national science foundation

ANNUAL REPORT 1991

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 2000 colleges, universities, and other research institutions in all parts of the United States. The Foundation accounts for about 25 percent of federal support to academic institutions for basic research.

In FY 1991, NSF received some 38,000 proposals for research, graduate and postdoctoral fellowships, and math/science/engineering education projects; it made almost 16,000 new and renewal awards. These typically went 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 Scientists and Engineers with Disabilities (FASED) provide funding for special assistance or equipment to enable persons with disabilities (investigators and other staff, including student research assistants) to work on NSF projects. See the program announcement or contact the Program 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 Foundation about NSF programs, employment, or general information. This number is (202) 357-7492.

***Cover Design*:** Rachel Delgado

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LETTER OF TRANSMITTAL

Washington, D.C.

DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1991 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

NSF Annual Report 1991

Director's Overview

The Annual Report is both a retrospective look at the past year and an opportunity to reflect upon the future. With this in mind, Chapter 1 introduces the 1991 Annual Report with excerpts from speeches, writings and testimony that NSF Director Walter E. Massey delivered during the year. Collectively, they provide a sense of Dr. Massey's views and priorities, as they address issues affecting not only the research and education enterprise but the entire nation.

Walter E. Massey
Director,
National Science Foundation

Science and Math Education

The education summit called by President Bush in concert with the governors of the states has presented us with an extraordinary challenge: "By the year 2000, U.S. students will be first in the world in science and mathematics achievement."

Someone remarked that this commitment is equivalent to President Kennedy's promise in 1962 to put a man on the moon by the end of the decade. I would submit that President Kennedy's pledge was a modest one by comparison—at least in 1962 there was general agreement on where the moon was located.

At the most elementary level, becoming number one in the world implies a zero-sum game that is reminiscent of the Cold War practice of keeping score on the number of gold medals we won in the Olympic Games. At a time when we were producing some of the best athletes in the world, we were content to suggest that the number of gold medals earned was a surrogate measure for the quality of our society—that in itself our Olympic performance reflected positively on our system of government and economics.

Even before the Cold War officially concluded, I think we came to realize that whatever was being measured by the performance of our Olympic athletes, it was far too simplistic to reflect the richness and diversity of our country.[1]

Economic Competitiveness

These are times of extraordinary change. The resources that are most critical to progress today are no longer mined from the Earth but are created in the mind. Knowledge and human talent are now the hallmarks of a modern, competitive and healthy society. Many of the hopes and promises of the future will be fulfilled through that aspect of knowledge created by science and engineering. Already there is scarcely any area of our lives that has not been touched by—or benefitted from—science and engineering . . . .

Increasingly, national competitiveness is based on important advances in science and engineering and the ability to introduce those advances into the market quickly, efficiently and creatively. For example, the late John Bardeen, a Nobel laureate, pioneered the development of the first transistor. Within his lifetime, this inspiration revolutionized computing, communications and electronics. We can expect equally dramatic and unexpected benefits from breakthroughs in areas as diverse as biotechnology, new materials and others—probably within our lifetime.[2]

[1] December 6, 1991, Keynote Address at the Secretary's (U.S. Department of Education) Conference on Improving Math and Science Education, Washington, D.C.

[2] February 7, 1991, Confirmation Testimony, United States Senate, Committee on Labor and Human Resources.

Public Trust

As a source of funding for much of the basic science that underlies progress in these areas, the National Science Foundation depends on widespread public acceptance of the idea that an investment in science is useful and valuable. For those gathered here, such a statement is so obvious as to be almost ridiculous. Of course we agree that science is valuable. Of course it is deserving of public support. Of course it is important that every citizen understand what science is, what scientists do, and how science affects their lives.

We often take this for granted without reflecting on the fact that widespread public faith in science is a relatively modern phenomenon. Even though we can point to heads of state throughout history who supported various intellectual pursuits, it is only in the past 50 years or so that governments have provided a significant, sustained investment in basic scientific research.

But this public trust in science is not automatic, nor is it guaranteed. It must be earned by the scientific community and by those of us who help set policy. And it must be earned anew every year. This demonstration of faith in science, backed up as it is by public funds, is in part an outgrowth of the expectation of a return on that investment. It is a belief that eventually all scientifically derived knowledge will be put to use that helps sustain public confidence in science.[3]

Scientific Integrity

In science and engineering, there can be no permanently unsolved mysteries nor perfect crimes. If a finding is important, sooner or later the experiment will be repeated and the results subject to independent verification. The rules of research keep science and engineering truthful.

Simply put, the whole edifice of science and engineering research is built upon honesty. More than in any other endeavor, individuals conducting fundamental research depend upon the veracity of the accumulated insights and accomplishments of others. Sir Isaac Newton expressed it best when he said, "If I have seen further, it is by standing on the shoulders of giants."

Not even giants can see clearly if their feet are on shaky ground. Few things are more damaging to the research enterprise than falsehoods—be they the result of error, self-deception, sloppiness and haste, or, in the worst case, dishonesty.

It is the paradox of research that the reliance on truth is both the source of modern science and engineering's enduring resilience and its intrinsic fragility.[4]

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[3] October 23, 1991, Address at the North Carolina State University Convocation, Raleigh, North Carolina.

[4] June 3, 1991, Commencement Address, Massachusetts Institute of Technology, Cambridge, Massachusetts.

[5] December 6, 1991, Statement of Goals and Priorities, Memorandum to NSF Staff.

On the Foundation

The National Science Foundation is uniquely positioned to contribute to the health and welfare of the nation through the creation and dissemination of knowledge resulting from our support for research and education . . . .

[NSF] enjoys an abundance of talent among our staff and considerable resources have been entrusted to us by the public. My highest priority is to use these resources to maintain and enhance the health and vitality of our nation's research and education enterprise. This includes building stronger bridges between academia and industry in order that the excellence of our academic institutions contributes substantially to the standard of living of all members of our society . . . .

First, I am committed to increasing support to individual investigators through budget allocations and larger grant size and extended award duration. To meet new needs in selected areas of research and education, I will continue to strive for balanced support for alternative modes of funding research, such as groups, centers and major facilities.

Second, NSF must be responsive to current critical national needs, particularly in education and human resources and in economic development. Foundation programs in all directorates should focus on educating our citizenry to meet current and future requirements for scientific and technical personnel, and on promoting retention of human resources.[5]

Physicist Walter E. Massey became the Foundation's ninth Director on March 4, 1991. He previously was Vice President of the University of Chicago for Research and for the Argonne National Laboratory. Dr. Massey also is a former member of the National Science Board.

Chapter 2

Research Reports

Geosciences and Biosciences

Kuwait Oil Fires

Retreating Iraqi troops set hundreds of oil fires in Kuwait during the last days of the Gulf War (late 1990 to early 1991). The resulting inferno emitted large amounts of carbon dioxide and other gases into the atmosphere, while locally the thick smoke blocked sunlight, lowered temperatures and engulfed the area in a mist of microscopic oil droplets.

NSF-funded researchers flew aircraft through daytime skies darkened by smoke, extreme heat, dust and fumes. Before emerging in oil-coated planes, they gathered data from every part of the plumes. From May 16 through June 12, the heavily instrumented planes completed a total of 35 flights, typically of six hours duration or more.

These data may be the most extensive yet collected on the atmospheric behavior of the fires' giant smoke plumes. NSF coordinated the U.S. study, which also was funded by the Defense Nuclear Agency, the Department of Energy and the National Geographic Society. *Peter Hobbs* at the University of Washington and *Lawrence Radke*, at the NSF-supported National Center for Atmospheric Research (NCAR), led 27 scientists who participated in the expedition.

Scientists returning from the Gulf said the black smoke was unlikely to reach the stratosphere. In addition, levels of toxic compounds such as ozone, oxides of nitrogen, carbon monoxide and sulfur dioxide were lower than anticipated. The airborne teams detected no smoke plumes above some 260 meters (19,000 feet). For smoke to have a significant impact on climate or weather, it must remain in the atmosphere for a long time. But evidence indicated no significant fraction of the smoke would

Oily twilight. A lunar-like sun appears through black smoke caused by Kuwait oil well fires. On ground, team member checks instruments for atmospheric data collected on flight by NSF-funded scientists, who sometimes needed to wear protective masks.

Robert Bumpas, NCAR

. . . And what is the meaning of so tiny a being as the transparent wisp of a protoplasm that is a sea lace, existing for some reason inscrutable to us —a reason that demands its presence by the trillion amid the rocks and weeds of the shore? The meaning haunts us and ever eludes us, and in its very pursuit we approach the ultimate mystery of Life itself.

Rachel Carson
The Edge of the Sea

reach the stratosphere, where it might escape relatively fast removal from the atmosphere. According to Hobbs and Radke, who studied the Mount Saint Helens volcanic eruption in 1980, the 1991 volcanic eruption of Mt. Pinatubo in the Philippines would result in a longer-lived atmospheric signature than the Kuwait oil fires did.

Kuwaiti oil fires.

Global Change: Selected Projects

Eastern Pacific Corals: Two species of reef-building corals apparently have become extinct from their ranges off Panama's Pacific coast, according to NSF-funded researcher *Peter Glynn*, a marine biologist at the University of Miami. The apparent extinctions are the result of ocean warming caused by a weather disturbance called *El Niño*. Since they are related to sea warming and coral bleaching caused by a severe *El Niño* event, such extinctions could indicate possible global climate changes ahead.

El Niño has been associated with Christmas on the Pacific coast of South America because of its timing. In an oceanic and atmospheric phenomenon that recurs with varying intensity every four to five years, the easterly trade winds slacken and warm water moves east across the surface of the tropical equatorial Pacific Ocean. The severe 1982-83 *El Niño* prevented upwelling of nutrient-rich cold water along South America's Pacific margins. It also was associated with torrential storms along the west coast of the Americas and with droughts in Asia and southeast Africa.

The "bleaching" and death of corals may result from sea-surface warming. Coral reef color is due mainly to symbiotic algae living in coral tissue. The algae provide food and receive nutrients and protection in return; the corals calcify and form reefs. When corals are stressed, algae are expelled and the corals whiten and may die.

With funds from NSF and the Smithsonian Institution, Glynn has studied the aftermath of the 1982-83 *El Niño* as it continues to affect corals in the Galapagos Islands and off Central America's Pacific coast. On many damaged reefs, predators such as snails and starfish find fewer corals to eat; the remaining coral fragments are attacked more frequently. If the corals are eradicated, key predator populations ultimately may plummet as well.

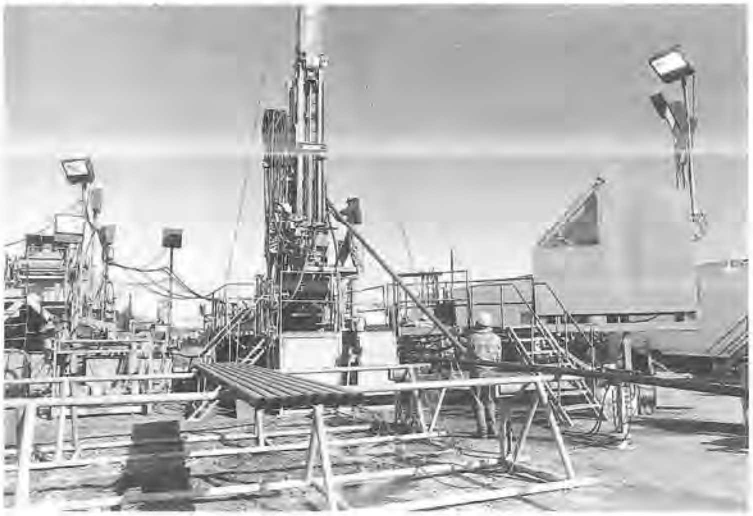
The Economics of Global Change: Scientists in the United States and abroad have embarked on research aimed at reducing scientific uncertainties and improving predictions about global change. There is also more attention on assessing the probable benefits and costs of various policies to mitigate the adverse impacts of changing environmental conditions.

U. Miami

Ecological omen. Diver investigates dead and eroded colony of Pacific coral resulting from the periodic warming of ocean waters known as El Niño.

William Nordhaus at Yale University has done economic analyses on some of these policies, including efforts to reduce greenhouse gas emissions. He concluded that such emissions could be reduced by up to 10 percent for relatively little money; for

Columbia University



Archaic archive. Scientists seeking clues to the earth's history use drilling-core equipment at a 200-million-year-old New Jersey formation known as the Newark Basin. The cores are expected to yield information about the sun's effect on the earth's climate, continental drift and the earth's magnetic field.

more substantial reductions, costs increase dramatically.

Research such as that done by Nordhaus was sponsored through a special NSF initiative called Economic Research on Global Change. Among the topics for which NSF will increase its research support are resource impacts and adaptation, the value of information and decision-making in the face of uncertainty, technology and economic practices in response to global change, and evaluation of policies and policy implementation.

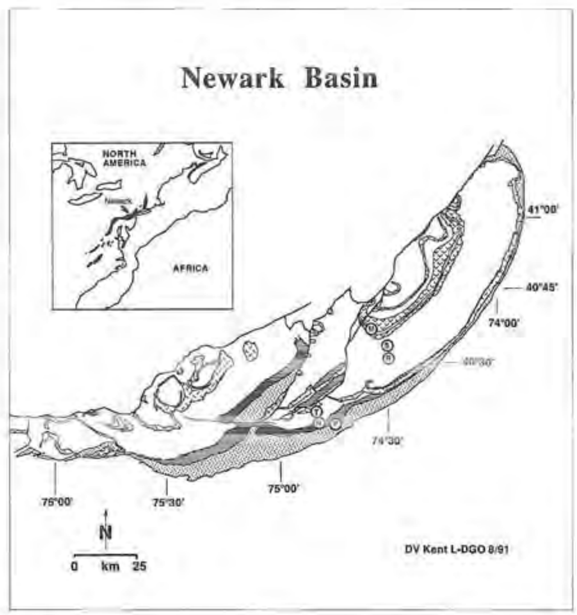
Ancient Climate Change: The drilling of a New Jersey rock core 944 meters long has revealed evidence for periodic climate change occurring over two-million-year cycles. The NSF-supported project also showed that shorter climate cycles were operating as far back in time as 215 million years ago. The rock chronicles a succession of wet and dry periods from a tropical time and may offer clues about such desert-forming processes as are now occurring in Africa's Sahel, perhaps leading to better predictive models.

