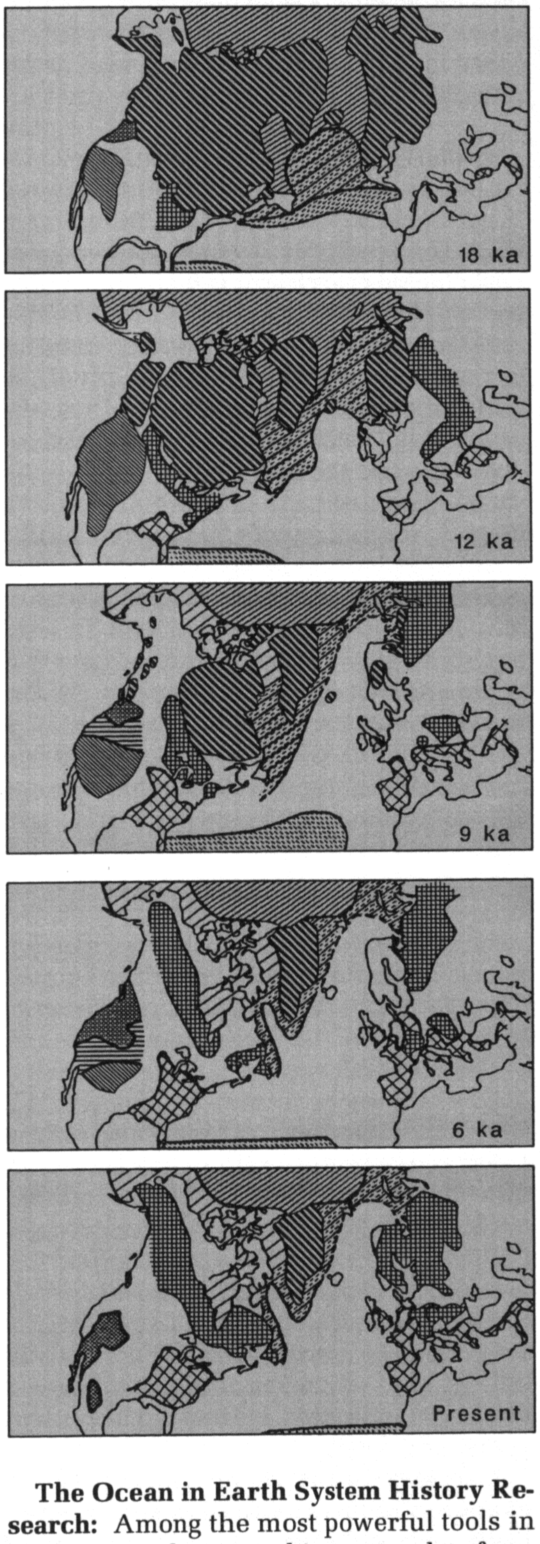


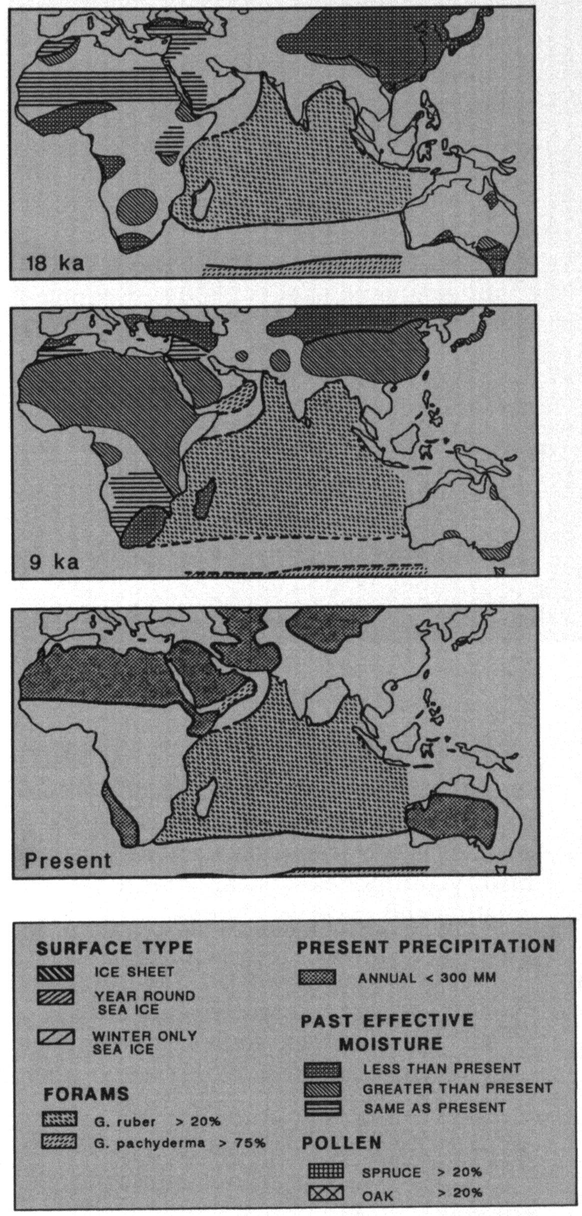
Lonnie G. Thompson

and undisturbed since the once-single continent that is now North America and Africa separated, will give scientists insights into the paleoclimates of that period.

Modeling Earth History: Compilations of such paleoenvironmental data also are used to construct empirical models of past global change and to develop synoptic reconstructions of past global environments. The goal is to improve the widely used general circulation models and mesoscale climate models of global change. One problem is accounting for the many important feedbacks that occur within a system as complicated as climate.

Another problem lies in validating models that predict climate 50 years in the future. One way to evaluate models is to understand the climate in terms of historical and paleoclimatic information, then predict the past and compare model results with proxy data. Recent research on earth system history contributed an important means of testing and improving these climate models.

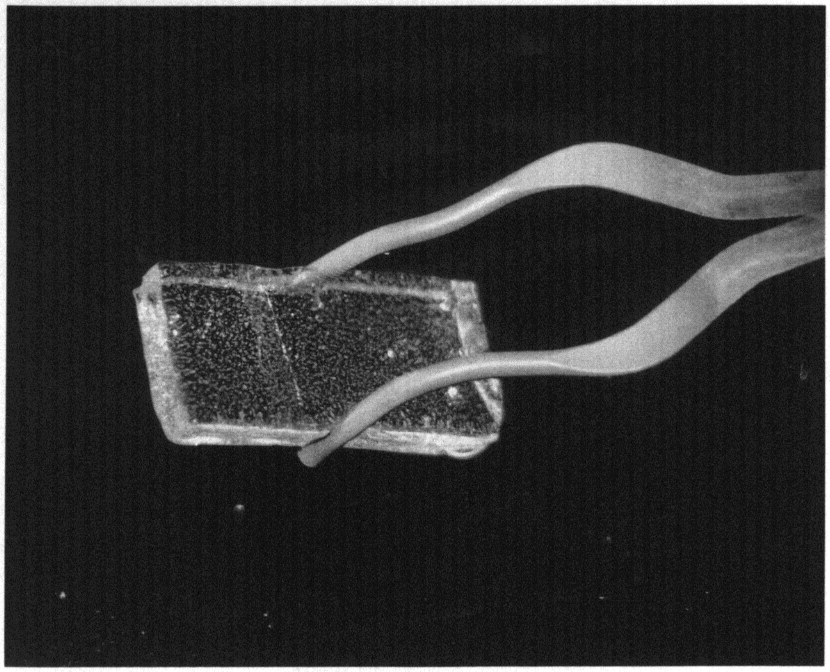




Climate changes. ***Over the last 18,000 years, ice sheets disappeared, vegetation was drastically altered, many types of large mammals became extinct, and the development of agriculture changed the course of human history, as shown in these maps constructed from geologic and paleoecologic evidence.***

The Ocean in Earth System History Research: Among the most powerful tools in studying earth system history are data from the oceans. Conditions in the very deep oceans preserve a continuous record of sedimentation; examination and dating of drill cores from NSF's Ocean Drilling Program can provide information back to about 130 million years, although many global change researchers are more interested in the past 10,000 years.

In 1990, NSF convened an advisory group of ocean scientists from around the country; they met for the first time to suggest research priorities and approaches for issues involving earth system history. Participants agreed on the need to study short-term variabilities



Michael Morrison

Ice Slice. ***This 1000-year-old ice cube, taken from 330 meters below the frozen crust of Greenland, has trapped the air (carbon dioxide bubbles) of the Little Ice Age.***

in the global system on a decadal to millenium time scale, the geological record of carbon dioxide and other carbon compounds, ocean-atmosphere stability in earth history, the modes of ocean-atmosphere circulation and sea-level change.

Abrupt Climate Change: One important question yet to be answered in the study of global climate change and earth system history is how rapidly ecosystems have adapted to past abrupt transitions in climate, and how ecosystem changes have influenced climate. There is potential for unprecedented rapid change in climate in the next century; investigators need more understanding of how parts of the system will respond and how that response will influence climate.

Studying examples of rapid transitions in the geological record allows investigators to understand how the components interacted and how the biosphere responded to climate shifts. The Little Ice Age, an intensely cold period in the northern latitudes from the 15th to the 19th centuries, is an example of such a rapid transition. Although the earth's immediate problem is the potential for global warming rather than cooling, understanding the climate system requires knowledge about all the earth's components.

Arctic System Science: Among the components especially useful for interpreting the geologic record are ice cores from Greenland. The idea here is to look at a history of past climate change as it is found in ancient ice samples from the Greenland continent—and elsewhere in the world. Falling snow incorporates a sample of the atmosphere; as snow accumulates it compacts into ice, which is layered like pages of a book. Scientists reading through the ice sheets get a chronology of past climate change by measuring parameters in the ice such as gases, dissolved chemicals and particulates.

This work came from the second Greenland Ice Sheet Program, or GISP II. The initial effort, GISP I, retrieved an ice core that approached an age of 100,000 years. GISP II is a five-year project taking place at a site called Summit, which has ice about 3,000 meters thick. Using new drilling technology, a consortium of scientists is working to retrieve a core estimated to be 125,000 years old.

GISP II is part of a larger effort called Arctic System Science (ARCSS). Research projects within ARCSS, which is coordinated through the Foundation's Division of Polar Programs, will study arctic paleo- and modern environments.

One of these projects is known as PALE (Paleoenvironmental Response in Arctic Lakes and Estuaries). While GISP II looks at climatic change over time, PALE examines ecological responses to climate change. Sediments of bogs, lakes and estuaries contain a detailed record of the physical characteristics, temperature and other aspects of the past environment. Changes in plant and animal distributions (resulting from climate change) can be seen by looking at pollen, spores and fossils.

A second element of the ARCSS program examines modern processes and interactions such as the response of vegetation to increasing carbon dioxide levels or temperature, and effects on permafrost, precipitation and runoff patterns. The program promotes investigations of terrestrial/biotic/atmospheric interactions and Arctic Ocean/sea ice/atmospheric interactions. By integrating the paleoenvironmental results of GISP II and PALE with knowledge derived from other ARCSS components, investigators will be better able to predict future arctic changes resulting from changing climate.

International Cooperation: During 1990 NSF engaged in scientific planning on global change with researchers from such organizations as the International Geosphere-Biosphere Program of the International Council of Scientific Unions and the World Climate Research Program of the World Meteorological Organization. A major initiative was the Past Global Changes core project, known as PAGES.

PAGES will coordinate the efforts of scientists and technicians from many nations gathering data about past environmental conditions from information preserved in natural archives of many types, including ice cores, marine and terrestrial sediments, tree rings and corals, and from instrumental records and documentary histories. Studies of physical, chemical and biological parameters recorded in these archives contain a wealth of information on the earth system's natural behavior.

Understanding the past behavior of the earth system is essential in meeting the goals of the U.S. Global Change Research Program. More understanding of natural variability in the earth's environment is needed both to discriminate human-induced changes from natural changes and to aid in the building and assessment of earth system models. Research supported by the National Science Foundation makes a major contribution toward achieving these goals.

Amy Tchao

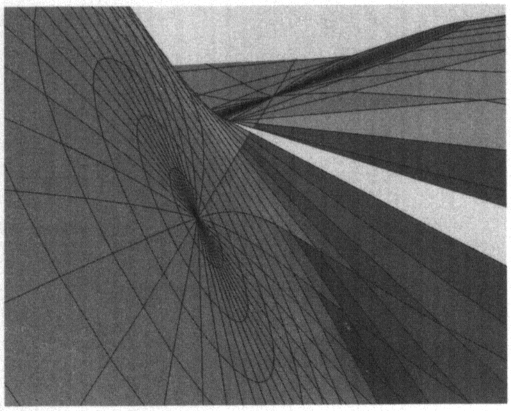
Research Power. ***Solar panel arrays provide power for the GISP II atmospheric sampling facility. Readings from this research are related to changes in the composition of Greenland ice.***

Special Focus: Mathematical Modeling, Solar Neutrinos, Advanced Materials

In NSF's Mathematical and Physical Sciences (MPS) Directorate, research ranges from mathematics and astronomy to chemistry, physics and the newest synthetic materials. Mathematics, for example, is a science in itself that also makes critical contributions to other research areas, although its role in the primary sciences is not always obvious.

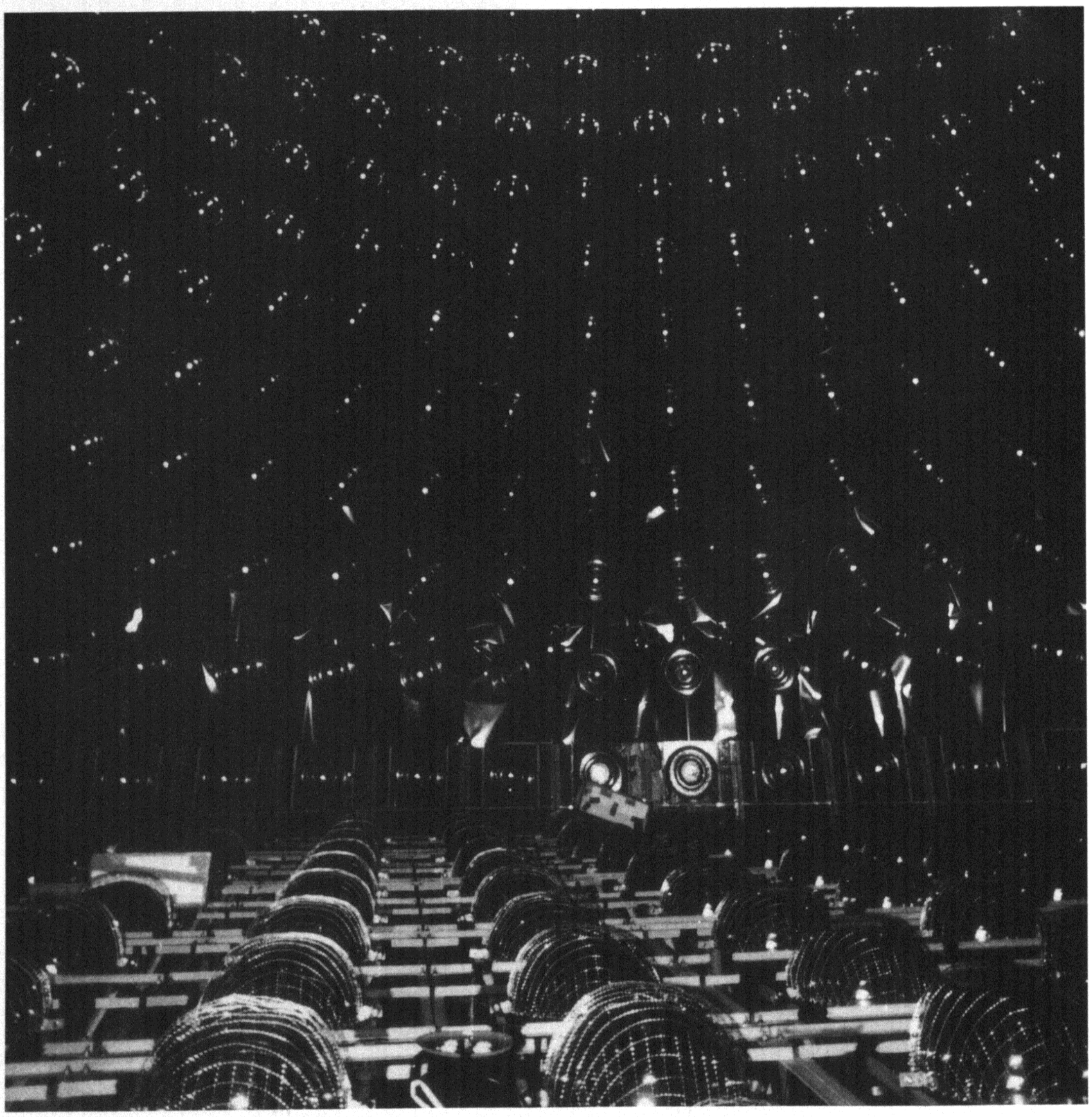
One way mathematics ties into other disciplines is through mathematical modeling of physical phenomena. Scientists translate math models into computer code to see if the models result in the phenomena being observed. These models simulate what happens in a process over time, giving investigators a clearer picture of chemical and material processes. It is increasingly difficult in modeling to separate mathematics from computer science or from the basic science involved.

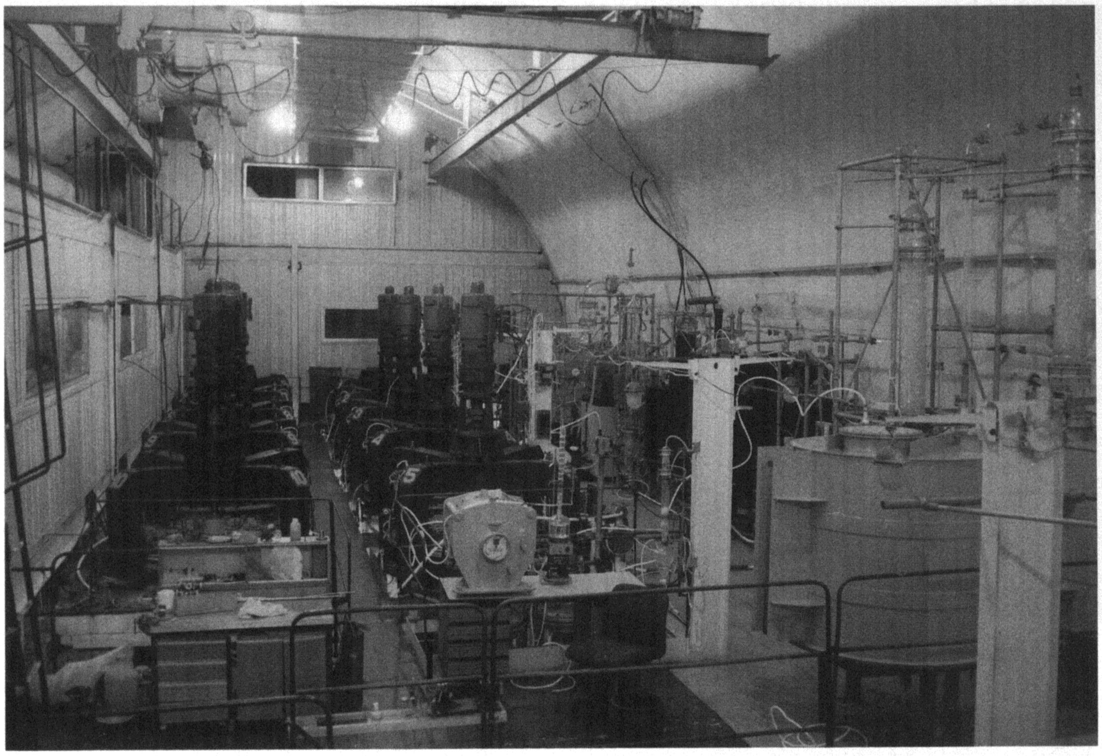
Modeling math. ***New tools, such as this computer visualization of a geometric surface under force, help advance mathematics research and education.***



The modeling tools now emerging are more sophisticated than those of the past. Older models usually have been based on linear differential equations and simplifications that allow scientists to deal with linear approximations. But mathematicians are beginning to develop techniques to deal with nonlinear phenomena, permitting a more realistic approach to coping with real-world problems in such areas as cosmology and materials science. The real world isn't linear, so nonlinear models and powerful computer tools would allow modelers to do more useful numerical simulations.