This core was the first of a series to be drilled in a rock formation known as the "Newark Supergroup." The series should help scientists learn more about how the sun controls the Earth climate system, how continents break apart and how changes in Earth's magnetic field are related to movements of the "dynamo" within the planet's mantle. The core also gives the oldest continuous record of long-term, cyclical climate variations that result from periodic changes in the Earth's movements around the sun. Future cores may offer evidence of a meteorite impact that some scientists believe caused a mass extinction of reptiles 205 million years ago.

In the Newark Basin, the Newark Supergroup is composed of seven distinct layers, seven kilometers thick, stretching from southern New York to southeastern Pennsylvania. Because weathering and uplifting have brought it close to the Earth's surface, the formation gives unusual access to a solid record of how Africa and North America went their separate ways more than 200 million years ago, when the world's supercontinent, Pangea, was breaking up.

When the core series is complete, the rock record should span 30 million years, from about 200 to 230 million years ago. The first core contains a late-Triassic record from 215 to 220 million years ago, when dinosaurs were modest-sized, mammals were just evolving and humans were nonexistent. Climate change is evident in the rock's changing color, texture and mineral content.

This project is part of the U.S. Continental Scientific Drilling Program, a joint effort by NSF, the U.S. Geological Survey and the U.S. Department of Energy.



Bioprocessing and Environmental Biotechnology

Biotechnology is a technique that uses living organisms or their parts to make or modify products, improve plants and animals, or develop microorganisms for specific uses.

It relies on the basic research contributions of science and engineering fields, applying research principles to novel goods and services. Bioprocessing and environmental applications such as waste management are two major biotechnology applications that benefit from NSF-supported research programs.

NSF funds research on the functional interactions among plants, animals and microorganisms and on the ecological and genetic bases for variations in organisms that let them respond to changing environments. This support is a strong basis for biotechnological developments. Funding to botanical gardens and zoos—and for other biological collections as well—maintains a germplasm resource base important to new biotechnologies. In addition, the Foundation, by supporting the Center for Microbial Ecology at Michigan State University and research sites dedicated to long-term ecological studies, is helping scientists do crucial research in developing environmentally focused biotechnologies.

In environmental engineering, NSF funds research on microorganisms to detoxify hazardous organic substances that threaten the quality of surface and ground waters. An NSF Engineering Research Center at Montana State University studies the effects of biofilms—layers of biomolecules formed on or adjacent to solid surfaces such as containers, pipes or other structures—on corrosion and biofouling in enterprises such as the electric power industry.

Bioprocessing and bioconversion include the efficient production of commercially valuable molecules such as specialty chemicals and pharmaceuticals, along with the use of diverse biological systems and bioreactors to recover, produce or modify novel molecules for commercial applications. Bioprocessing and bioconversion are especially strong in the NSF engineering programs that focus on new ways to culture bacteria, yeast and fungi; plant, insect and mammalian cells; and hybrid cells. For example, plant cell culturing produces secondary metabolites that may be useful as therapeutic compounds, and insect cells are used to synthesize viral insecticides.

An Engineering Research Center at MIT seeks new ways to use mammalian cells to synthesize highly valued proteins. Engineering research is also directed at economical, commercial-scale processing, including separation and purification processes for biochemicals. And Montana State University's Engineering Research Center is examining the possibilities for "bioleaching" valuable minerals from mine wastes.

Plant Genome Megamap

Arabidopsis thaliana is a simple weed that has spawned international collaboration among plant scientists. Their goal is to map the complete set of *Arabidopsis* genes, called a genome. This achievement will result in a better understanding of all flowering plants and will help genetic engineers improve economically important species. This project, in which many individual investigators worldwide are coordinating their

Elliot Meyerowitz

Scientific mutant. Worldwide research to uncover more secrets of plant biochemistry is focusing on the simple weed Arabidopsis thaliana. The plant is shown as it buds, normally flowers and grows in cauliflower mutant form, which was engineered to aid in identifying genes.

research, is a model for multinational collaboration.

First-year research accomplishments include expanding by 36 percent the plant's number of known genetic markers. This increase is due in part to advances in techniques developed with *Arabidopsis* for singling out, identifying, mapping and moving genes. International collaborators have tried to identify as many genes as possible by inducing mutations in the plants and relating genetic changes with changes in form and function. Researchers have identified more than 200 new mutations associated with genes controlling embryo development, metabolism, reproduction, photosynthetic capacity and resistance to disease.

Pigs Make Protein for Humans

Molecular biologists at the American Red Cross have used milk from pigs to make a protein that prevents the formation of blood clots in humans. This transgenic research aims to generate animals with a human gene that makes the therapeutic Protein C. Pigs are used because they have a short gestation period, about 3.5 months, and have six or seven piglets per litter. In this research, a gene that encodes a specific protein is isolated from a human cell, then placed into a one-cell pig embryo. Pigs born with the special gene produce the protein in their milk. The milk is then purified, processed and used to treat patients who have unwanted blood clots.

NSF was a key supporter of research that the Red Cross performed in collaboration with Virginia Tech University. Drugs are available now to prevent clotting, but they have unwanted side effects that appear to be absent in Protein C.

Vitamin K Research

Until recently, little was understood about vitamin K's role in physiological processes such as bone calcification. Now, NSF-funded researchers at the University of Pittsburgh have discovered new methods to analyze the effects of vitamin K, a substance essential for blood clotting in mammals. Chemists *Paul Dowd, Seung Wook Ham* and *Steven J. Gelb* developed a model that simulates the clotting process in humans and will help unlock the role vitamin K plays in tandem with other blood-clotting agents. The potential for these models is enormous—comparable findings in other areas have revealed previously unknown biochemical processes that led to better approaches in treating disease.

Experimental Program to Stimulate Research

Millions of dollars are spent annually in attempts to halt the growth of watermilfoil, a reedy aquatic plant that has spread from lake to lake in the northeastern United States and Canada since its accidental intro- duction in the early 1980s. NSF, through its Experimental Program to Stimulate Competitive Research (EPSCoR), has been supporting *Sallie Sheldon's* efforts to find a biological control for the weed.

In 1989, biologist Sheldon discovered that watermilfoil had mysteriously declined on its own in Brownington Pond near Middlebury, Vt., where she conducts her research. Samples taken from the pond showed the plants were covered with herbivorous weevils. Further investigation revealed that these weevils dine almost exclusively on watermilfoil fronds. Sheldon's research could show whether the weevils will control watermilfoil's growth if transplanted to other lakes, and whether or not the weevils are harmless to beneficial plants. These studies may result in an economically viable, environmentally non-toxic answer to the watermilfoil problem—a bonanza for failing aquatic ecosystems.

NSF created the EPSCoR program in 1976 to strengthen research at institutions in states that generally receive a small share of federal research dollars. In 1990, program grants totaling $6 million were awarded to Arkansas, Maine, Montana, South Carolina and West Virginia. EPSCoR benefits scientists, engineers and mathematicians who are at the threshold of competitive funding; the grants help them overcome barriers to their research and obtain financial support from major funding agencies.

Experimental Research. Under an NSF program targeted to key states, biologist Sallie Sheldon has done research on controlling the watermilfoil weed.

Social and Behavioral Sciences

Language and the Brain

The principal research aim of those in the new field of cognitive science is to understand the human mind; an important part of such research is learning how the mind relates to the brain. Aphasiology, the study of how different kinds of brain damage affect a person's ability to use language, has produced key knowledge in this area and continues to be a source of significant new discoveries.

Howard Poizner of Rutgers University/Newark is studying the effects of brain damage on users of American Sign Language, the manual-visual language of Northern America's deaf community. Sign language offers an interesting research perspective because linguistic abilities typically are centered in the brain's left hemisphere, while spatial cognition (the ability to recognize visual patterns) typically is centered in the right hemisphere.

To demonstrate how the brain deals with a language based on visual patterns, Poizner has been observing brain-damaged signers, noting differential effects of lesions to the brain's left and right hemispheres. The results are striking. He found that lesions to the left, but not to the right hemisphere, affect linguistic properties of sign language such as grammatical organization. People with right-hemisphere damage show distinct losses in non-linguistic spatial cognition, but their sign-language proficiency is unimpaired. This finding advances understanding of the neuroanatomical structures important for language, and of the way neural mechanisms for language seem to function.

Family Income Changes

Recent attention has focused on the relative decline in the number of middle class families. Most discussions center on the aggregate number of households in different income categories, but *Timothy Smeeding* at Syracuse University is studying the changing income levels of specific families over time. He uses data from the NSF-supported Panel Study of Income Dynamics (PSID), a longitudinal survey begun in 1967.

Interviewers gather information annually about income and related factors in about 7,000 households drawn from a representative national sample. Because the same families are monitored each year, the PSID permits analyses of how individual households respond to changing conditions—information often lost through aggregate statistics. Smeeding's analysis of PSID data compared trends across the 1970s and 1980s to identify significant changes in factors that explained why income levels for some households rose faster than others.

In the 1970s, formal education and job experience were the two most important predictors of a family's likely economic success. The higher the educational attainment and the greater the job experience of a family's head, the more likely it was that family income would increase and that the increase would be permanent. During the 1980s, however, the influence of education increased while the effect of job experience virtually disappeared. This finding implied that job experience no longer could substitute for education if families wanted their incomes to grow. Income earned by women also became more important in the 1980s as a factor contributing to household income growth.

Political Representation and Redistricting

Once every decade, all U.S. political jurisdictions that hold elections within districts redraw the boundaries of those districts, in response to population changes. This process of redistricting has important consequences for who wins elections and how well voters are represented. Two measures of redistricting effects are *electoral responsiveness,* which indicates how sensitive electoral results are to changing votes from one election to the next, and *partisan bias,* which indicates whether one party is generally favored by the drawing of district boundaries. *Gary King* at Harvard University has examined these effects both theoretically and by analyzing 20th-century congressional election data.

Using new procedures that minimize the statistical bias plaguing earlier studies, King has found that redistricting increases electoral responsiveness. He also noted that any partisan bias in the system was entirely a result of the electoral advantages of incumbents, which is almost twice as large as some previous measures had indicated.

Along with analyzing the changing dynamics of political representation, King and his colleagues developed a computer program that allows measurements of partisan bias, thereby aiding the redistricting process. These programs not only have stimulated more research on this important topic; they also have been used by officials involved in several federal and state redistricting cases around the nation.

Physical Sciences

New Route to Nylon Building Block

In the wake of reports that nylon production may cause atmospheric increases in ozone-depleting nitrous oxide, chemists have found a better way to convert a simple molecule to adipic acid, a key nylon intermediate. The discovery, by *Maurice Brookhart* at the University of North Carolina and *Sylviane Sabo-Etienne* at the Laboratory for Coordination Chemistry in France, resulted in part from NSF-funded research on metal-directed catalysis.

The chemists discovered a catalyst based on the metal rhodium, which links two molecules of the three-carbon compound methyl acrylate to produce hexenedioate, a six-carbon compound easily converted to adipic acid. The researchers designed an improved catalyst after using a technique called magnetic resonance spectroscopy to reveal the chemical mechanism that rendered their first-generation catalysts inactive. The new catalyst system accomplished the chemical transformation more rapidly and with a higher yield.

Straining for New Magnetic Materials

Researchers at the University of Illinois, Johns Hopkins University, the University of Nebraska, Notre Dame and the University of Michigan are applying the technique of "strained layer epitaxy" to fabricate new magnetic materials, layer by layer, on an atomically smooth starting substrate. The structure and spacing between the epitaxial layers of atoms—iron atoms, for example—are controlled by atomic spacings in the substrate, and are generally different from that in ordinary bulk iron. The stretching or compression is "strain."

Strained-layer epitaxy "sandwich" films are of interest to those studying fundamental and practical magnetism because the magnetic properties of materials are exquisitely sensitive to the atomic spacings between the adjacent atoms in the materials—which can be metals, oxides, or even complex high-temperature superconductors. New materials are being created and known materials customized by scientists studying the coupling between these sandwiched layers.

Physicists at participating institutions find remarkable differences in magnetic behavior as the films' thickness varied from tens of atoms (three-dimensional-like conditions) to a few atoms (two-dimensional-like conditions). This effect leads to enhanced optical properties and other unusual magnetic phenomena. All are of fundamental interest and a key to new materials for practical applications—for example, ultra-high-capacity, magneto-optical recording devices.

Astronomy

Size and Age of the Universe

A clearer understanding of huge cosmological structures and better estimates for the universe's age and size are possible thanks to a technique used to make the most precise measurements yet of relative distances among astronomical objects. To make the measurements, NSF-funded astronomers at the Massachusetts Institute of Technology (MIT) used sensitive electronic detectors and statistical techniques newly applied to astronomical data. They focused on 13 galaxies in the Virgo cluster. Although the galaxies are nearly equidistant from Earth—about 50 million light-years away—the technique revealed new depth within the cluster.