Cosmic watch. ***Part of an international effort to detect solar neutrinos reaching earth, an underground detector in Japan has recorded about half of the elusive neutrinos that scientists expected to detect.***





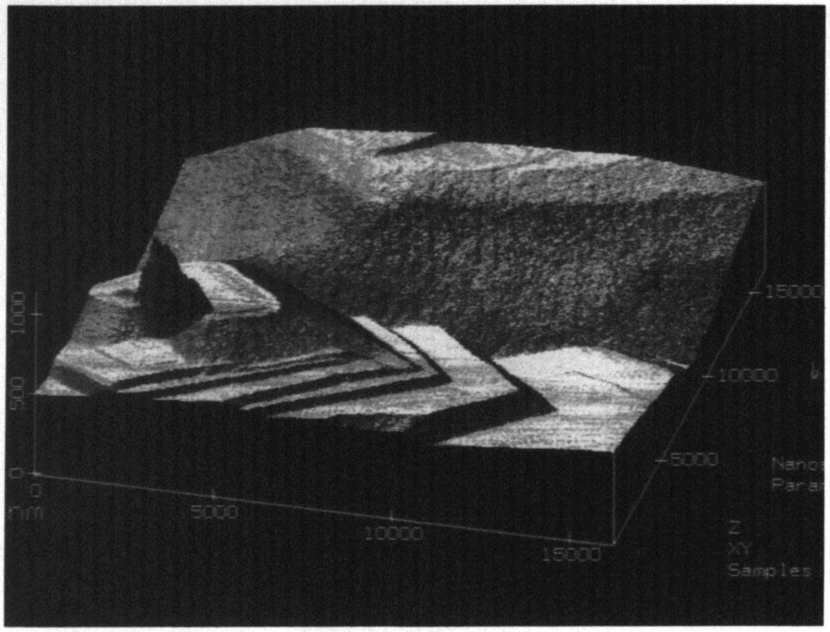
Neutrino Search. ***At a Soviet-American facility called SAGE, in the USSR's North Caucasus region, no solar neutrinos were detected during the first few months of operation—leading some scientists to reconsider the basic properties of neutrinos.***

Working with NSF's Directorate for Biological, Behavioral and Social Sciences, MPS-supported researchers have been looking at the interactions between mathematics and molecular biology. One large project will help determine the extent of mathematical contributions in such areas as genome sequencing.

NSF also has requested proposals for Regional Geometry Institutes. New developments in geometry have given all areas of mathematics new geometric tools. The institutes were designed to include research and education components, with close ties between the two. Boston University received the first award for a program that explores cutting-edge research in dynamical systems. Among those involved are scientists, undergraduate students and faculty, and participants from related projects that are also supported by NSF (e.g., teacher enhancement and a Young Scholars Program for high school students.)

Solar Neutrinos: Recent excitement was generated by these subatomic particles produced by thermonuclear reactions in the center of the sun. They are electrically neutral and thought to have a rest mass of zero. Such particles would travel at the speed of light in a vacuum and could go straight through any star as if it were empty space. The three types are the electron neutrino, the muon neutrino, and the tau neutrino.

The theory of thermonuclear reactions taking place in the sun calls for a huge quantity of solar neutrinos to bombard the earth continuously. But so far none of the three experiments designed to detect electron-type neutrinos—in South Dakota, Japan and the Soviet Union—have detected as many neutrinos as expected (see box).



Rice University

Grow a diamond. ***One advance in materials science is more economical crystalline diamond, which can be used in aircraft windshields and scratch-resistant lenses.***

Advanced Materials: Collaborations among chemical and physical scientists have prompted many stunning advances, but none as dramatic as some of the recent NSF-supported work in materials science. Epitaxial deposition of films (depositing an atom-thin layer of one substance on a single crystal of another) has led to new semiconductor devices that exhibit optical and electronic phenomena not found in natural material. The discovery makes possible nearly unlimited flexibility in designing integrated optical and optoelectronic circuits, which use light to generate, transmit, display, store or process information.

NSF also supports work in growing diamond and boron nitride films on the surfaces of materials; this research was done at Case Western and North Carolina State Universities. Crystalline diamond films, once grown at high pressures and temperatures, now are developed with more economical techniques for depositing epitaxial layers at much lower temperatures and pressures. Diamond films are used in electronics and as resistant coatings. As chemical processes improve, these films will be used in windshields for supersonic aircraft, in coatings for long-life cutting tools or scratch-resistant lenses and in semiconductor chips that can survive the rigors of outer space. Cubic boron nitride, second only to diamond in terms of useful properties, has been deposited as uniform thin films on silicon subtrates—on which diamond films can be grown for advanced microelectronics applications.

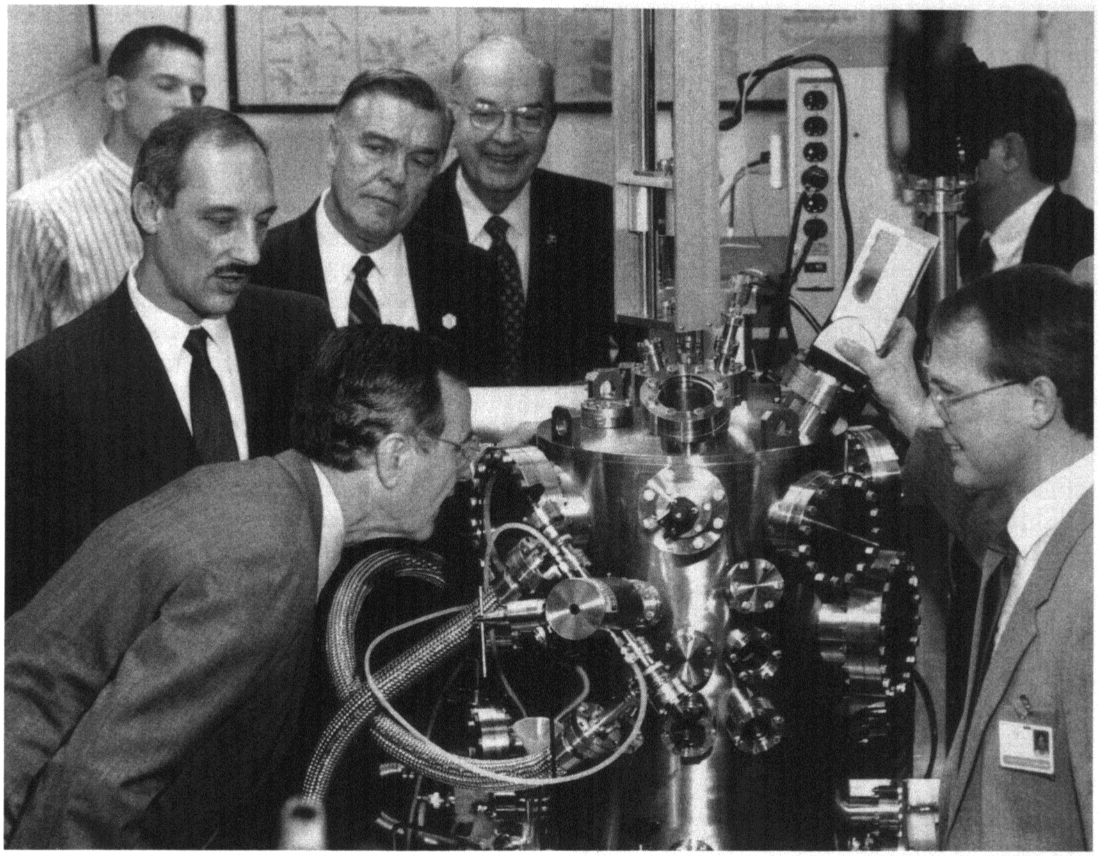
Neutrino Search

Since 1955, at the bottom of a mile-deep old mine in South Dakota, *Ray Davis* (University of Pennsylvania) has used a giant tank to detect solar neutrinos, which convert chlorine into a form of the element argon. This tank is about the size of a 25-meter swimming pool and is filled with liquid carbon tetrachloride. The experiment routinely sees only about 27 percent of the expected neutrinos.

In Japan, researchers looking for electron-type, high-energy solar neutrinos in a water-based experiment have found 46 percent of the expected neutrinos. In the Soviet Union, in collaboration with NSF-funded scientists Davis and *Kenneth Lande* (University of California), the Soviet-American Gallium Experiment (SAGE) stunned scientists by detecting no neutrinos at all in its first few months of operation.

SAGE is a gigantic low-energy-neutrino detector located inside a mountain in the USSR's North Caucasus region. In this experiment, neutrinos would be detected by turning the rare metallic element gallium into the crystalline element germanium. SAGE, much more delicate than the South Dakota or Japanese experiments, is designed to detect very-low-energy neutrinos, which theoretically should constitute the bulk of neutrinos generated by solar fusion.

As the experiment continues, some scientists speculate the mysterious results mean that electron neutrinos are transformed into muon or tau neutrinos before they reach the earth and therefore are invisible to the electron-type neutrino detectors. Others propose that the results could be accounted for if neutrinos, long assumed to have no rest mass, actually do have mass.



New chips. ***President George Bush peers into a spectrometer, a device used to analyze properties of semiconductor surfaces. The President was visiting the NSF-supported Advanced Electronic Materials Processing Facility at North Carolina State University.***

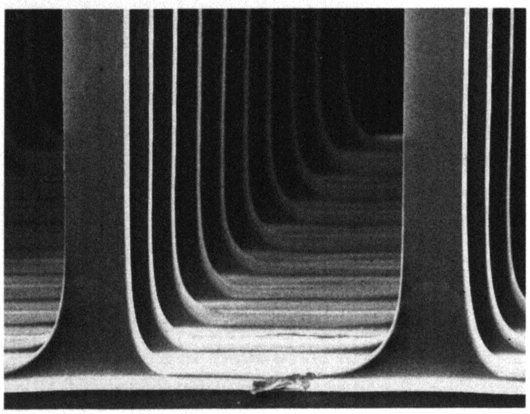
Thanks to advances in chemistry, polymers have shed their primary role as inexpensive commodity materials to become a staple of the high-tech sector. Not only are polymers strong, flexible and lightweight; they also have useful thermal, electrical and optical properties. For instance, tough, lightweight polymers are transparent to radar and can be used as armor.

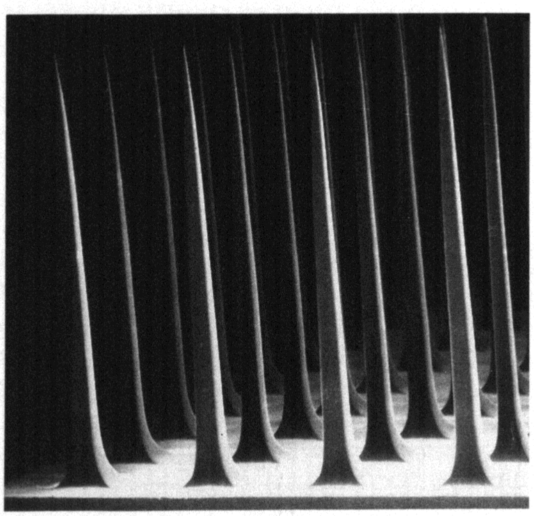
NSF-funded researchers have synthesized advanced materials using molecular engineering techniques. Metals, alloys, ceramics and glasses usually are made by converting bulk oxide or sulfide ores into a desired material through smelting and melting. But these and other materials can be made using advanced processes such as metalorganic chemical vapor deposition (MOCVD). By designing organometallic precursor molecules—containing, for instance, gallium and arsenic, boron and nitrogen, and barium, copper and rare earths—and then decomposing them, scientists have made advanced semiconductors, boron-nitride ceramics and even high-temperature superconductors.

In NSF-supported work at Northeastern University in Boston, simple mixing of chemicals produced molecules containing several metals. These metals can be replaced with others using a simple new process called transmetalation. Spontaneously formed molecules that contain four copper atoms can be transmetalated with cobalt or nickel atoms to give mixed-metal clusters. Decomposing these clusters yields useful new alloys that cannot be made via conventional mixing and melting techniques. Large families of new molecules have been made this way, including molecules containing as many as four different metals.

Special Focus: Materials Engineering

Electrical engineers work with electronic and optical materials, integrating them into devices for communications, computing, and more. Chemical engineers focus on chemical processing for thin films and plasmas, microstructures, non-linear optical materials, and conducting polymers. Mechanical engineers work with structural materials, metal matrix and ceramic composites, and with the mechanics of stress and fracture. Bioengineers study adhesive proteins, biosensors, artificial tissues and membranes and engineering processes that turn biotechnology research into products.





Recreate sight. ***Researchers hope that this microelectrode array, as seen in two scanning electron micrographs, will interface with the human central nervous system, providing a perception of light to the blind.***

In 1989, a National Research Council (NRC) report, *Materials Science and Engineering for the 1990s*, took a close look at the field's frontiers and identified research needed to help the United States remain competitive. Among other findings, the report noted a weakness in the areas of materials synthesis and processing. Synthesis refers to the chemical and physical means by which atoms and molecules are combined to produce materials. Processing refers to the way materials are transformed to form bulk materials, components, devices, structures, and systems.

The NRC report strongly urged all institutions involved with materials research, including NSF, to emphasize synthesis of new materials and, in materials processing work, to stress science and technology relevant to manufacturing. In 1990, responding to NRC's recommendations, NSF continued to strengthen its multidisciplinary efforts in materials science and engineering.

Synthesis and processing form a critical stage in materials research. Together they are responsible for boosting the strength of advanced alloys and composites, increasing the number of components on integrated circuits, and producing new superconductors with higher transition temperatures and current-carrying capacities. Work in this area ranges from synthesizing artificially structured materials to engineering new alloys. Synthesis and processing—central to the production of high-quality, low-cost products—lead to materials with new properties and performance and to improved manufacturing processes.

Prototyping, Precision Machining, Chemical Research: A recent NSF initiative in rapid prototyping has helped researchers create prototype products using ceramic, composite and other powders—as well as lasers and computer-controlled equipment—rather than the traditional casting, forging and cutting methods.

In one type of rapid prototyping, a model of the new product is created by using a laser and a computer-controlled graphics process. To make a prototype object such as a crankshaft, for example, a computer is used to slice a drawing of the crankshaft into thousands of thin layers, each an outline of the crankshaft itself.

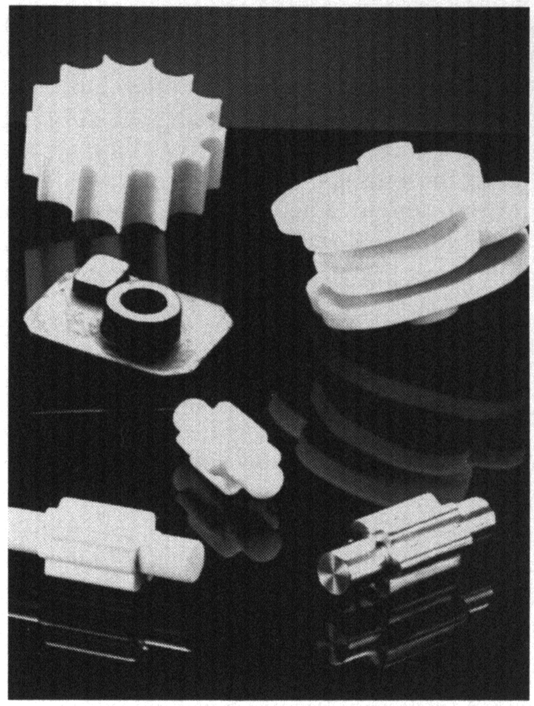
A prototype done this way can be tested, its properties studied, and design changes made before an expensive manufacturing process begins. Also, a rapid prototype can be made in a matter of hours, whereas using traditional manufacturing methods takes months, even years. Rapid prototyping is especially useful for making computer chips.

Another 1990 initiative, in precision machining, has helped scientists create products of extreme high quality by cutting components out of solid material with new synthetic diamonds and other materials. These components are cut so precisely—in very clean rooms with rigorously controlled temperatures—that they need no further cutting or polishing and are virtually flawless.

With similar new tools, materials such as gold can be cut into slices so thin they are transparent. One material can be deposited on another using processes of such high precision that the material layers are only a few atoms thick and are uniformly deposited on a surface.

Also in 1990, new awards were made through an initiative on materials chemistry and chemical processing.* This program involves a broad multidisciplinary group that includes chemists, materials scientists and engineers. Research ranges from work in new polymeric materials for lightwave communication to new compositions of matter. For example, researchers at the *University of Washington* have been studying heat transfer in thin semiconductor film melting. Thin-film heat treatment using lasers is important to microchip technology because it potentially improves a semiconductor's electrical properties.

Investigators at the *University of Iowa* began work on a generic computerized model of casting processes to bolster Iowa's metal-casting industry. The casting model is based on computer-aided design and manufacturing techniques; work involves developing a theoretical model, validating the experimental model and transferring project results to industry.



Rapid prototyping. ***Built by lasers and computer graphics at the University of Texas in Austin, these prototype machine parts can be turned out in a matter of hours—instead of the months that traditional manufacturing methods require.***

Photonics: This growing technology involves replacing electrical wires with light in communications and information processing. For centuries, light has been an important tool in technology development. When the laser was developed in 1960, it became clear that coherent light from lasers had potential for communications, information processing and countless defense and scientific applications.

In electronics, electrons flow through a wire; in photonics, light waves flow through an optical fiber. The advantage is that light waves carry much more information than electrons; one small optical fiber can carry an estimated 1,000 times more information than an electrical wire. And, unlike electronics, photonics can carry a variety of signals—television cable, telephone, video—in the same fiber.

*The initiative is jointly administered by two NSF directorates: Engineering and Mathematical and Physical Sciences.

Photonics is the dominant technology in applications such as transmitting long-distance, high-data-rate information. But electronics is well established in computing and switching, and many control functions common in electronics have not yet been demonstrated with photonic circuits. A hybrid technology, optoelectronic circuits, combines the advantages of photons with electrons.

Today, almost all information processing is done electronically, but growing numbers of researchers are exploring the power of lightwave technology in computing. The potential leverage of photonics on information processing stems from inherent advantages of optics, including ultrawide bandwidth, freedom from electromagnetic interference and coherent parallel-processing capabilities.

Biological Molecules, Bioprocess Engineering: In another burgeoning technology area, researchers are capitalizing on advances in molecular biology, genetics, microbiology, cellular physiology and biochemistry to produce biological molecules. These substances are processed from nature (or synthesized to mimic nature) and used in such areas as tissue engineering and bioprocess engineering.

In tissue engineering, for example, NSF-supported researchers at the *University of Nebraska* at Lincoln produced a mechanical engineering model of the way leg cartilage grows. Similarly, researchers at the *Massachusetts Institute of Technology* began an engineering study of the *in vitro* growth of cartilage. The project requires cooperation among engineers, cellular physiologists and biochemists. Their research has introduced a known strain on a section of cartilage grown *in vitro* and tested the cartilage for synthesis of molecules related to the cartilage's structure or function. This work could lead to the production of cartilage forms that could be used for transplanting.

Finally, an NSF initiative in bioprocess engineering linked engineering expertise with the biological sciences to build an engineering basis for manufacturing substances based on modern molecular biology. A bioprocess is one in which living cells or their components are used to produce commercial quantities of an end product. Bioprocess engineering involves the use of manufacturing processes characterized either as *upstream* or *downstream*.

One example of an upstream process is a biological reactor (bioreactor) in which microorganisms or animals produce chemical or pharmaceutical compounds. Once the compounds are created, they are processed, or engineered, into useful products. The sequence of steps for recovering and purifying the substances is known as downstream processing. In most bioprocesses, recovery and purification are much more expensive than upstream processing—up to 70 percent or more of the bioproduct's total cost.