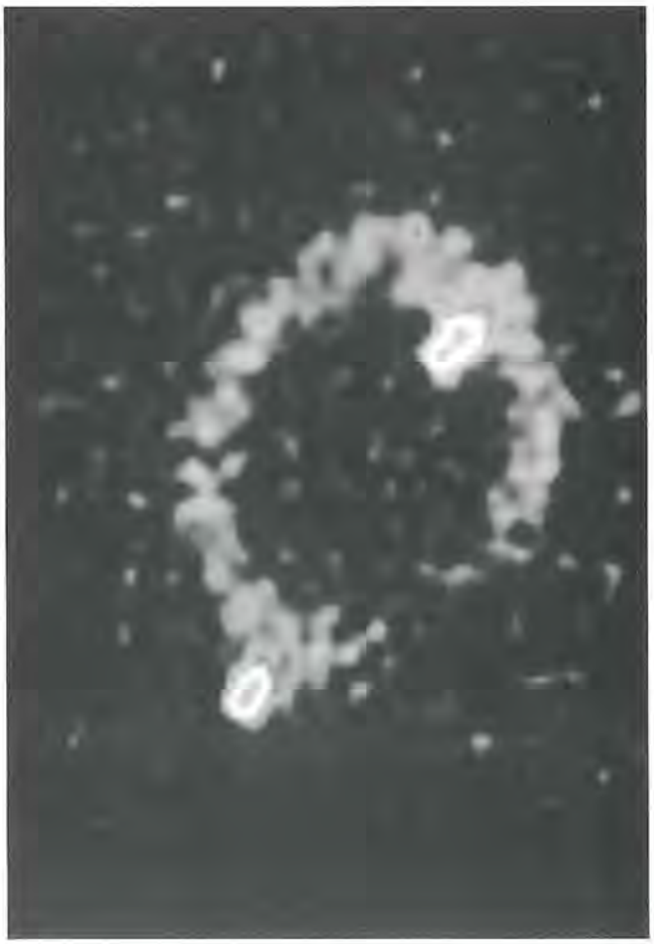
This approach was developed under a team led by MIT astronomer *John Tonry.* It enables scientists to measure objects of 29th to 31st magnitude. (An observer on Earth can see only stars as faint as 5th magnitude with the naked eye.) The technique should immediately be applicable to studies of mysterious large scale structures; these include the "Great Wall," a string of immense galaxy clusters; the "Great Attractor," a region that exerts a strong gravitational pull on stars and galaxies in surrounding space; and voids in space where little matter is apparent.

Tonry believes the approach will prove valuable in efforts to determine the age of the universe, now estimated to be between 10 and 20 billion years old. The new method involves measuring the light recorded from a small piece of the galaxy, then determining how many stars are within that piece.

Stellar Destruction

A team of astronomers has found evidence of one star actively destroying another. In this bizarre double-star system, a pulsar—a rotating star that emits radio waves— is slowly vaporizing its companion. The pulsar and its accompanying white dwarf are so close together that the former is literally boiling away the white dwarf. Astronomers hope the discovery will illuminate what causes these celestial bodies to evolve and die.

Researchers at the NSF-funded National Radio Astronomy Observatory in Socorro, N.M., and other institutions located the double-star system by tracing intermittent radio signals that indicated a second body was moving rapidly around the first. Like other pulsars, this one is a remnant of a past supernova explosion. It is only 10 kilometers across but has a mass 1.5 times that of the sun. Its companion, a white dwarf, is probably a small star about the size of the Earth with a mass about a tenth of the sun's. The first indications of this unique pair arose from telescope observations made in June 1989 by astronomers from Australia, Italy, Britain and the United States.



NRAO

Astronomy research. An "Einstein Ring" (a symmetric case of gravitational lensing proposed by Einstein in 1936) has been observed at the NSF-supported National Radio Astronomy Observatory. The lensing occurs when the radio emission of a distant source is bent by a massive unseen radio galaxy. The Observatory has an ongoing major project to identify many more lensing candidates.

Mathematics and Computer Science

A New Sorting Algorithm

For more than 30 years, instructors and textbooks have taught that there is a limit to how fast a computer can sort—a barrier called the "information-theoretic lower bound." In 1991, two NSF-funded computer scientists developed a new algorithm that debunked this conventional wisdom and ultimately will have an impact on information technology, sorting, searching and retrieval.

An algorithm is a precisely specified mathematical procedure for processing data on computers. *Michael Fredman* at the University of California at San Diego and *Dan Willard* at the State University of New York at Albany devised one that could allow surprisingly fast sorting of huge databases. Its speed relative to standard sorting algorithms improves as the database grows.

Fredman and Willard used a new method of organizing data, called a fusion tree, which allows a computer to compare one number against many others during a single computational step. The method may be useful in very large data processing tasks, such as transportation problems involving the least costly way to ship supplies and materials, or determining the cheapest way to connect nodes in a telecommunication network. The researchers stumbled across the method while trying to solve another data-retrieval problem.

Early results suggest that future avenues of research eventually may benefit from this discovery. And the new method of sorting variables will work on common-variety computers because it allows computers to "fuse" numbers so they can sort hundreds of them simultaneously.

The Drum and the Spectrum

Picture a figure from plane geometry stretched over a frame to form a drum. (While most drums are round, there is no requirement that they be so.) To each plane figure, mathematicians assign a set of numbers they call the spectrum of the Laplacian, which roughly describes the sound a drum makes when struck. A question that puzzled experts for years was neatly phrased as, "Can you hear the shape of a drum?" That is, does the spectrum of the Laplacian completely determine the size and shape of the plane figure?

Mathematicians *Carolyn Gordon* and *David Webb* of Washington University and Scott Wolpert of the University of Maryland have shown that the answer to this question is no. By using knowledge of how the spectrum of the Laplacian behaves for three-dimensional surfaces (such as that of a sphere) and by taking advantage of three-dimensional symmetries, they were able to squash surfaces together to produce two plane figures with identical spectra that are visibly different.

For mathematicians this work is important because analytical tools such as the spectrum of the Laplacian provide a means to compute the characteristics of geometric objects. The tools being developed in this research may also have important consequences in materials research, where one method of determining flaws involves measuring the spectral response of the material.

Applications of Advanced Technologies

This NSF program supports research and development on applying advanced technologies—particularly computer and computer-controlled technologies—to science and mathematics education. It supports innovative projects to lay the conceptual foundations for technology that will be available within 10 years. The program also aims to speed the advent of revolutionary computer and telecommunications ideas and developments into classrooms. These applications include the following 1991 awards:

- Intelligent Tutors in Algebra and Geometry, *John R. Anderson* at Carnegie-Mellon University. Goals of this research are to develop and demonstrate greatly improved intelligent (computerized) tutoring techniques, and to produce an integrated algebra and geometry tutor that will cover in one year the material normally covered in two.
- Visual Modeling: A New Experimental Science, *Wallace Feurzeig*, BBN Systems & Technologies Corp., Cambridge, Mass. Computer modeling is becoming a standard tool for both experiment and theory, used to study complex processes ranging from the proton's inner structure to the formation and decay of star

clusters. This project aims to make modeling accessible and comprehensible to high school students through the use of powerful new kinds of modeling tools.

- Using Astronomy to Teach Precollege Science and Mathematics, *Irwin R. Shapiro*, Harvard University Observatory. This project supports the continuing development of a high school science course that teaches physical science and mathematics, using astronomy as its focus. Material is designed for students who would not elect traditional science courses such as physics and chemistry during their last years in high school.

William Dwyer

Supercomputer learning. Two representatives from Northwest Indian College learn to use software produced at the National Center for Supercomputing Applications.

Touchstone

Several research institutions, universities and government agencies have formed the Concurrent Supercomputing Consortium[1] combining their resources, ideas and experience in parallel computation to tackle some of the most challenging computa- tional problems.

In November 1990 the consortium announced it would acquire the limited-production Intel Touchstone Delta System, a high-performance, message-passing, concurrent computer. This ultra-high-speed multicomputer will enable consortium scientists to tackle the kinds of problems that could not be attempted on less powerful systems. These include global climate modeling, determining the structure of viruses, analyzing radio telescope data, visualizing information returned from the *Magellan* and *Galileo* spacecraft, simulating brain circuits, and developing certain engineering enzymes. Foremost among consortium goals is stimulating progress in massively parallel supercomputing.

NSF Supercomputing Centers

These centers bring together members of the academic, industrial and governmental communities to collaborate on scientific and engineering research with the aid of high-performance computation and visualization tools. The four centers are:

- Cornell Theory Center at Cornell University in Ithaca, N.Y.;
- National Center for Supercomputing Applications at the University of Illinois/Urbana-Champaign;
- Pittsburgh Supercomputing Center at Carnegie Mellon University and the University of Pittsburgh;
- San Diego Supercomputer Center at the University of California at San Diego.

In addition, supercomputing resources also are available at the National Center for Atmospheric Research in Boulder, Colo., established in 1960 by a consortium of universities to further research in atmospheric science, oceanography and related sciences.

Typical projects using supercomputers include studies of air pollution dispersal, long-term analysis of global warming, gene sequence analysis, drug design, and the development of

[1]Members of the consortium include the California Institute of Technology and its Jet Propulsion Laboratory, Argonne National Laboratory, Pacific Northwest Laboratory, the Center for Research on Parallel Computation (an NSF Science and Technology Center led by Rice University), the Defense Advanced Research Projects Agency, Intel Corporation's Supercomputer Systems Division, NASA, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Purdue University, and Sandia National Laboratories.

superior materials. In 1991, research involved everything from oysters to magnetic recording technology (see box).

RayCasting Engine

Researchers seeking to speed the process of solid modeling traditionally apply supercomputers to their problems. These ultrafast instruments perform calculations serially, one after another. But such an approach is expensive and still too slow for very complex problems. Another approach is to program general-purpose parallel computers, but many think this is also too expensive. A third approach—developing an application-specific computer that closely matches the problem's computational structure—promises to be fast and efficient.

NSF-funded researchers at Duke University and Cornell University have developed a new computer that uses thousands of individual processors working in parallel to analyze

Two Supercomputer Centers

At the Pittsburgh Supercomputing Center, *Y. Peter Sheng,* from the University of Florida, has developed a special three-dimensional model for estuaries, lakes and coastal waters—one that deals with exploding algae and suffocating fish, as described below.

Some summers in the Chesapeake Bay, fish can be seen rushing toward the shore and leaping out of the water. They are suffocating in the bay's oxygen-depleted water. Because of excess nutrients—nitrogen and phosphorous—that enter the bay from phosphate detergents, treated sewage, agricultural runoff and acid rain, algae in the water grow more rapidly than usual. Biologists call this growth explosion an algal bloom, and it uses so much of the water's oxygen that the fish, particularly bottom dwellers such as crabs and oysters, do not have enough. The result? In the 1970s, Maryland fishermen caught more than two million bushels of oysters a year in the bay; in the early 1990s, they are catching fewer than half a million.

To help manage this problem, Sheng has applied his computer model to several Florida lakes and also in the Chesapeake Bay. Using his simulation of the circulation patterns in a water body, environmental agencies now have a way to relate measured contaminant concentrations to pollutant sources. With this information, it is possible to initiate appropriate control strategies. Sheng's approach—a three-dimensional, curvilinear-grid, hydrodynamic model call CH3D—provides that management tool.

Testing a model such as CH3D requires dozens of long-term simulation runs, and the project is only feasible with a supercomputer like the Pittsburgh Cray Y-MP, on which a month-long Chesapeake Bay simulation takes only 40 minutes. The supercomputer model can help calculate how much to reduce nutrient flow, and it can tell researchers how long a system will take to respond to reduced nutrient levels.

At the San Diego Supercomputer Center, *Neal Bertram* has been anticipating the need for rapid advances in magnetic recording technology—for applications ranging from high-definition television (HDTV) to collecting data from NASA's earth-orbiting satellites. In 1991, Bertram held one of four endowed chairs at the Center for Magnetic Recording Research, an institute on the University of California/San Diego campus funded predominantly by NSF and 21 corporations involved in storing and retrieving magnetically written information. These include IBM, Hewlett-Packard, Kodak, Digital Equipment Corp. and Seagate Technology, a disk-drive maker.

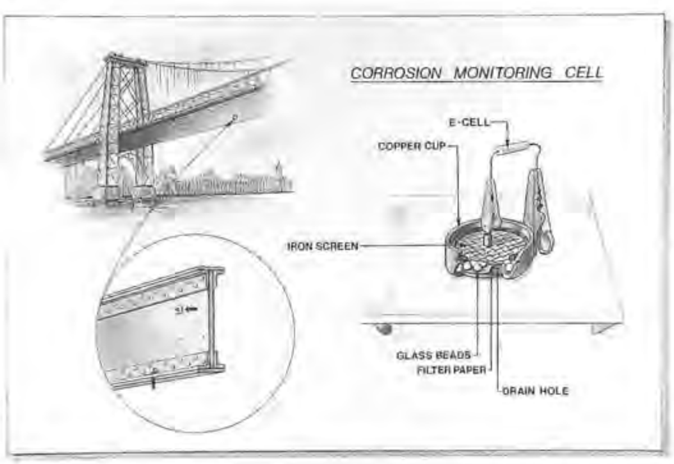
One big problem was magnetic noise in the metallic thin-film media used to coat high-density disks. Bertram and postdoctoral research *Jian-Gang-Zhu* (now at the University of Minnesota) have used the SDCS supercomputer to model thin-film microstructures composed of many tiny grains. Each grain is like a tiny cobalt magnet surrounded by nonmagnetic materials. This grainy, particulate nature of the medium is a source of noise and produces errors in digital recording. Grains interact, and these interactions can increase noise.

The researchers have explored the effects of two primary types of interactions, concluding that the smaller they could make distinctly separable grains, the higher the density at which they could record and retrieve digital bits. The key was to devise alloys and fabrication processes to assure nonmagnetic boundaries between grains, thus eliminating noise.

and render shapes of three-dimensional objects. The relatively inexpensive, special-purpose machine is called the RayCasting Engine (RCE). By rapidly producing mathematical models of complex geometric shapes such as mechanical parts, the RCE promises to affect profoundly the field of mechanical design. The engine allows engineers to design mechanical parts quickly and automatically sculpt their intricate surfaces with computer-controlled machine tools. The RayCasting Engine easily allows machines to be built at multiple levels of performance by scaling the number of processors.