The Foundation made five 1990 awards for downstream processing research in high-molecular-weight proteins. The initiative was based on advances made in processing commercial quantities of Protein C, a natural anticoagulant. Scientists now are able to recover—from blood plasma—gram quantities of Protein C, once available only in microquantities. This advance moves them closer to recovering quantities of other such proteins previously unavailable for testing—and for turning those proteins into products.

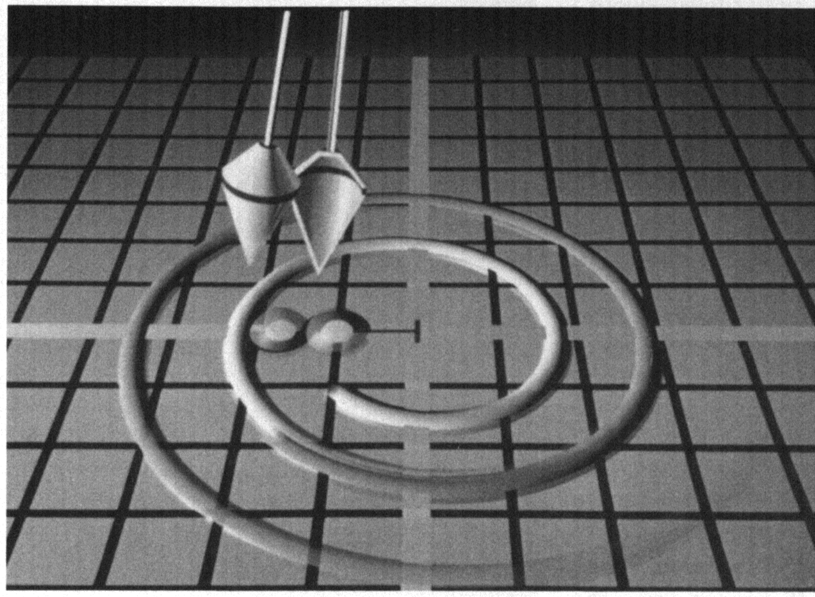
Special Focus: Computer and Computation Research

Advances in computer and computational science have dramatically increased the capabilities of other areas of science and engineering to analyze, interpret and apply a wide variety of phenomena. Computer science and engineering research has laid the basis for new machine architectures, programming languages, computational methodologies, human-machine interfaces and software. Progress in computer hardware and software, numerical techniques, visualization and simulation has radically increased the power of computational science and engineering in solving scientific problems—so much so that some consider this to be virtually a third avenue of scientific pursuit, complementing theory and experiment.

Scientists in computer and computation research study the way computers can be built and used, determine their limitations and ways to work around them, and create software tools for a wide variety of scientific, technical, economic and daily activities. For example, recognizing that catastrophes may result from poor or failure-prone computer systems, NSF is supporting research on engineering highly fault-tolerant software. Researchers — primarily at Princeton University, the University of Chicago, and the University of California at Berkeley — have demonstrated theoretically that they can ensure certain kinds of computer software will never fail. If these results can be translated to practice, certain kinds of critical signal-processing software—e.g., that used in aircraft control, submarines and communication systems— eventually can be made virtually foolproof.

Other research has focused on increasing the power and speed of computers. Researchers are now exploring hardware and software advances with the potential for increasing the productivity of engineers by 1,000 times or more over present levels. Theoretical work on one of the discipline's latest efforts—computer programs that check their own work—has been done at the Center for Discrete Mathematics and Theoretical Computer Science, an NSF Science and Technology Center at Rutgers University in New Jersey. Such computer programs not only supply data but immediately inform scientists that an error has occurred. At this writing, these programs operate only in specialized domains.

NSF-supported researchers also are laying the foundations for next-generation technologies such as highly parallel computers, which consist of hundreds or thousands of ordinary computer processors connected together. At the NSF Center for Parallel Processing Research, a joint effort of Rice University, the California Institute of Technology and several industrial firms, researchers are developing software to exploit the full potential of such computers.

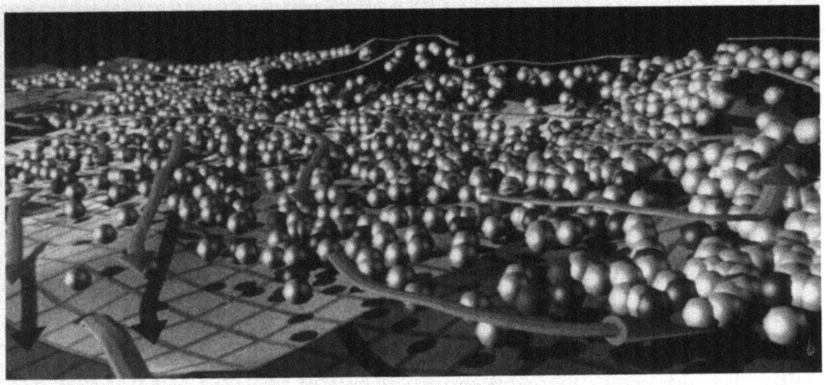


Mark Bajuk

Pendulum swings. ***Dynamic phase space behavior, modeled as a pendulum driven by various oscillators, illustrates a visualization technique used at the National Center for Supercomputing Applications to explain complex science and engineering problems.***

Supercomputers and Computational Research: Supercomputers, sometimes defined as the fastest computing systems currently available, are at the leading edge of technology and are becoming increasingly essential for working on complex research problems in science and engineering. The NSF Supercomputer Program gives scientists and engineers access to the advanced computing resources at the Cornell Theory Center (Cornell University), the National Center for Supercomputing Applications (University of Illinois, Champaign), the Pittsburgh Supercomputing Center (Mellon-Pitt-Carnegie Corporation) and the San Diego Supercomputer Center (GA Technologies).

These centers not only make available supercomputer research tools to carry out research, they also provide education and training in their use. All have held summer institutes, workshops, conferences and training sessions for faculty, postdoctorals, graduate students and industrial researchers. Other programs enable undergraduate students to perform research with center scientists.



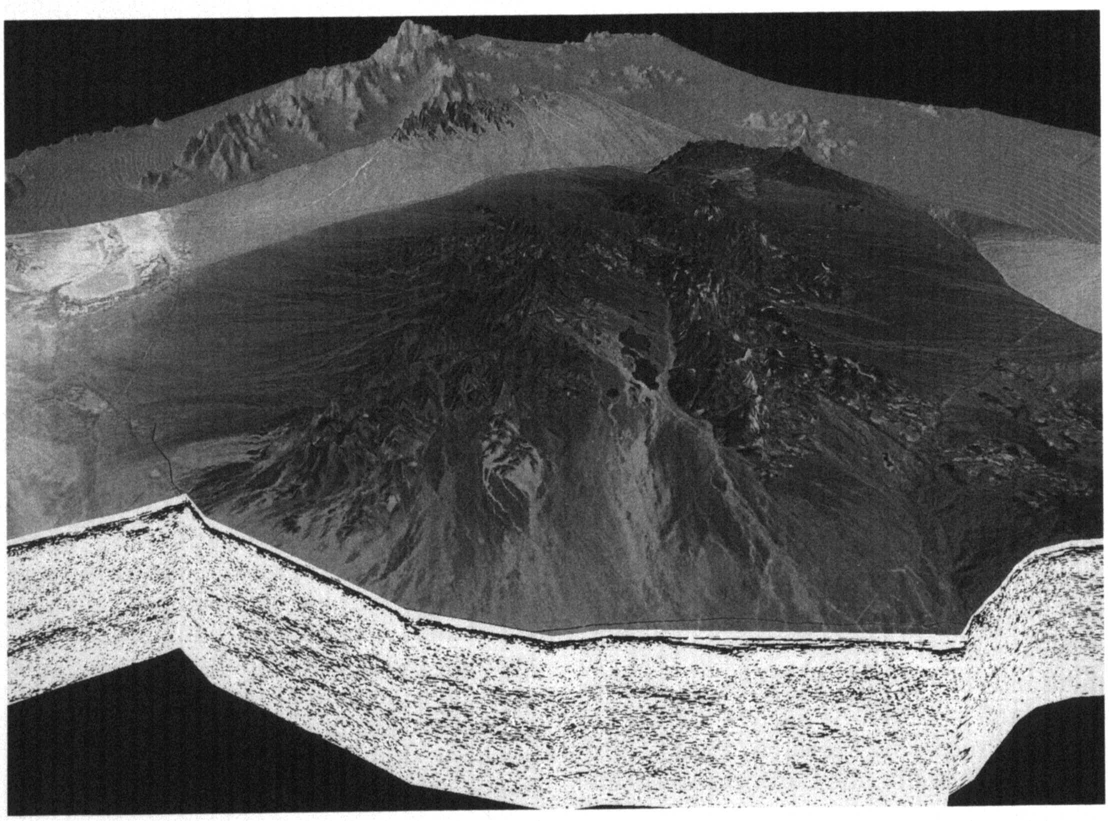
M. McNeill and W. Sherman, NCSA

Smog stream. ***A supercomputer visualizes carbon monoxide and other smog elements as they move across the Los Angeles Basin.***