This product resulted from a collaboration between researchers with expertise in applications and systems development. *John Ellis* and *Gershon Kedem* at Duke, and *Richard Marisa*, *Jai Menon* and *Herb Voelcker* at Cornell described their research in the February 1991 issue of *Mechanical Engineering* magazine. The team seeks to integrate the RCE into commercial modelers, expanding the system with more processors and redesigning the engine to plug into workstations. The researchers predict a commercial RayCasting Engine could be available in a few years and should cost less than $100,000. Such a device will preserve and enhance the engineering design industry's $3 billion investment in hardware and $5 billion investment in software.

Lehigh University



Corrosion warning. This cell, developed at Lehigh University's Engineering Research Center, can be mounted on a bridge to warn of needed repairs. It results from a program to develop sensors that detect deterioration of large structures.

Engineering and Related Research

Manufacturing Research

Engineering Research Centers (ERCs) were established in FY 1985 with a strong orientation toward manufacturing. About half the centers now funded deal directly with manufacturing, design and materials processing; the rest indirectly affect manufacturing. Typically, these centers address such issues in a large-scale, cross-disciplinary and systems-integrated way that is difficult if not impossible with individual projects. A good example is Purdue University's Center for Intelligent Manufacturing Systems—those that go beyond current emphases on flexibility and computer integration to the next logical step in the evolution of manufacturing practices. Such systems will have the capacity to respond promptly and correctly to changes in requirements. Creating a manufacturing system that has this property of intelligence requires cross-disciplinary system integration. A variety of software is needed to assess rapidly the information aspects of alternative manufacturing choices, and these tools must function as a coherent system.

Research is organized in three areas: product design, materials processing and factory systems. The key technical issue in product design is to anticipate the consequences of design choices on later "downstream" activities. In materials processing, it is to achieve process predictability,

Engineering Research Centers

Five Engineering Research Centers (ERCs) received new five-year awards from NSF in 1991. ERCs are large, campus-based organizations jointly funded by industry, state government and NSF. They bring together faculty, students and industry professionals from various disciplines in multi-faceted efforts to solve fundamental engineering problems. These researchers also develop new interdis-ciplinary engineering courses and curricula related to questions under study in ERC laboratories. The Centers receiving renewal awards include:

- Center for Telecommunications Research, Columbia University.
- Cardiovascular Technologies Research Center, Duke University.
- Biotechnology Process Engineering Center, MIT.
- Center for Advanced Technology for Large Structural Systems, Lehigh University.
- Systems Research Center, University of Maryland.

Engineering excellence. A University of Maryland research center was established through an NSF grant that stresses research to maintain U.S. industry's global competitiveness. Here two researchers inspect a laboratory-manufactured part while another works on the rotary magnetostrictive motor.

John T. Consoli, U. Maryland

while integration is the key technical issue in factory systems. Projects include models that relate materials and process limitations to final properties; flexible materials handling with sophisticated traffic control; sensing systems and information processing; basic assembly theory and methods; tools and methods to design and control large-scale factory systems.

The NSF manufacturing focus is university-based research on generic manufacturing and automation. One of these special efforts is STRATMAN, the Strategic Manufacturing Initiative, which aims to expand strategic efforts in integrating manufacturing processes and systems, rapid prototyping, and next-generation tools and equipment.

NSF also supports research on fabrication manufacturing and processing technologies for the microelectronics, photonics and optoelectronics industries. This includes funding for the National Nanofabrication Facility at Cornell University. Research there includes work on ultra-miniaturization of electronic devices, quantum mechanical devices, and integrated electronics.

Industry-University Cooperative Research Centers

WINLAB: In networks of the future, telephones and telephone numbers will belong to people, not to specific locations. A network will find users at the beginning of a communication and keep them connected as they move around. To make this possible, WINLAB—the Wireless Information Network Laboratory at Rutgers University—has pioneered new approaches to network control and information routing. WINLAB is working to unite the features of cellular and cordless telephones with those of pagers for wireless access to information networks and services. NSF has designated this lab as one of its Industry-University Cooperative Research Centers; a five-year grant for research on network infrastructure, equipment and computer programs will support the 21st century's wireless communications industry.

The laboratory is a cooperative effort of industry, government and university representatives, focusing on third-generation wireless technology. The grant is being used to study computers that coordinate the complex work of a large-scale wireless network's dispersed equipment.

Small Business Awards Spur Cutting-Edge Research

Small high-technology firms in 29 states received NSF grants to conduct cutting-edge, high-risk, and potentially high-payoff research under the Small Business Innovative Research (SBIR) program. In FY 1991, some 184 Phase I awards were made to 146 firms. Under Phase I of the three-phase program, NSF awarded up to $50,000 to each firm, selected from more than 1,200 proposals. Funded projects range from new instrumentation and detectors to the growth of cells on textured surfaces.

Upon completion of Phase I research, projects that appear most likely to result in economically and socially beneficial products or services receive Phase II grants of up to $300,000 for two years of continuing research. Private investors then fund Phase III product development, manufacturing and marketing efforts.

Cumulative private investment and product sales attributable to the SBIR program now exceed $1 billion. Awards in previous years have resulted in commercial products such as truck drag-reduction devices for increased fuel economy, extended-wear orthopedic implant devices and hybrid bass for improved fish farming. Other examples:

- DTM Inc. of Austin, Texas, received an SBIR Phase I award to investigate a concept for a desktop manufacturing system. The system uses a computer with a three-dimensional rendition of the object to be manufactured; the computer controls a laser, which "builds" the object by sintering powders, layer by layer. This work led to a buyout of the firm by B.F. Goodrich Inc., and production units are being built to order.

- The quality of fruits, berries and vegetables that have been frozen for storage can be damaged by the effects of ice. But under another SBIR project, several proteins were identified that inhibit ice crystal growth. A grant to DNA Plant Technology Inc. of Oakland, Calif., allowed company researchers to identify a gene for one of these proteins. Researchers *Pamela Dunsmuir* and *Peter Lund* seek to modify the gene so that the protein is larger and more easily detected.

Desktop prototype. This part, produced by a method called laser sintering, illustrates a technique developed through NSF's Small Business Innovation Research Program. Introduced into the marketplace when the researchers' small firm was acquired by B.F. Goodrich, the technique will enable engineers, operating with off-site computers, to convert ideas quickly into hard-to-produce parts.

Fresher frozen. To improve the quality of frozen produce, Pamela Dunsmuir and her fellow scientists developed transgenic tomato plants with "antifreeze" genes, under an NSF Small Business Innovation Research grant.

DNA Plant Technology Corp.

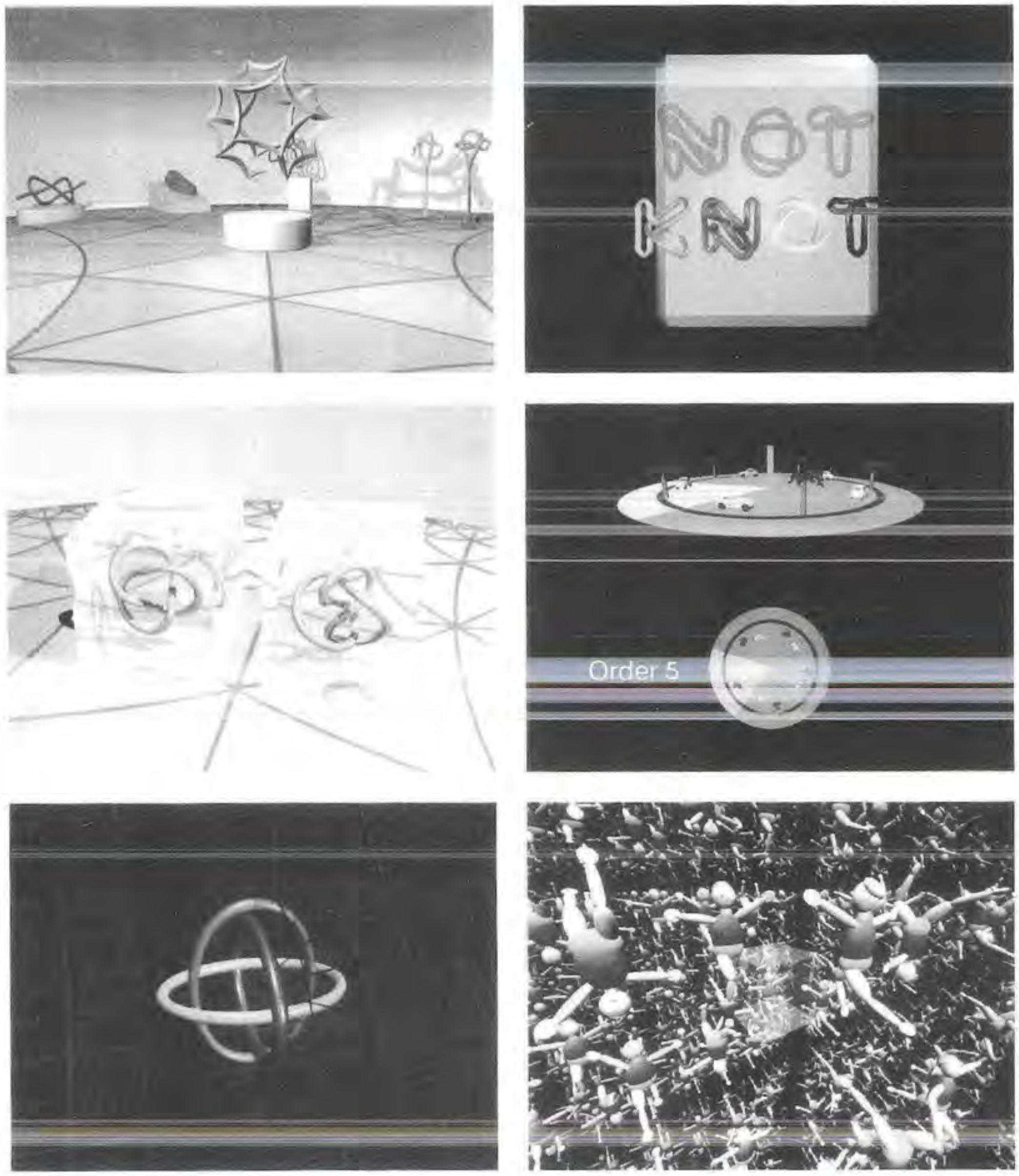
Multidisciplinary Research at Science and Technology Centers

Geometry Center

In 1991, mathematicians and computational scientists from an NSF Science and Technology Center (STC) at the University of Minnesota began working together to create everything from computer models of beating hearts and soap bubbles to dynamic illustrations of abstract mathematical concepts in fractal geometry and chaos theory. The Center for the Computation and Visualization of Geometric Structures is a joint effort by NSF, the U.S. Department of Energy, the University of Minnesota and the Greater Minnesota Corp. Its goal is to link researchers from many universities and mathematical subdisciplines under the unifying topic of geometry and geometric representation on the computer. Computer graphics designed at the center will help researchers carry out their work, and will be used to teach mathematics concepts to high school and university students.

The center has received a five-year award from NSF. Its scientific program is based on a core of scientific investigations whose origins are in pure mathematics and models of physical phenomena. (See box for examples of other Science and Technology Centers supported by NSF in 1991.)

U. Minnesota



Geometry illustrated. These scenes are from Not Knot, a videotaped production illustrating computer graphics used to teach mathematical concepts. The tape and accompanying study supplement were produced for the NSF-funded University of Minnesota Geometry Center.

Southern California Earthquake Research Center

NSF designated the University of Southern California as the site for one of its 1991 Science and Technology Centers. The Southern California Earthquake Center is creating a central data archive for scientists and developing an outreach/education program to give the public up-to-date information on earthquakes before they occur and immediately after major events. Research areas include the history of fault movements, a look at past earthquake sources, and a study of how the earth's surface responds to seismic waves generated by earthquakes.[2]

[2] NSF also awarded a second five-year grant to the National Center for Earthquake Engineering Research, based at the State University of New York at Buffalo. Established in 1986 with NSF monies and matching funds from the state of New York and others, this center focuses on topics such as risks to lifeline systems, seismic retrofitting of existing buildings, control of building vibrations, and disaster preparedness. Researchers are affiliated with a consortium of institutions, including SUNY-Buffalo, Cornell University, Princeton University and Rensselaer Polytechnic Institute.

Scientists have determined the crystalline structure of a microscopic bismuth wire about one-tenth the width of a bacterium. The filament—a single unbroken the smallest sample for which a structural determination has been made using x-rays, according to NSF Science and Technology Center researchers from the Camegie Institution D.C. The Camegie researchers are associated with the NSF Science and Technology Center for High-Pressure Research at the State University of New York/Stony Brook.

The scientists collaborated on a Naval Research Laboratory (NRL) project to make the stmctural determination. Theoretically, a enough filament confined at high pressure could be a high-temperature superconductor. (Such materials are sought for their potential to carry electricity without losing current to electrical resistance.) Although the initial filament is not superconducting, at this writing the research group was studying another wire, about three times thinner, which could help scientists make that breakthrough.