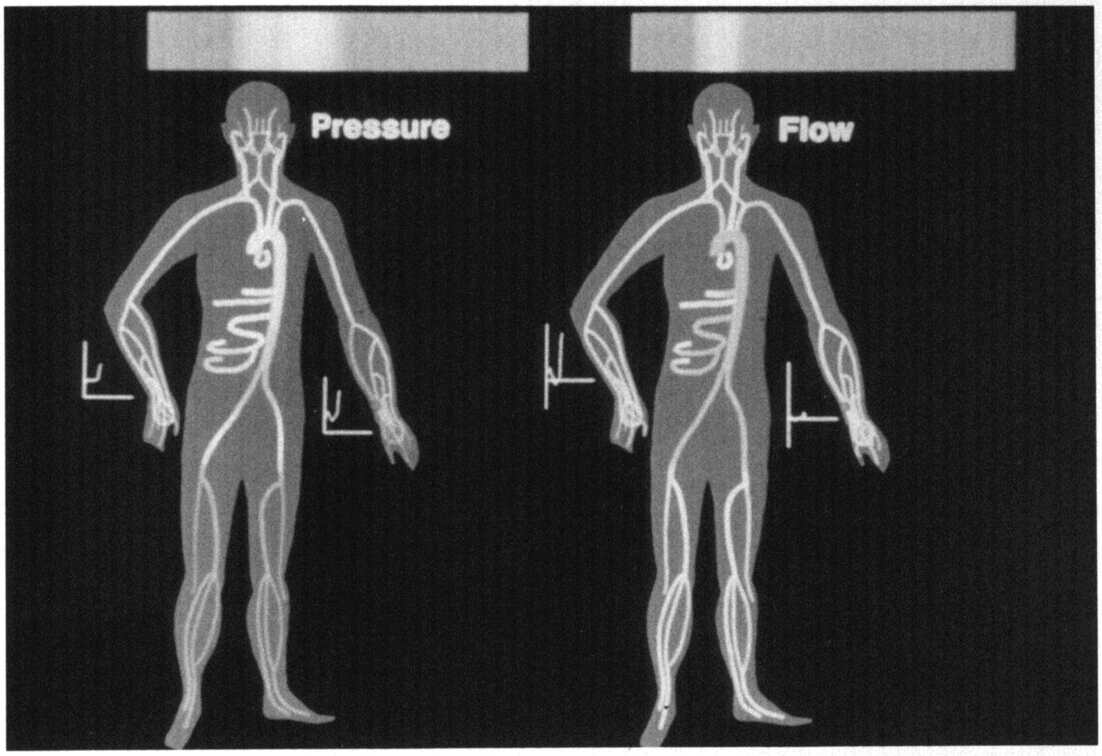
At *Cornell*, through a program called Superquest, staff held a nationwide competition for high-school students. Four teams of teachers and students were selected to spend four weeks at Cornell working on summer research projects. In addition, there was access during the school year for the students to continue working on their projects, using supercomputing resources.

The nature and power of scientific visualization, a major focus at the *Illinois supercomputer center*, was demonstrated through footage on the Big Bang beginning of the universe, provided to ABC's *20/20* television show. On the research side, the Illinois center has been a leader in developing an integrated software package for workstations and supercomputers; the package is used to process astronomy data and images. It also helps in the analysis of radio astronomy data from the Very Large Array and the Very Long Baseline Array (telescopes supported by the Foundation).

The *San Diego Supercomputer Center (SDSC)* received a three-year grant in 1990 from the state of California to establish a state-of-the-art visualization laboratory which will feature remote visualization across a high-speed computer network. In addition, SDSC established a computational biology center with support from NSF's Directorate for Biological, Behavioral and Social Sciences. At the Pittsburgh center, a five-year renewal grant from the National Institutes of Health enabled biologists to use supercomputers in such research areas as molecular dynamics, large proteins and viruses and genome sequencing.



Geologic visualizations. ***A computer constructed view of California's Turtle Mountains combines satellite and ground-based seismic and topographic data in an effort to improve earthquake predictions. Different shadings reflect vegetation and surface minerals.***



Michael McNeill

Blood visualization. ***This simulation of the human cardiovascular system is an example of the type of information sharing tested on the national gigabit network.***

NSFNET Expansion and Gigabit: In developing its nationwide computer network, NSFnet, the Foundation has created the world's fastest openly available network for research and education. The expansion project adds three new nodes to the NSFnet backbone and increases data transmission speed to 45 million bits of information per second.

Work on the new gigabit network stems from an award made by NSF and the Defense Advanced Research Projects Agency (DARPA, part of the Department of Defense). This three-year award for research on very high speed communication networks went to the Corporation for National Research Initiatives (CNRI), a nonprofit organization in Reston, Virginia.

Communication networks operating at speeds of about a billion bits per second or more (called gigabit networks) will enhance the ability of users to access remote facilities and collaborate with colleagues in other parts of the country and the world. This will allow researchers to interconnect remotely connected supercomputers, workstations, graphic processors and large data bases, aiding the use of advanced collaboration techniques.

CNRI will lead research involving universities, national laboratories, supercomputer centers and industrial organizations focusing on gigabit testbeds. Industry will participate in research and will provide advanced workstations and other technologies, as well as access to transmission and switching facilities. Applications of this new technology will include weather and storm modeling, geologic mapping, chemical dynamics and biomedical imaging.

Research on the gigabit network has been focused on five diverse testbeds—AURORA, BLANCA, CASA, NECTAR and VISTANET—that will give users a chance to explore applications for the network (see box).

AURORA: This testbed explores alternative network technologies and investigates distributed system and network service paradigms. As research participants, MIT's Laboratory for Computer Science explores a new paradigm for network resource control and allocation; the University of Pennsylvania's Distributed System Lab in Philadelphia is examining distributed virtual memory on gigabit wide-area networks; Bellcore's Morristown Research and Engineering Lab in Morristown, N.J., collaborates with participants on high-speed protocols, network architectures and broadband network applications; and IBM's Computer Science Lab in Hawthorne, N.Y., provides a prototype of its gigabit network architecture and switching system for joint experimentation. Applications planned for this testbed include experiments with online collaboration in business and science.

BLANCA: This is a collaboration among AT&T Bell Labs and the computer science departments at the University of California/Berkeley, the University of Illinois/Urbana-Champaign and the University of Wisconsin/Madison. Work includes switch control and design (AT&T, Illinois, Wisconsin), fast-call setup (Wisconsin), developing traffic models (Berkeley), burst handling and congestion control (AT&T, Berkeley, Wisconsin), real-time communication (Berkeley), high-speed channel interfaces for supercomputers (AT&T, Wisconsin) and network virtual memory (Illinois). The group studies applications that include multiple remote visualization and control of simulations, radio astronomy imaging, multimedia digital library storage, and medical imaging. Cray Research, the National Center for Supercomputing Applications and the Astronautics Corporation provided supercomputers for the BLANCA testbed.

CASA: Here scientists investigate the use of distributed supercomputing over wide-area high-speed networks to increase computational resources for scientific research—initially in chemistry, geophysics and climate modeling. The testbed connects the Los Alamos National Laboratory in New Mexico, the California Institute of Technology, the Jet Propulsion Lab in Pasadena, Calif., and the NSF-supported San Diego Supercomputer Center. At CASA, chemical reaction dynamics are used to study the reaction of fluorine and hydrogen, used in powerful chemical lasers. An interactive visualization program for geological applications that takes input from LANDSAT, seismic and topographic databases should help improve earthquake magnitude predictions and more clearly identify fault zones. The climate modeling application, which combines oceanic and atmospheric models simultaneously running in separate computers, will be used to study global change in long-term climate simulations.

NECTAR: Collaborators include Carnegie Mellon University (in cooperation with the Pittsburgh Supercomputing Center) and Bell Atlantic/Bell of Pennsylvania. Among the first applications run on the gigabit NECTAR testbed is a process flowsheeting problem that models the control, design and economic performance of large-scale chemical plants. Other work will help solve large combinatorial optimizations that represent a class of problems whose solutions are critical to many engineering designs.

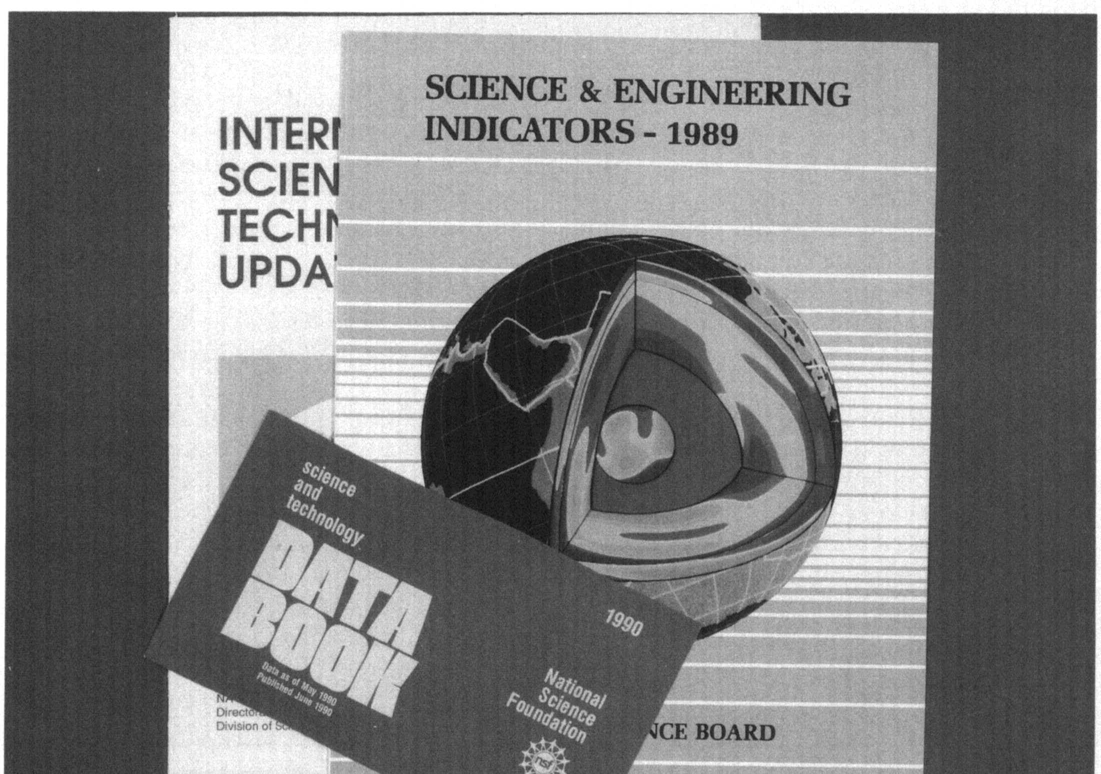
VISTANET: Collaborators include BellSouth, GTE, MCNC (formerly the Microelectronics Center of North Carolina) and the University of North Carolina at Chapel Hill. VISTANET will demonstrate the results possible when geographically dispersed research teams and specialized resources are networked together at gigabit speeds. The resulting feedback computation system will advance communications research, computer visualization and medical treatment planning. From a networking perspective, the application will test initial assumptions about how such distributed networks perform. Technology research focuses on protocols, performance analysis and switching technologies needed to support multiple service-class gigabit networks.

Special Focus: International S&T Data Collection

NSF's Division of Science Resources Studies (SRS) has a long history of leadership in collecting, analyzing and publishing quantitative information on science and technology. SRS, part of the Directorate for Scientific, Technological and International Affairs, also has played a pivotal role in developing international comparisons of such data. In 1990, the Foundation put more emphasis on international comparisons of science and engineering indicators; NSF also began expanding its outreach activities to enhance data collection and comparability in several countries. These include the Soviet Union, newly industrializing nations and smaller European countries.

SRS collects data on the United States from government, industry and academia, integrating the data to establish national totals and trends. Similar S&T data also are compiled for foreign countries from international and foreign sources. All this information fills a major need of science policymakers and R&D managers in both Congress and the executive branch, in industry, in international organizations, and elsewhere.

The success of the United States in the global marketplace depends on the standing of our science and engineering compared to that of other trading countries. To improve our competitive position, we must know where we are compared to these nations. Recent trends in the globalization of science and technology, the increasing unification of Europe as a common market, world trade and competition, the opening up of Eastern European countries and the economic and technical development of countries in the



Global data.
NSF regularly publishes comparisons of the technological capabilities of many countries.

Pacific Rim—all these factors make it even more important for the United States to have a comprehensive, global S&T data base that includes all countries with significant science and technology activities.

Over the past five years, NSF has developed extensive data for the large R&D-performing countries such as France, West Germany, Japan and The United Kingdom. In 1990, the Division of Science Resources Studies, together with the Division of International Programs, began planning a major outreach effort to encourage other countries to collect and develop comparable information. As one way to approach this task, NSF has provided training on S&T indicators to countries such as Japan, Italy, Sweden, Yugoslavia, India and Brazil.

There were major data collection breakthroughs with the Soviet Union over the past year. For decades, U.S. researchers have sought reliable and comparable statistics about science and engineering personnel and R&D expenditures in the Soviet Union. Until recently very little data were available, and the U.S.S.R.'s data collection procedures and definitions differed substantially from those used here and in many other countries.

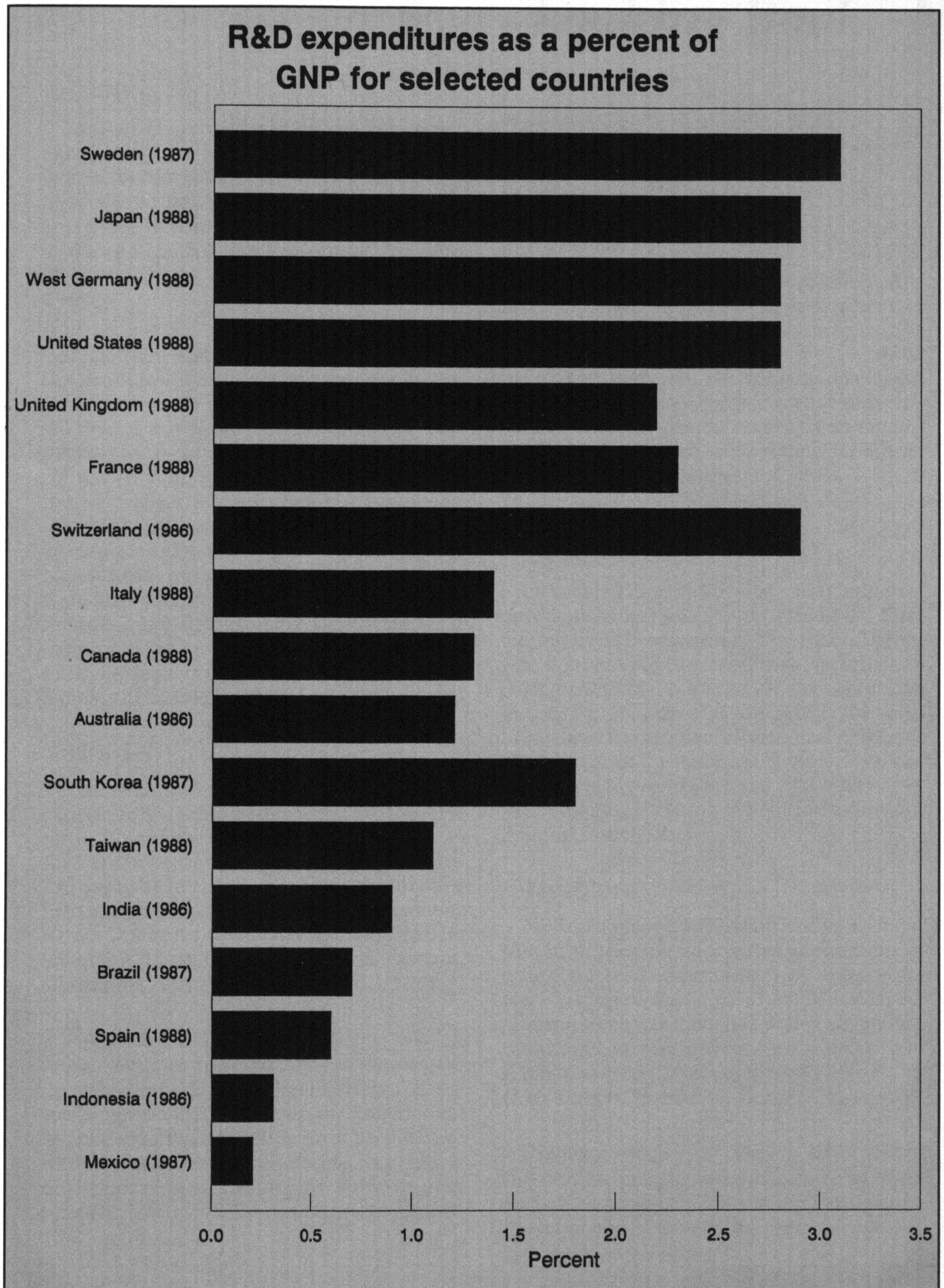
In May 1990, under an agreement on basic research with the Soviet Academy of Sciences, NSF hosted a bilateral workshop. The Soviets presented previously unavailable and detailed information on science and engineering activities, investments and data collection procedures. The Soviets are now changing a number of their methods, making them more compatible with those of the United States and others. Workshop participants agreed on working to understand and reconcile the two sets of national data. This workshop was a good basis for future cooperation in compiling science and engineering indicators.

NSF has worked with the Organization of Economic Cooperation and Development (OECD) to develop an international standard for collecting data on research and development and on science and technology. The guide, commonly referred to as the Frascati Manual, includes standard definitions for such concepts as basic research, applied research and development; it is used by OECD member states—among them the 12 European Community nations, Austria, Switzerland, the Scandinavian countries, the United States, Japan, Canada, Australia and New Zealand.

Over the past year, the United States began plans with the OECD and its member states to revise the Frascati Manual in order to reflect changing R&D conditions, improve concepts and definitions and enhance data comparability. The United States, and specifically the National Science Foundation, were chosen among OECD members to play the lead role in developing standards for scientific and engineering personnel data. (The United States is one of the few nations that systematically collect such data.) NSF's role in the Frascati Manual revisions will both encourage and influence international data collection in this important area.

Last year NSF discussed science and engineering indicators with the Commission of the European Communities and Eurostat, its Luxembourg-based statistical agency. The European Community (EC) nations have established within Eurostat a new science and technology indicators group and an R&D statistics group. The EC has asked NSF to join in efforts to achieve more comparable results.

This international activity is a boon to NSF's own data-related activities and will enable the Foundation to expand its global indicators work. For example, the biennial *Science & Engineering Indicators* already contains many international comparisons on R&D expenditures, S&T personnel and public attitudes about science and technology. The 1991 *Indicators* edition—as well as the new *International Science and Technology Data Update*—will present a broader range of both international comparisons and geographic coverage.



Research and development: international comparisons. ***Nations tend to fall into four groups in their levels of R&D spending: major industrialized countries, which typically spend between 2.0 and 3.0 percent of their gross national product (GNP) on R&D; smaller industrialized countries, which spend between 1.0 and 2.0 percent; middle income nations, many of them newly industrialized, spending between 0.5 to 1 percent; and low income economies that spend less than 0.5 percent.***

Looking Back: NSF at 40

1940's:

New frontiers of the mind are before us, and if they are pioneered with the same vision, boldness and drive with which we have waged this war we can create a fuller and more fruitful employment and a fuller and more fruitful life.—*President Franklin D. Roosevelt to Vannevar Bush, Nov. 17, 1944*

* * *

It has been basic United States policy that Government should foster the opening of new frontiers. It opened the seas to clipper ships and furnished land to pioneers. The frontier of science remains.

I recommend that a new agency be established. Such an agency should be composed of persons of broad interest and experience, having an understanding of the peculiarities of scientific research and scientific education. It should have stability of funds so that long-range programs may be undertaken. It should recognize that freedom of inquiry must be preserved.—*Vannevar Bush, Science, The Endless Frontier, 1945*

1950's:

Ten second-rate scientists or engineers cannot do the work of one who is in the first rank. Therefore, if the aims of Congress as set forth in the National Science Foundation Act are to be fulfilled, there must be all over the United States intensive effort to discover latent scientific talent and provide for its adequate development.—*James B. Conant, Chairman, National Science Board, 1951*

* * *

Basic research, directed simply toward more complete understanding of nature and its laws, embarks upon the unknown. It extends beyond the fringes of knowledge, beyond existing limitations and preconceptions. Basic research enlarges the realm of the possible.— *Development of National Science Policy, NSF Second Annual Report, 1952*

1960's:

Scientists alone can establish the objectives of their research, but society, in extending support to science, must take account of its own needs.—*President John F. Kennedy, 1963 (speaking to the National Academy of Sciences)*

1970's:

The Foundation is an appropriate instrument of leadership for a large segment of American science, and we are prepared to accept that leadership. Since the decisions we make today will set the new directions for the future, I am keenly aware of the critical role the Foundation must play in the immediate years ahead.—*William D. McElroy, Director, NSF Twentieth Annual Report, 1970*

1980's:

Increasing the supply of knowledge requires solving two serious problems. First among them is education. The second problem is to devote the necessary resources to basic research. There are no easy solutions to these problems. But the search for solutions deserves our best efforts, and it defines the mission of the National Science Foundation as we move toward the 21st century.—*Erich Bloch, Director, NSF Thirty-Seventh Annual Report, 1987*

1990's:

NSF has been a catalyst, playing a major role in producing successive generations of scientists and engineers; in supporting pace-setting research in a host of fields, including some which it has done much to initiate; and in monitoring the pulse of the science and engineering enterprise.—*Frank H.T. Rhodes, President, Cornell University**

* * *

[NSF's creation is] very much a part of the contemporary revolutions in science and the evolution of modern thought.—*Philip M. Smith, Executive Officer, National Academy of Sciences**

*These remarks were made at NSF's 40th Anniversary Symposium, held May 11, 1990 in Washington, D.C.