Science and Technology Centers

NSF announced the awarding of $15 million to 14 new Science and Technology Centers infiscal1991. Through partnerships with the private sector, state governments and other federal agencies, these Centers will receive another $26.9 million. They are an important model for enhancing education, encouraging technology transfer and developing innovative approaches to problems. The new Centers* are:

CALIFORNIA

Southern Califomia Earthquake Center, University of Southern Califoraia
Center for Engineering Plants for Resistance Against Pathogens, University of

ILUNOIS

Center for Astrophysical Research in Antarctica, University of Observatory
Center for Magnetic Resonance Technology for Basic Biological Research, University of
Clouds, Chemistry and Climate Center, University of Chicago

MICHIGAN

Center for Ultrafast Optical Science, University of Michigan

MINNESOTA

Center for Computation and Visualization of Geometric Stmctures, University of Minnesota

YORK

Center for High-Pressure Research, State University of New York/Stony Brook

OHIO

Center for Advanced Liquid CrystalUne Optical Materials, Kent State University

Center for Research in Cognitive Science, University of Pennsylvania
Center for Light Microscope Imaging and Biotechnology, Camegie-MeUon University

TEXAS

Center for the Synthesis, Growth and Analysis of Electronic Materials, University of Texas/Austin

UTAH

Center for Computer Graphics and Scientific Visualization, University of Utah

Center for Biological Timing, University of Virginia

Grantees only (some centers involve researchers from more than one institution)

Education and Outreach

Statewide Systemic Initiative

Ten states received NSF support in 1991 for system-wide reform of math and science education programs, from kindergarten through teacher training. The awards—totaling $75 million for up to five years, to be matched by the states—were the first under NSF's Statewide Systemic Initiatives (SSI) program.

There was intense competition for these awards, designed to act as a catalyst for comprehensive reform in science and mathematics education. Unlike most NSF grants, SSI awards are part of a cooperative agreement between NSF and each state, allowing the Foundation to give technical and management advice as the projects are developed and implemented, and to establish agreed-upon, measurable project milestones. To ensure the programs' permanence, state legislatures and other public and private sources are expected to support systemic changes through long-term fiscal commitments.

Proposals from the 10 funded states—Florida, Montana, Nebraska, North Carolina, Ohio, Rhode Island, Louisiana, Delaware, South Dakota and Connecticut—reflected a variety of integrated plans to focus on major components of their educational systems. Each project involves a partnership of executive, legislative, educational, business and public leadership. In Florida, for example, the SSI-funded project takes a thematic approach to elementary science and mathematics, one based on the environment. Connecticut has targeted poor urban and rural districts through state and local cooperative efforts. Nebraska is improving science and mathematics education by featuring "distance learning," an opportunity for students in a rural state to overcome isolation. They are participating in lessons presented through the state's interactive telecommunications system.

Scope, Sequence and Coordination

A far-reaching reform effort in U.S. 7th- through 12th-grade science education is being tested through the Scope, Sequence and Coordination (SS&C) model, which receives partial support from NSF. Students could have new class schedules, with time spent in science courses increased by as much as 50 percent. Course content is closely coordinated from one subject to another, and subjects are offered over three or four years instead of one, leading to a more integrated high school science education. For instance, concepts from physics, chemistry, biology and earth science might be coordinated in a teaching approach to depletion of the ozone layer.

Pilot projects, reaching more than a million students in five states, could help transform middle-level and high school science classes nationwide. Some examples:

- In California, teams of teachers in 199 schools are adapting existing materials to the SS&C model, and the University of California system has approved several high school courses for college-entrance laboratory credit.
- At the University of North Carolina/Wilmington and East Carolina University/Greenville, teachers and project staff use a

computer network and interactive video telecommunications to help the State Education Department revise curriculum guidelines based on SS&C concepts.

- At Puerto Rico's Center for Science and Engineering, junior high school teachers are integrating science and mathematics instruction.
- University of Iowa science teachers are working with social studies, English, music and art teachers to develop modules that explore science-related issues in conjunction with other topics of interest to students. The modules are helping motivate students to study science in more depth.

Scope, Sequence and Coordination Program. Houston students see science in action under this program, coordinated at Baylor College of Medicine in Texas.

Baylor College of Medicine

Science and Mathematics Education: State Indicators

The Council of Chief State School Officers led the development in fiscal 1991 of a state-by-state system of indicators on the condition of science and mathematics education. The project, partly supported through an NSF grant, is expected to help state, national and local decision-makers assess the rate of progress in improving educational quality. Following is a summary of some indicators for 1990:

Baylor College of Medicine

Taking Courses in Mathematics and Science: By the time they graduated from public high school, the following percentages of U.S. students took these courses:

- 9 percent—calculus; 49 percent—algebra 2; 81 percent—algebra 1; 2 percent—advanced placement calculus;
- 20 percent—physics; 45 percent—chemistry; 95 percent—biology.
- In advanced placement science courses, 2 percent—biology; 1 percent—chemistry; less than 1 percent—physics.

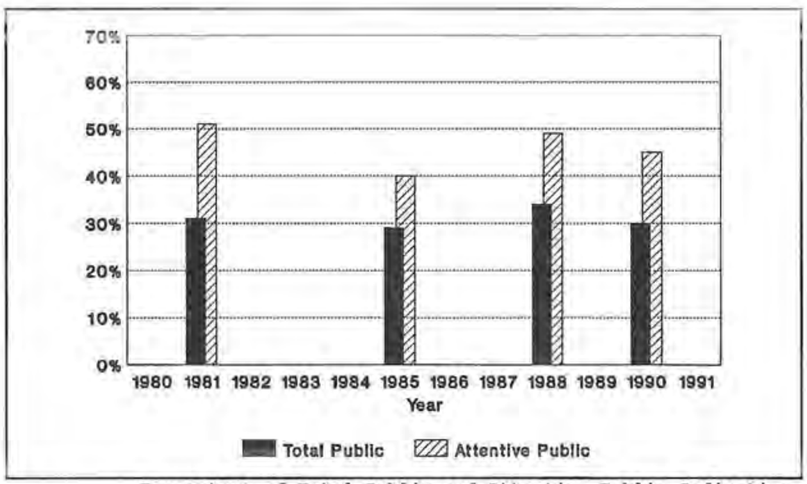
Elementary Instruction: Elementary teachers (grades 4-6 in the median state) reported that they spent 4.9 hours per week on mathematics and 3 hours per week on science. State figures for mathematics vary from 4.1 to 5.5 hours a week, and the time spent on science varies from 2.2 to 4.1 hours a week.

Role of State Policies: State indicators on high school course-taking show higher enrollments in science and math during the 1980s, when

Survey Results

Half of a representative sample of 2,033 adult Americans said they believed Japan has forged ahead of the United States in basic scientific achievement, according to a 1992 study, *Public Understanding of Science and Technology in the United States*. The report was based on a survey by *Jon Miller*, director of the Public Opinion Laboratory at Northern Illinois University in DeKalb. Other findings:

- Some 46 percent of the Americans polled expressed the view that the United States was ahead of Europe in basic scientific achievements, although 14 percent thought Europe was ahead of the United States.
- Only 7 percent said that the then Soviet Union was in front of the United States in these achievements.
- In terms of industrial technology, most survey respondents assigned dominance to the Japanese. About 70 percent thought Japan was ahead of the U.S. in technological developments in 1990.
- The survey also showed broad public concern about science and mathematics education. Some 72 percent of those polled felt the quality of such education in American schools was inadequate. Those with more formal education and with more courses in science and mathematics tended to be more critical of American education.
- About 73 percent supported high school requirements of one science course each year, while 87 percent supported one math course each year.



Percentage of Total Public and Attentive Public Indicating that the Government is Spending Too Little for Scientific Research, 1981-90.

Attitudes on science funding. Measuring public attitudes toward science, a survey conducted by Jon D. Miller showed the percentage of total public and "attentive public" who felt that the government spends too little for scientific research. "Attentive Public" refers to those who said they were very interested in scientific research, consider themselves well informed and regularly read newspapers and relevant national magazines.

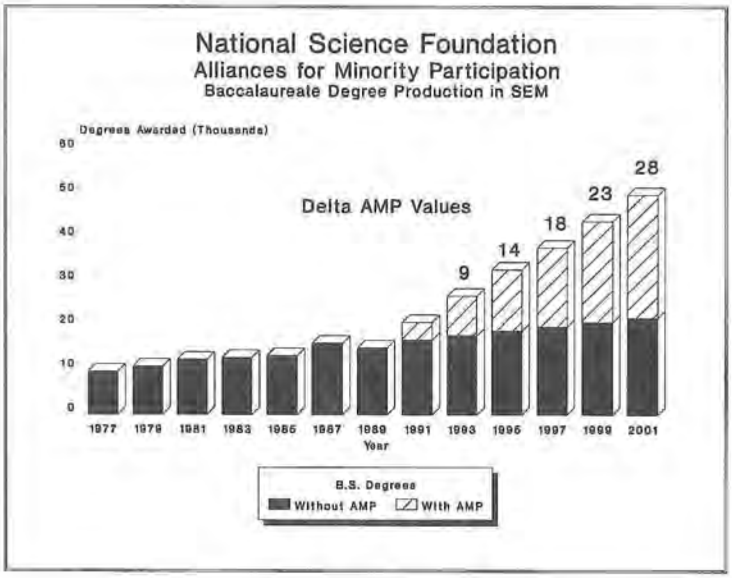
A key to greater U.S. achievement in science and mathematics education is fundamental change in U.S. colleges and universities, according to a 1991 report prepared by Project Kaleidoscope. This NSF-funded project is outlining effective models; its report, *What Works: Strengthening Undergraduate Mathematics and Science*, advocates a change in the way teachers are prepared, replacing the education major with a regular major in traditional arts and sciences. A key component of the report is advocacy of a lean, lab-rich curriculum that concentrates on making a limited number of courses superb, integrated and important—rather than creating a menu of courses to provide an exhaustive survey of the disci-pline. Such a curriculum, the report noted, would help expose students to the research-like modes of taking initiative, figuring things out and working with others.

many states raised graduation requirements. Generally, the results of this project tend to confirm previous studies, which show overall higher enrollment figures in science with higher requirements.

Gender Differences: Girls and boys in 16 states that reported data by gender had almost equivalent rates of enrollment in science and math, up to the advanced course levels. In most states, boys had higher enrollments in physics and advanced mathematics courses (trigonometry and calculus); girls had higher enrollments in advanced biology courses.

Alliances for Minority Participation

National goals spurring this NSF program are ambitious: to produce 50,000 minority baccalaureates and 2,000 doctorates annually in the natural sciences and engineering by the year 2000. The United States now produces 14,000 minority bacca-



Minority participation. Shown here are ten-year goals for increasing B.S. degrees to minorities in science, engineering and mathematics, under NSF's Alliances for Minority Participation (AMP) Program. "Delta AMP Values" indicate projected changes resulting from the program, beginning in 1991.

laureates and 300 doctorates. The Alliances for Minority Participation (AMP) initiative, focusing on the undergraduate years, aims to stem the loss of Black, Hispanic and Native American students from science and engineering careers. For its investments in the AMP initiative over the next decade, NSF seeks other federal support and matching efforts from the private sector. In 1991, the Foundation announced the first of several AMP grants for *planning* activities.[1]

Course and Curriculum Grants

NSF made its first set of awards under a new Undergraduate Course and Curriculum Development (UCC) program, which encourages faculty responsible for undergraduate instruction to work toward better classroom and lab instruction in science, mathematics and engineering. Almost 90 projects in 31 states, the District of Columbia and American Samoa were funded.

An award to the American Institute of Physics supports an effort to introduce more contemporary physics into introductory, calculus-based physics courses. A similar project in chemistry involves 10 campuses across the country and was stimulated by an earlier NSF workshop on undergraduate curriculum development. In biology, the Biological Sciences Curriculum Study Group in Colorado is developing life science curricula for high schools, community colleges and universities. Awards in mathematics, to the University of Florida and California State University-Hayward, could lead a national effort to improve the teaching of statistics.

Another group of these awards involves using computers to improve course offerings. The University of North Carolina/Asheville, for example, is developing an introductory meteorology course in which undergraduates use microcomputers to archive weather data, satellite and radar imagery and weather plots. Integrating meteorology, mathematics and computer science, students can visualize the development and movement of weather systems.

Many UCC awards aim to improve courses for non-science majors. One such project at Columbia College, Princeton University and Indiana University involves developing a freshman chemistry course that centers on environmental issues and emphasizes hands-on, exploratory activities.

Engineering Education Coalitions

From transforming classrooms to teaching young engineers about the societal impact of their work, two university coalitions funded by NSF seek to revolutionize the education of those who design computers, chemical processors and environmental systems. The coalitions were formed to represent diverse geographic locations, missions and institutions. One group is the eight-university *National Engineering Education Coalition*; its members are California Polytech, Cornell, Hampton, Iowa State, Southern, Stanford, Tuskegee, and the University of California/Berkeley.

With its NSF award, this coalition is developing tools and curricular materials for alternative modes of instruction and access; these include visualization technologies, variable pacing and individual attention, and

[1] In early FY 1992, NSF funded the first final grants. AMP awards went to the University of Alabama/Birmingham, Arizona State University, University of California/Irvine, Jackson State University in Mississippi, Texas A&M University, and the University of Puerto Rico. These institutions have established partnerships with other universities, community colleges, national laboratories, government agencies, private firms and other institutions. Their goal is to establish far-reaching networks of educational opportunities for minority undergraduates in science, engineering and math.

frameworks for next-generation modular textbooks. The frameworks allow successive instructors to add special chapters, case studies, problems, demonstrations and software.

The second NSF-funded group, the *Engineering Coalition of Schools for Excellence in Education and Leadership* (ECSEL), includes the engineering schools of Howard University in Washington, D.C., the City College of New York, MIT, Morgan State in Baltimore, Pennsylvania State, and the universities of Maryland and Washington. ECSEL is establishing a communications network for support and faculty exchanges and to make workshop reports and other publications available to all engineering schools. Another effort is an outreach program for industry and for K-12 and community college students. Coalition targets include teaching and learning innovations in the form of course modules and new delivery systems; recruiting and retaining prospective students, especially women and minorities; and aiding faculty development.

GIFT to Materials Research

Georgia high school teacher *B. Booth* Quimby helped advance semiconductor materials research in 1991, during her summer as an NSF-funded research assistant through GIFT—Georgia Industrial Fellowships for Teachers. GIFT is an industry-initiated and directed partnership involving corporations, research centers and teachers. Other partners are Georgia Tech and the American Association for the Advancement of Science; they are collaborating on a project called Initiatives in Science and Engineering Education.

GIFT began in 1990 in response to the prospect of diminishing science and technical talent in the United States. Program sponsors hope to combat declining student achievement in science and mathematics by improving the quality of precollege instruction. During the summer of 1991, eight teacher fellows, including B. Booth Quimby, helped Georgia Tech faculty with research through NSF's Research Opportunity Awards program.

GIFT: Georgia Industrial Fellowships for Teachers. Through this program to improve high school science instruction, B. Booth Quimby worked with university faculty to fabricate a device (shown here) for etching semiconductor components. She also produced a videotaped lab tour for students.

In research performed with *K.P. Martin* and *T.J. Drabik* of Georgia Tech and *C. Fan* of the University of California at San Diego, Quimby fabricated a "quantum effect" device for etching semiconductor components. She also developed a videotaped tour of a materials laboratory—including the clean room, microscopes, silicon chips and micromotors—to introduce high school students to the field of microelectronics.

Engineering Faculty Internships

A common criticism of U.S. education and research in the field of manufacturing is that many faculty have no practical experience in manufacturing organizations. In 1991, NSF developed the Engineering Faculty Internship Initiative to address this gap. The initiative supports up to half the total budget for a one-summer or one-semester internship with an industrial partner; proposals must include written commitments from industry partners to support the other half. The amount of NSF support depends on industry matching funds, up to $25,000 per grant. This initiative was launched as a pilot program in 1990, with 15 awards totaling $600,000 in NSF-industrial support. Some proposals not funded by NSF were supported by industry instead, thus expanding the initiative's impact.

Outreach to Disabled Students and Faculty

NSF has awarded the American Association for the Advancement of Science (AAAS) a five-year grant to address the needs of engineering students and faculty with disabilities. This project follows a 1990 report by the Foundation's Task Force on Persons with Disabilities.

Under this long-term project, engineering schools will develop recruitment and retention strategies, also identifying technologies and support services that give the disabled easier access to careers in science and engineering. Among the schools selected as sites for model projects:

- *The University of Wyoming,* where senior-year students in electrical engineering have worked to develop custom-designed electronic hardware for people with disabilities, to improve their quality of life. Projects have included a modified wheelchair controller, a remote dialing device, a heat alarm, an electric wheelchair diagnostic unit and an infrared data link between a client's remote controller and the device it operates.

- *Mississippi State University,* where undergraduates in biological engineering have designed and built such devices as a door opener to work with conventional doorknobs, a bookholder and page turner, a paint tube squeezer, an elevator button-assist device, an exercise bike for wheelchair-bound students and a space-heater controller.

- *Mercer University,* where freshmen and senior engineering students have designed a crawling device for children with cerebral palsy, an electronic self-feeding device, alternative and augmentive communication devices, mobility aids and other equipment.

Ocean wonderland. Design shows new Stephen Birch Aquarium-Museum at the Scripps Institution of Oceanography, San Diego. The museum will feature exhibits and simulated rides to the undersea world.

Scripps Institution of Oceanography

Hastings Star-Gazette

River researchers. High-school students from Hastings, Minnesota worked with students from 41 other communities along the Mississippi River, analyzing its waters. Some water samples showed high levels of pollution and led to identification of a creek as their source.

STIS—Reaching Out Electronically

In 1991, NSF began offering a computerized alternative to searching through volumes of printed material from the Foundation. The Science and Technology Information System (STIS) makes it possible to search quickly through scores of NSF publications, using words or terms that appear in the materials. Users can view the full text of a publication online or print it while on the system. Anyone with a personal computer and a modem, or with access to the Internet or BITNET computer networks, can use the system without charge. Access hours are unlimited and there is no need to register in advance or obtain a password.

STIS was developed by NSF as a prototype for electronic dissemination. Its database includes the NSF *Bulletin* (newsletter), the *Guide to Programs* (annual catalog), NSF program announcements, news about international science and technology, abstracts of many NSF awards and other documents and publications.

Science and Humanities Education

Three federal agencies joined in a 1991 effort to help colleges and universities develop undergraduate courses and curricula linking the sciences and the humanities. NSF, the National Endowment for the Humanities (NEH) and the Department of Education called for grant proposals that cut across traditional academic disciplines to give students a coherent, interrelated view of varied fields of human knowledge. Projects may include efforts to improve core curricula, create new majors or develop new, integrated course sequences or senior "capstone" courses. The three federal agencies hope these projects will become models for other colleges and universities.

Megaherbivores. Museum workers drape themselves in a soft sculpture representing a giraffe's digestive system. Others prepare a life-size model of a tree-grazing giraffe. NSF Informal Science Education funds were used for the exhibit.

Field Museum of Natural History

Informal Education

A simulated ride in a deep-sea submersible is one of the highlights of a new museum exhibition at the Scripps Institution of Oceanography. Funded in part by NSF, the exhibit will be in the new Stephen Birch Aquarium-Museum, being built on the Scripps campus at the University of California/San Diego.

The museum offers exhibits on ocean science, marine biology, global warming, and sea-floor plate tectonics. Visitors can view an exhibit on early oceanography, followed by a recreated below-deck laboratory of the historic *HMS Challenger*, used in the late 1800s as the first oceanographic research vessel. In a "Life in the Sea" exhibit, visitors can take a simulated ride in a deep-sea submersible and view the undersea world through observation ports showing a kelp forest, the La Jolla Canyon wall, the open ocean's sandy sea floor, and a deep-sea hot spring.

Star Date, a two-minute NSF-funded radio broadcast that takes 10 million listeners on a daily star trip, marked a milestone in February 1991 with the airing of its 5,000th episode. A production of the McDonald Observatory at the University of Texas/Austin, *Star Date* aired in June 1977 on Austin station KLBJ-FM as *Have You Seen the Stars Tonight?* The show was an expanded version of a telephone message service the observatory had offered for several months. With NSF's help, the show was syndicated nationally in 1978 under its current name.

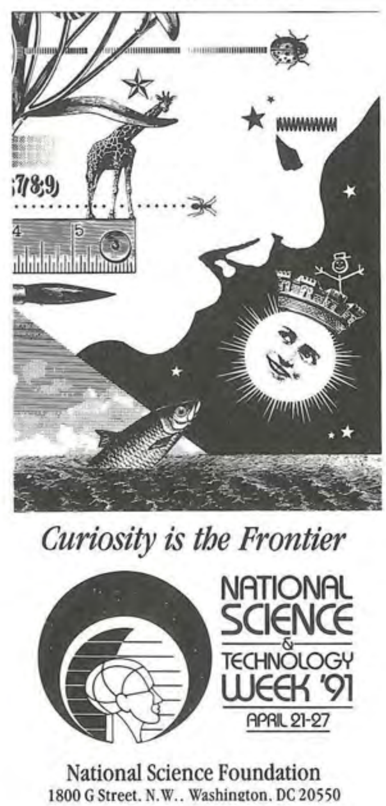
Mars mission. A would-be astronaut explores the surface of Mars in a simulated voyage that is part of an exhibit at the Center of Science and Industry in Columbus, Ohio.

Center of Science and Industry

SuperQuest finalists. This student team from J. Oliver Johnson HIgh School in Huntsville, Alabama, applied classroom knowledge to a supercomputer at the National Center for Supercomputing Applications, University of Illinois. Eleven high-school computing teams won the NSF-sponsored SuperQuest competition to attend expense-paid summer institutes at three research centers.

Science Week. Family Science Night at the National Air and Space Museum in Washington was part of several 1991 activities for National Science and Technology Week, held each year in April.

Special Week."Curiosity is the Frontier" was the theme for National Science and Technology Week 1991.



International News

Antarctic Research: Record Year

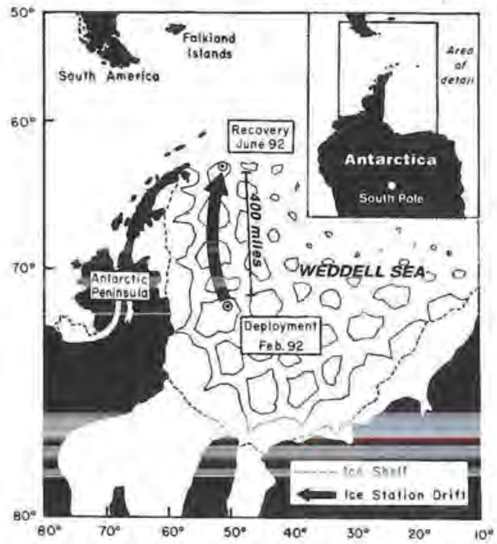
The NSF-managed U.S. Antarctic Program had its most ambitious field season in 1991, with a record 111 projects scheduled. Researchers were on land, sea and in the air, solving mysteries across many scientific disciplines. Natural phenomena under observation included unusual invertebrates, some of which produce substances that could lead to new drugs or other products; the rumblings of volcanic Mount Erebus; the formation and break-up of continents; the distant origins of cosmic rays; and the dynamics of the sun and the *aurora australis*—the southern lights. Success in Antarctic research depends on the efforts of scientists working in remote, barren field sites and on data gathered from sensitive instruments borne aloft on aircraft. Some highlights:

Ice Research: With 1991 funds from NSF, 10 U.S. scientists joined 10 researchers from the former Soviet Union in February 1992 on an Antarctic ice floe. There they drifted for months and studied how the ice cover affects ocean circulation and climate. The research team and a support staff of 12 camped on an ice floe 300 centimeters thick, 1.6 kilometers long and .8 kilometers wide; they drifted some 640 kilometers over a four-to-five month period.

This was the first manned station ever established on floating ice of the Southern Ocean. The scientists disembarked from the *Akademik Fedorov*, an icebreaking research ship, 2,080 kilometers south of the tip of South America. There, on the frozen surface of the western Weddell Sea, they set up camp and an airstrip. After drifting northward several kilometers per day on the moving ice floe, they were evacuated in the summer of 1992, before the camp reached the open ocean or the floe began to melt.

Helicopters, icebreaking research ships and satellites aided the researchers as they conducted experiments on the ice floe and gathered extensive data on the complex and poorly understood interactions of air, ice and ocean in the ice-riddled Weddell Sea. The delicate balance of this system affects global climate and ocean currents. The poles are the only regions on Earth where water becomes cold enough and dense enough to sink. During this process, large quantities of heat, carbon dioxide and other gases are exchanged with a huge deep-water reservoir. But unlike areas to the east, where ice melts in summer and remains thin even during winter, the western Weddell is covered all year by ice and has never been surveyed from research ships.

Columbia University



Floating lab. Map shows projected path of pioneer ice-floe lab carrying scientists investigating ocean circulation and climate in Antarctica.

A chief goal was to discover rates of heat exchange between the atmosphere and ocean, the intervening role of the sea-ice cover, and the nature of ocean circulation beneath the ice.

Antarctic Environmental Efforts: In 1991 NSF suspended the practice of open burning at McMurdo Station and ceased operating the landfill there. The one-acre landfill adjacent to the scientific base existed for more than 30 years. It was built to dispose of solid and liquid waste generated from construction and other materials deposited in an era when environmental knowledge, sensitivity and concerns were not as great as they are today. NSF is in the midst of a five-year Safety, Environ-

When moving forward toward the discovery of the unknown, the scientist is like a traveler who reaches higher and higher summits, from which he sees in the distance new countries to explore.

—Louis Pasteur

ment and Health Initiative designed in part to clean up debris from past operations and enhance protection of the Antarctic environment. The Foundation first built a temporary incinerator, then in October 1991 installed a more efficient three-chambered commercial device. The state-of-the-art incinerator burns nonhazardous materials, waste food and food-contaminated waste.

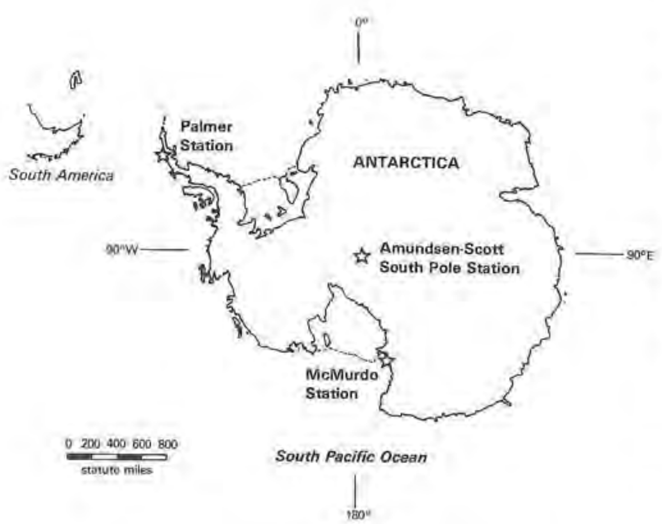
U.S. Department of Agriculture regulations prevent waste food and food-contaminated wastes (such as napkins and paper plates) from entering the United States without prior sterilization. Thus these materials are burned at 1600 degrees F to preclude human health hazards; incinerator ashes are then removed from the continent. Plastics, metals, rubber tires and hazardous materials (batteries, solvents and waste oil) are recycled or segregated from the waste stream and removed from Antarctica.