We shall not cease from exploration,
And the end of all our exploring
Will be to arrive where we started,
And know the place for the first time.

T.S. Eliot

Appendixes

Appendix A: NATIONAL SCIENCE FOUNDATION SENIOR STAFF AND NATIONAL SCIENCE BOARD MEMBERS (FISCAL YEAR 1990)

NATIONAL SCIENCE FOUNDATION SENIOR STAFF
(as of September 30, 1990)

Director,
Erich Bloch (until August 31, 1990)

Deputy Director
(Acting Director, Sept. 1990/March 1991)
Frederick M. Bernthal

General Counsel,
Charles H. Herz

Director, Office of Legislative and Public Affairs,
Raymond E. Bye, Jr.

Controller, Office of Budget and Control,
Sandra D. Toye

Director, Office of Information Systems,
Constance K. McLindon

Director, Office of Science and Technology Centers Development,
William C. Harris

Director, Research Facilities Office,
Richard J. Green

Assistant Director for Biological, Behavioral, and Social Sciences,
Mary E. Clutter

Assistant Director for Computer and Information Science and Engineering, (Acting)
Charles N. Brownstein

Assistant Director for Education and Human Resources,
Luther S. Williams

Assistant Director for Engineering,
John A. White

Assistant Director for Geosciences,
Robert W. Corell

Assistant Director for Mathematical and Physical Sciences,
David A. Sanchez

Assistant Director for Scientific, Technological, and International Affairs,
F. Karl Willenbrock

Assistant Director for Administration,
Geoffrey M. Fenstermacher

NATIONAL SCIENCE BOARD
(addresses current as of September 30, 1990)

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FREDERICK P. BROOKS, JR.,
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University of North Carolina,
Chapel Hill, NC

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W.T. Doherty-Welch Foundation Distinguished Professor of Chemistry and Director, Laboratory for Molecular Structure and Bonding,
Texas A&M University,
College Station, TX

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JOHN C. HANCOCK,
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Consultant,
Kansas City, MO

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Vice Chairman, Koger Properties, Inc., and Koger Equity, Inc.,
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Portland, OR

FRANK H. T. RHODES,
President, Cornell University,
Ithaca, NY

HOWARD A. SCHNEIDERMAN,
Senior Vice President for Research and Development and Chief Scientist,
Monsanto Company,
St. Louis, MO

Terms Expire May 10, 1994

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San Luis Obispo, CA

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Cleveland, OH

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William A. M. Burden Professor of Astrophysics,
Massachusetts Institute of Technology,
Cambridge, MA

DANIEL C. DRUCKER,
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Department of Aerospace Engineering,
Mechanics and Engineering Science,
University of Florida,
Gainesville, FL

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Counselor, Hoover Institution,
Stanford University,
Stanford, CA

CHARLES L. HOSLER,
Acting Executive Vice President and Provost for the University and Senior Vice President for Research and Dean of Graduate School,
Pennsylvania State University,
University Park, PA

PETER H. RAVEN,
Director, Missouri Botanical Garden,
St. Louis, MO

ROLAND W. SCHMITT,
President, Rensselaer Polytechnic Institute,
Troy, NY

BENJAMIN S. SHEN,
Reese W. Flower Professor of Astronomy,
Department of Astronomy and Astrophysics,
University of Pennsylvania,
Philadelphia, PA

Terms Expire May 10, 1996

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Chancellor, The Texas A&M University System,
College Station, TX

THOMAS B. DAY,
(Vice Chairman, National Science Board),
President, San Diego State University,
San Diego, CA

JAMES J. DUDERSTADT,
President, The University of Michigan,
Ann Arbor, MI

(VACANCY)

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Provost, Duke University,
Durham, NC

JAIME OAXACA,
Vice Chairman,
Coronado Communications Corporation,
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HOWARD E. SIMMONS, JR.,
Vice President for Central Research and Development,
E. I. DuPont DeNemours & Co.,
Wilmington, DE

(ONE VACANCY)
*Pending Senate Confirmation

Member Ex Officio

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(Chairman, Executive Committee),
Acting Director,
National Science Foundation,
Washington, DC

***

THOMAS UBOIS,
Executive Officer,
National Science Board,
National Science Foundation,
Washington, DC

***

LINDA G. SUNDRO,
Inspector General,
National Science Foundation,
Washington, DC

Appendix B: PATENTS AND FINANCIAL REPORTS FOR FISCAL YEAR 1990

PATENTS AND INVENTIONS RESULTING FROM ACTIVITIES SUPPORTED BY NSF

During fiscal year 1990, the Foundation received 228 invention disclosures. Allocations of rights to 63 of those inventions were made by September 30, 1990. These resulted in dedication to the public through publication in 16 cases, retention of principal patent rights by the grantee or inventor in 44 instances, and transfer to other government agencies in 3 cases. Licenses were received by the Foundation in 83 patent applications filed by grantees and contractors who retained principal rights in their inventions.

FINANCIAL TABLES

Table 1. Biological, Behavioral and Social Sciences, Fiscal Year 1990

(Dollars in Millions)

	Number of Awards	Amount
Molecular Biosciences	631	$ 48.18
Cellular Biosciences	878	57.66
Biotic Systems and Resources	862	66.54
Behavioral and Neural Sciences	888	45.80
Social and Economic Science	591	32.27
Instrumentation and Resources	464	38.31
Science and Technology Centers	2	4.92
Total	4,316	$293.68

Table 2. Computer and Information Science and Engineering, Fiscal Year 1990

(Dollars in Millions)

	Number of Awards	Amount
Computer and Computation Research	371	$ 21.96
Information, Robotics and Intelligent Systems	287	19.97
Microelectronic Information Processing Systems	210	16.60
Advanced Scientific Computing	101	62.79
Networking and Communications Research and Infrastructure	179	22.33
Cross-Disciplinary Activities	98	19.62
Science and Technology Centers	2	6.57
Total	1,248	$169.84

Table 3. Engineering, Fiscal Year 1990

(Dollars in Millions)

	Number of Awards	Amount
Biological and Critical Systems	551	$ 35.62
Chemical and Thermal Systems	505	30.79
Electrical & Communications Systems	497	29.75
Mechanical and Structural Systems	399	21.61
Design and Manufacturing Systems	291	19.11
Engineering Centers	125	46.37
Engineering Infrastructure Development	154	16.80
Total	2,522	$200.05

Table 4. Geosciences, Fiscal Year 1990

(Dollars in Millions)

	Number of Awards	Amount
Atmospheric Sciences	659	$104.13
Earth Sciences	970	60.09
Ocean Sciences	923	147.35
Arctic Research Program	146	12.45
Science and Technology Centers	1	.98
Total	2,699	$325.00

Table 5. Mathematical and Physical Sciences, Fiscal Year 1990

(Dollars in Millions)

	Number of Awards	Amount
Mathematical Sciences	1,399	$ 69.28
Astronomical Sciences	338	91.51
Physics	675	123.82
Chemistry	1,241	97.92
Materials Research	941	117.01
Science and Technology Centers	6	14.55
Major Research Equipment	1	4.41
Total	4,601	$518.50

Table 6. Scientific, Technological and International Affairs, Fiscal Year 1990

(Dollars in Millions)

	Number of Awards	Amount
Science Resources Studies	47	$ 5.27
Policy Research and Analysis	9	1.09
Experimental Program to Stimulate Competitive Research	34	9.78
Industrial Science and Technological Innovation	231	20.01
International Cooperative Scientific Activities	486	11.64
Total	807	$47.79

Table 7. Education and Human Resources, Fiscal Year 1990

(Dollars in Millions)

	Number of Awards	Amount
Teacher Preparation and Enhancement	588	$ 80.97
Materials Development, Research and Informal Science Education	194	48.23
Undergraduate Science, Engineering and Mathematics Education	579	22.70
Research Career Development	297	36.79
Human Resource Development	140	27.62
Studies, Evaluation and Dissemination	21	4.32
Total	1,819	$220.63

Table 8. United States Antarctic Program, Fiscal Year 1990

(Dollars in Millions)

	Number of Awards	Amount
U.S. Antarctic Research Activities	237	$71.76
U.S. Antarctic Logistics Support	2	79.71
Total	239	$151.47

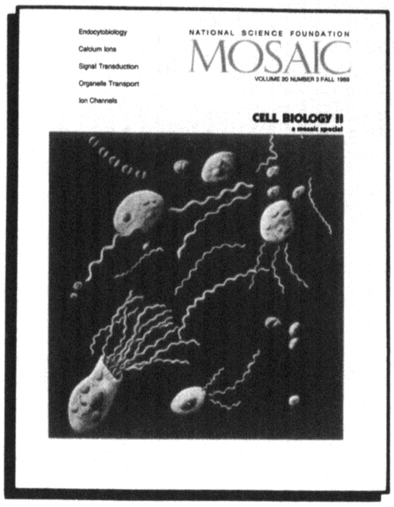
Source: Fiscal Year 1992 Budget to the Congress-Justification of Estimates of Appropriations (Quantitative Program Data Tables).

Other NSF Publications of General Interest

About the National Science Foundation (flyer)
NSF Bulletin (published monthly except in July and August)
Publications of the National Science Foundation (list)
Grants for Research and Education in Science and Engineering (how to apply)
Guide to Programs (catalog)
NSF Film and Video Catalog
Mosaic Magazine (quarterly)
NSF Directions (newsletter)

Single copies of these publications are available from Forms and Publications, NSF, 1800 G Street, N.W., Washington, D.C. 20550, (202) 357-7861.

FY 1990 Annual Report:
Principal writer: Cheryl Pellerin/Editorial Experts, Inc.



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