Exploring the Antarctic Marine Ecosystem: NSF awarded a six-year grant in 1991 to begin new studies on how populations of Antarctic organisms are influenced by seasonal and year-to-year variability in the harsh polar physical environment. This new Long-Term Ecological Research site could act as an early warning system for changes in Antarctic ozone, temperature, Southern Ocean Water circulation and sea ice cover.

Field studies began in October 1991, led by researchers from the University of California at Santa Barbara and Old Dominion University in Norfolk, Va. The scientists are gathering data and developing computer models to describe ecosystem dynamics. The models will relate changes in the food chain, or food web (the term ecologists prefer) to physical factors, including sea ice cover, ocean circulation and meteorology.

NSF launched the Long-Term Ecological Research program in 1980 to help scientists learn more about ecosystems and their dynamics over time. These studies could help researchers distinguish among rare events, cyclical ecological processes and long-term environmental trends. The Antarctic location is the first of 18 active research sites established outside U.S. territory. Work is centered near Palmer Station just off the western Antarctic Peninsula, one of three U.S. Antarctic research stations managed by NSF (see box). Studies involve established field sites at and near penguin colonies, along with regional cruises in the Southern Ocean. Satellite imaging provides data on the extent and thickness of sea ice and on ocean surface temperatures, while weather stations gather meteorological data.

The Next Frontier: The remote and barren Antarctic continent could serve as a testbed for technologies and systems to support human life beyond Earth, thanks to an agreement signed in January 1991 by NASA and NSF. The interagency program, called the Antarctic Space Analog, builds on NSF's polar experience and paves the way for the Bush Administration's Space Exploration Initiative, aimed at establishing a permanent presence on the moon and sending humans to Mars. Under the Analog program, NSF and NASA are pursuing research and technology demonstrations in life support



Antarctic activity bases. Researchers study Antarctic environment at these major stations.

Antarctic Station Report

McMurdo Station:

Operating from a sea-ice runway on Antarctica's frozen McMurdo Sound, aircraft from six nations supported science in the Transantarctic Mountains and west Antarctica, marking the growing coordination among countries involved in research on the continent. The airfield is associated with McMurdo Station, the largest research operation managed by NSF as part of the U.S. Antarctic Program. The airfield hosted planes from the United States, the then Soviet Union, Germany, Italy, New Zealand and Canada. The flights delivered equipment and scientists, dispatching them to study sites for the short Antarctic summer season, which ends in February.

McMurdo, with a peak population of 1,100 during the austral summer, normally is visited by U.S. Antarctic Program planes and those of one or two other nations. Just 830 miles from the South Pole, the station is well placed for high-latitude research. It has the world's southernmost port for receiving ship-borne cargo and fuel for planes.

New facility. This science and engineering facility at McMurdo Station includes (in center from right to left) main lab, geoscience lab, and seawater aquarium. Administration and dormitory facilities are in background and foreground.

In 1991, a 28-million-cubic-foot balloon was launched near McMurdo for a three-week South Polar circumnavigation. It carried astrophysics experiments aloft and was part of a joint NASA-NSF effort.

Amundsen-Scott Station:

October stratospheric ozone levels over Antarctica have been declining for at least 10 years. In 1991 ozone levels were more highly depleted than in other years, just as they were in 1987 and 1989. Ozone monitoring continues at all three U.S. stations, including Amundsen-Scott South Pole Station, also a site for studying greenhouse gas and other atmospheric chemistry.

The South Pole is an exceptional site for researchers conducting astronomy and astrophysics experiments because it is high, dry and provides nearly constant viewing angles. Amundsen-Scott Station also is an ideal spot to study variations of the sun, which can be observed for extended periods.

During the 1990-1991 season, solar observers attempted to make nearly continuous images of the sun for three months. The images should allow unprecedented determinations of solar vibrations, which provide information about the sun's internal structure. These helioseismologic studies already have improved our understanding of the sun.

Historic site. Across the bay from pioneer explorer Robert F. Scott's hut (dating from 1902 expedition) is McMurdo's new Albert P. Crary Center. Installation's air strip is behind hut point.

Palmer Station:

Biological research was a major thrust at Palmer Station, on a small island off the Antarctic Peninsula. Biologists studied the area's marine ecosystem, focusing on seals, penguins, seabirds, fish, marine worms and other invertebrates and microbes. A research cruise in the waters off Palmer aimed to determine the impact of the ozone hole on the continent's marine ecosystem. Researchers used a new underwater spectrophotometer to obtain data on ultraviolet (UV) levels from Antarctic waters. The scientists measured visible and UV light at many depths to study how water circulates and transports plankton. They also examined photosynthesis, biomass pigment production and genetic damage to several species.

and environmental control systems, energy generation and storage subsystems, automation and robotics, telescience, and human behavior and performance research.

Scientists believe Antarctica's climate, terrain and isolation provide an Earth environment that most closely parallels conditions of isolation and stress to be faced on long-duration human missions in space. The program enables NASA to do scientific research and demonstrate new technology while tapping NSF's 35 years of experience in the harsh Antarctic environment.

Arctic Research

Arctic System Science: The U.S. Global Change Research Program is both a major thrust in the geosciences and a good example of interdisciplinary cooperation. As part of its contribution to this broad initiative, the Foundation launched a program called Arctic System Science, or ARCSS. Efforts to document and understand global change focus special attention on sensitive regions of the globe, such as the Arctic, where anticipated changes will be great and where changing processes could have global consequences. ARCSS is an interdisciplinary, "system science" effort; through it, scientists seek to understand the physical, geological, chemical, biological and social processes of the arctic system that interact with the total Earth system. Researchers also hope to advance a scientific basis for (1) predicting environmental change on a decade-to-centuries time scale, and (2) formulating responses to the effects of changing climate on humans.

ARCSS is seen as a 10-year effort. Its three components are:

Paleoenvironmental Studies. This effort is made up of two initiatives—GISP2, the second Greenland Ice Sheet Project (see box), and Paleoclimates of Arctic Lakes and Estuaries (PALE), underway since 1988.

*Ocean/Atmosphere/Ice Interactions.*This component, implemented in 1991 and due to be expanded as funds become available, addresses such priority areas as Arctic Ocean circulation, atmospheric radiation and clouds, the Arctic Basin's hydrologic cycle and paleoceanography in the region.

Land/Atmosphere/Ice Interactions. Research areas identified for initial emphasis (beginning in fiscal 1992) include changes in biotic communities, how these will affect Arctic and global systems, and the interaction of those changes with human activities.

ARCUS: In the mid-1980s, evidence of sensitivity and change in the higher latitudes led to several proposals from the U.S. Arctic Research Commission and the Polar Research Board (National Academy of Sciences) for more emphasis on scientific research in the Arctic. Other proposals included the NASA Global Tropospheric Experiment to study atmosphere-biosphere interactions in the uppermost regions of North America; a call for an Arctic component of the International Geosphere-Biosphere Programme developed by the Royal Society of Canada; and new elements of Arctic research proposed in NSF's Long—Term Ecological Research and Global Change programs.

As part of its contribution to the U.S. Global Change Research Program, NSF started a program called Arctic System Science (described above). Its goals—to understand the many Arctic system processes and to advance a scientific basis for predicting environmental change—were determined by the Arctic research community through the Arctic Research Consortium of the United States (ARCUS), inaugurated in October 1988.

Today, ARCUS has 21 voting-member institutions from 17 states, and four non-voting international affiliates. Its long-term goals are to produce identifiable improvements in U.S. Arctic science; build research communities of scientists and scholars in the United States; and open avenues for interdisciplinary approaches and new techniques. In the near term, the consortium has been focusing on the Arctic's role in global change and requirements for a national education program on the region.

What we know is a drop.

What we don't know is an ocean.

—Isaac Newton

Bruce Koci

Arctic science. Researchers examining ice core from Quelccaya Ice Cap, Peru.

Greenhouse Gas Studies

In greenhouse gas studies, carbon is the coin of the realm. Increases in atmospheric carbon dioxide measured in recent decades do not match increased emissions caused by the burning of fuel and forests, leaving scientists struggling to account for the difference. Now it appears that more carbon ends up as biomass in tiny ocean plants than previously thought. This finding comes from the first international field study to examine the fate of carbon and other nutrients in the ocean.

The ocean biomass reservoir acts as a buffer that offers a control on atmospheric carbon dioxide. Scientists know that much of the missing CO_2 ends up in ocean waters through a simple chemical reaction. Now, as part of a long-term international effort called the Joint Global Ocean Flux Study, scientists are calculating for the first time the impact of ocean plant life perturbations on atmospheric CO_2.

The Flux Study targets processes that control the movement of biologically important chemicals in the ocean and the way this chemical cycling interacts with the global atmoshere. Records of the ancient past, obtained from cores drilled in polar ice, show that changes in certain chemicals—CO_2, for example—occurred during ice ages and may have caused more extreme climate conditions then.

Biodiversity Studies

NSF-AID Projects: In 1991, NSF and the U.S. Agency for International Development (AID) jointly supported 14 biodiversity projects around the globe. The agencies teamed to sponsor research that will expand knowledge of potential threats to ecosystems and species in developing countries, which harbor much of the world's wealth of

For Global Change Researchers, Ice is Nice

Near the summit of the Greenland ice cap—667 kilometers north of the Arctic Circle—*Paul Mayewski* is scientific leader at a base camp housing 40 researchers, engineers, equipment operators, drillers, cooks, laborers and a physician. For the third year, he guided the most ambitious U.S. drilling effort ever undertaken to recover an ice core, an unbroken record of past climates. The drilling is part of the Greenland Ice Sheet Project Two (GISP2). When drilling is completed in 1992 or 1993, the continuous core should provide an archive of environmental history spanning 200,000 years or more.

Climate modelers have predicted that global temperatures will rise because of increasing atmospheric concentrations of greenhouse gases caused by fossil fuel burning and deforestation. However, these predictions need refining. The ice-core record will enable scientists to learn more about how natural phenomena interact over time to bring about climate changes; this knowledge should be useful in refining the models.

The U.S. team is using a new, specially designed drill and drilling fluid. The 13.2-centimeter core sections—the largest ever extracted from deep ice—provide more ice for analysis than did previous equipment. This special equipment also ensures the purity of samples drawn from the core's center. Purity is especially important because the concentrations of chemical markers are so low that a human touch or exhalation could contaminate the sample.

NSF coordinates the U.S. GISP2 effort with the European Science Foundation. The European scientists are coring ice from the summit of the Greenland Ice Sheet, while U.S. researchers are drilling 32 kilometers away. Having data from two ice cores will allow scientists to check and reinforce their findings. And the two cores considered together should reveal how physical properties of the Greenland Ice Sheet have changed over time.

biodiversity. The projects will help strengthen biodiversity research and education in these countries, and will foster productive working relationships between U.S. and foreign scientists.

With these awards, U.S. researchers led studies in 1991 in Argentina, Bolivia, Brazil, Chile, Costa Rica, the Dominican Republic, Ecuador, Gabon, Madagascar, Panama and Venezuela. Projects included studies of ecosystems, individual species and land-use impacts.

For example, anthropologist *Emilio Moran* at Indiana University in Bloomington has studied Amazon deforestation and carbon cycling in Brazil. In collaboration with Brazilian agencies and graduate students, he and other researchers studied revegetation on deforested lands in the Amazon basin. The size of clearings, soil type, land-use patterns, and the presence of seed-dispersing animals all can influence reforestation rates. Through field studies and access to satellite imagery, Moran's team tracked changes in ground cover. The project focused on the ways native people affect reforestation near Belo Monte in the central Amazon Basin. For example, natives and peasants often plant fruit trees a few years after clearing the land, attracting bats and other organisms that reseed the deforested land with native species.

Sustainable Ecological Systems and Biological Diversity: Tropical rain forests are being degraded at an alarming rate, and our ability to restore these ecological systems depends on an understanding of ecologically sustainable communities. Work by *John Ewel* of the University of Florida, Gainesville, assesses the amount of biological diversity needed to sustain the complex processes and interactions of tropical rainforest communities. Ewel's work compares experimentally restored rainforest, communities with original rainforests, looking at key processes such as gas exchange, nutrient retention, soil protection and the ability of the forest tree community to resist pest outbreaks.

This study aims to identify the minimum amount of biological complexity of the rainforest tree species that uses the resources, while minimizing the risk that the community will collapse. The work is being done at La Selva Biological Station of the Organization for Tropical Studies in Costa Rica.

Biodiversity studies. Scientists and graduate students studied mammals and their parasites in Bolivia under several NSF grants. Animals native to the area include short-tailed opossum and llamas, shown here.

American Researchers in Japan

During 1991, 50 American science and engineering graduate students spent two months at Japan's science city, Tsukuba. They studied the language and pursued research in Japan's national labs, and—for the first time—in some leading corporate laboratories. The Summer Institute in Japan, sponsored by NSF and Japan's Science and Technology Agency, is an NSF effort to help balance the flow of science and technology between Japan and the United States.

The 1991 summer interns represented two dozen disciplines, ranging from engineering (21) and computer science (8) to the physical and geological sciences (13) and biological sciences (8). Their fields of research include biomedical engineering, entomology, marine chemistry, polymer science and technology management. The students come from 29 univer-

Intern in Japan. Shown here is one of several U.S. students who studied in Japan under a special NSF program.

sities and 19 states. Twelve of the interns are women; seven are from racial or ethnic minorities. They were hosted by 20 Japanese government laboratories and nine corporate laboratories.

In 1991, NSF also increased salary and travel support for U.S. researchers who wish to visit Japan for six months or more.

Science Achievement Assessments

Third International Mathematics and Science Study (TIMSS): Supported in part by NSF, this is expected to be the most important international survey of educational outcomes in the 1990s. TIMSS involves more than 40 countries and four age-grade levels of students: those ages 9 and 13, those in the last year of secondary education, and students in the last year of secondary education who are studying mathematics or science as an important part of an academic program.

Program goals include constructing parallel descriptions of the educational systems of participating countries and comparing curricula in mathematics and science. The TIMSS timeline extends from 1991 until the turn of the century. Data collection began through task forces set up for each student population; they collected and cataloged achievement items from international sources. Further data will be gathered in the 1993-94 school year, then in 1997-98. International reports of preliminary results will appear in 1995 and 1999.

International Assessment of Educational Progress: In 1991, with funding from NSF, 20 countries surveyed the mathematics and science performance of 13-year-old students; 14 nations also assessed 9-year-old students in the same subjects. The United States, Canada, France, Hungary, Ireland, Jordan, Korea, Scotland and Taiwan were among those involved. Some 175,000 children were assessed in March 1991.

In mathematics, achievement ranged considerably, from an average of 28 percent to 80 percent correct on a one-hour test that included 76 questions. There is evidence for the potential of each nation's population, as shown by the top 10 percent of students in each country. Data from the bottom 10 percent indicate that even the most successful countries have students who need help.

While students in most countries believed mathematics is equally important for boys and girls, in more than half the participating populations 13-year-old boys performed significantly better than girls did. In science—on a one-hour test that included 72 questions—achievement ranged from an average of 52 percent to 78 percent correct, with boys performing better than girls.

Network News

NSF-U.S. Sprint Agreement: NSF has entered into a five-year cooperative agreement with the U.S. Sprint Corporation to implement and manage international connections to NSFNET. The agreement calls for U.S. Sprint to provide and manage circuits, initially linking NSFNET to INRIA, operator of the French scientific and research networks, and to its Scandinavian equivalent, NORDUNet in Stockholm. (NORDUNet links the academic networks of Denmark, Finland, Iceland, Norway and Sweden.)

NSFNET, which connects more than 400 U.S. academic and research institutions, is a major component of the international network, Internet, which links several thousand networks and more than 350,000 host computers worldwide. Sprint international circuits will give NSFNET more cost-effective control of its overseas data communications and will handle growing traffic demand. As NSFNET's international connections manager, Sprint will operate a round-the-clock network operations center through Cornell, reporting to NSF on reliability and performance, "reachability" of nodes or access centers, hardware outages and traffic patterns.

New Model for Eastern Europe

Poland, Hungary and Czechoslovakia (now the Czech and Slovak Federated Republic, or CSFR) have embraced *peer review* as the chosen instrument of reform for their research communities. As each entity moves away from centrally controlled block funding, peer review has come to mean much more than the technical critique of proposals by qualified experts. Rather, it is a way to introduce a more open, competitive system of resource distribution across broad national research and development sectors. By integrating peer review principles into new national systems for research funding, the three political entities hope to develop merit-based decision-making that stimulates innovative thinking and rewards the best applicants. This will help channel limited resources to the healthiest elements of research communities.

Since resource limits and other problems are known to Western countries having more experience with peer review and various competitive models, NSF has responded to requests for advice from Poland, Hungary and CSFR. Timely assistance has helped them avoid costly mistakes as they formulate new science and technology policies.

One thing I have learned in a long life: that all our science, measured against reality, is primitive and childlike— and yet it is the most precious thing we have.

—Albert Einstein

Instrumentation and Facilities

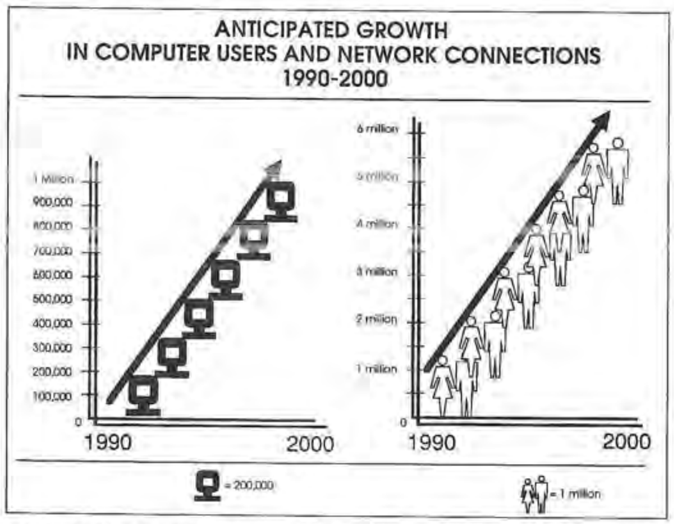
Computers and Supercomputers

NREN Data Superhighway: The National Research and Education Network (NREN) is a national high-speed computer *network of networks* that ultimately will provide computer access to millions of people in research and educational institutions. NREN dramatically expands and enhances the U.S. portion of an existing worldwide infrastructure of interconnected computer networks called Internet, which already links three million researchers, educators and others around the world. A substantial fraction of the domestic Internet is supported by Federal agencies, principally the Defense Advanced Research Projects Agency (DARPA), the Department of Energy, NASA and NSF.

A recent research agenda—the Federal High Performance Computing and Communications program—aims to extend U.S. leadership in high performance computing and computer network technologies. To satisfy this program's goals, NREN must do more than provide network access to research and educational institutions at all levels and locations—it must also deliver new capabilities. Some of these, such as distance learning, may initially be extensions of current technology. The new technology is needed to support access to digital libraries, to perform computationally intensive applications that turn modeling and simulation results into pictures, and to control experiments and simulations remotely.

NREN's developers seek to connect the nation's educational infrastructure to its knowledge and information centers. In this system, elementary schools, high schools, two and four year colleges and universities will be linked with researchers and laboratories, so all can share access to libraries, databases and such diverse scientific instruments as supercomputers, telescopes and particle accelerators.

Merit Network,. Inc.



Network of networks. The anticipation of explosive growth in computer network connections and users underlies creation of the National Research and Education Network.

NSF has been coordinating early NREN activities by upgrading the NSFNET backbone, helping regional networks upgrade their facilities and capacities, and connecting the backbone networks of other agencies. A major activity of the interim NREN: developing and deploying safeguards to enhance security and control over access to the connected computer systems and the individual network components.

NSFNET: NSF's new "T3" network was completed in 1991, increasing capacity for the more than 4,400 university, industry and government research networks linked by NSFNET. T3 operates at 30 times the speed of the original network infrastructure (called T1). It also supports a Fiber Distributed Data Interface (FDDI) to regional sites, with which T3 exchanges information. The FDDI is a specification for an optical-fiber local area network that operates at high speed—100 megabits per second.

Increased T3 capacity also was extended to eight T3 network nodes ("gateway" computers connecting to a local area network); these nodes are now operational at all 13 sites of the original T1 network—Ithaca, N.Y.; College Park, Md.; Pittsburgh, Penn.; Ann Arbor, Mich.; Urbana-Champaign, Ill.; Princeton, N.J.; Houston, Texas; Lincoln, Neb.; Boulder, Colo.; Salt Lake City, Utah; San Diego and Palo Alto, Calif.; and Seattle, Wash. Three new sites are operational in Cambridge, Mass.; Atlanta, Ga.; and Argonne, Ill. When all T3 installations have been tested, the T1 network will be dismantled.

The NSFNET partnership includes NSF, the state of Michigan and four companies: Merit Network Inc., Advanced Network & Services (ANS), IBM and MCI.

NCAR's New Cray: A new supercomputer, one of the few systems in the world devoted solely to climate-modeling research, began operation at the NSF-funded National Center for Atmospheric Research (NCAR) in Boulder, Colo. The two-processor Cray Y-MP will boost the capability of NCAR's eight-processor Cray Y-MP supercomputer in analyzing climate research experiments from around the world.

Mathematical and statistical models are the primary tool for investigating possible future climate variations caused by both human activities and natural events, including changing land-use practices, deforestation, greenhouse gas emissions, and volcanic eruptions. Such models generate huge amounts of data and require calculations that can be made only in a supercomputer laboratory. For example, climate models examine geographic areas in 500-kilometer or smaller grid areas, often requiring three months or more of supercomputer time to simulate 100 years of the Earth's climate. In contrast, it takes about five hours of Cray Y-MP time to produce an accurate 10-day forecast.

Among the NCAR projects the Cray will assist are efforts to predict weather in space and to understand rainfall development in the tropics.

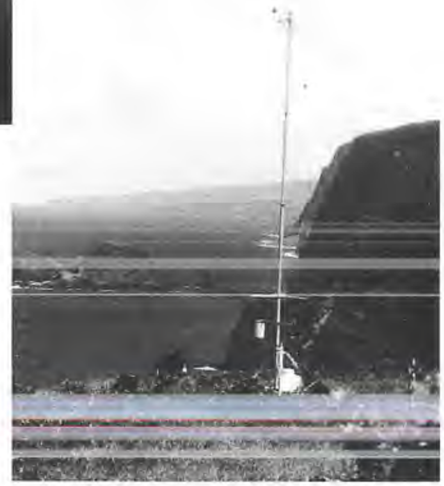
Understanding Rainfall in the Tropics: The Hawaiian Rainband Project (HaRP) gathered data on the development of warm-weather rain over Hilo, Hawaii in July and August 1990. More than 75 NCAR staff, researchers from universities and scientific institutions in five nations, and dozens of instruments were stationed near Hilo for this project. HaRP insights into the formation and depletion of Hawaiian rainbands—elongated shower clusters without thunder or lightning—are helping to illuminate theories of rainfall development throughout the tropics and the world's temperate regions near coastlines.

Mathematical, statistical and computational models run on NCAR's Cray supercomputers played a significant role in HaRP. Researchers consulted computer models during each step of planning, from deciding where to place instruments to choosing the best time of day for data-gathering flights. Models also con-

NCAR

Global data cruncher. A new Cray supercomputer at the National Center for Atmospheric Research will be used to analyze scenarios for future climate variations.

Hawaiian rainbands. Clusters of heavy rain, seen here from the ground, are analyzed with the help of computers, providing data on tropical and warm-climate coastal rainfall. Data-gathering tools include tethersonde (left) and solar-powered portable stations (right), which use satellite relays.



NASA, NCAR, D. Dempsey/San Francisco State Univ.

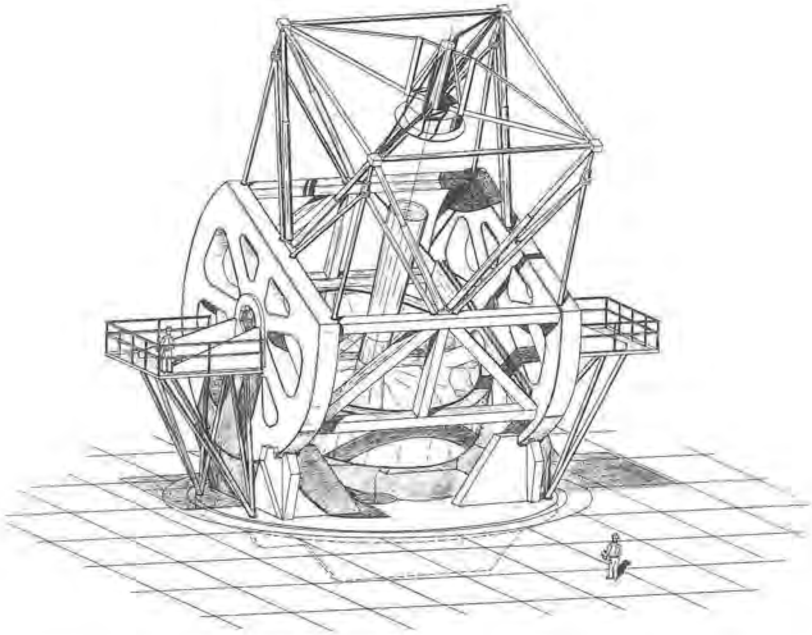
tributed to daily decisions in the field. Internet—the U.S. portion (funded in part by NSF) of a worldwide infrastructure of interconnected computer networks—connected the University of Hawaii's Hilo campus to NCAR headquarters in Boulder; there precipitation models were run on the Cray Y-MP using HaRP data. Results were relayed in minutes to Hilo, where researchers used the real-time data to deploy data-collection instruments and aircraft.

Five years before HaRP, NCAR scientists explored the microphysics of Hawaiian rainband formation as part of the Joint Hawaii Warm Rain Project. With those results, computer modelers produced a set of hypotheses on rainband origin and structure that were field-tested by HaRP in 1990. HaRP was one of the largest field experiments ever to compare a large-scale atmospheric process with computer models.

The Hawaiian site was chosen because almost every summer—as air flows down mountainous terrain and encounters opposing trade winds offshore, rainbands form off the east coast of Hawaii's largest island. As they sweep toward the island, these bands can produce heavy rain, but researchers are more interested in the regularity with which they form. Isolated in the mid-Pacific from other influences, Hawaii provides a giant natural laboratory for cloud physics and dynamics research. Over Hawaii, rain forms and falls as water; over much of the rest of the world rain forms as ice or snow and melts as it falls. HaRP research will help scientists separate the effects of water droplets from the effects of ice crystals, furthering the study of lightning and other phenomena tied to ice formation.

Telescopes and Other Instrumentation

Gemini International 8-Meter Telescopes: The United Kingdom and Canada have agreed to join the United States in funding a pair of 8-meter ground-based telescopes. These will be located in the northern and southern hemispheres. The U.K. Science and Engineering Research Council and the National Research



Future giant. This Gemini eight-meter telescope, yet to be built, is expected to be the world's best for ground viewing in the late 1990's.

Council of Canada voted to collaborate with NSF in building two advanced-technology telescopes, each 8 meters (26 feet) in diameter. One will be built on Mauna Kea, a volcano in Hawaii; construction begins in 1992 and is scheduled for completion in 1998. The other—on Cerro Pachon, a peak in the Chilean Andes—will be completed in the year 2000.

To ensure full coverage of the entire sky, telescopes are required in both hemispheres. For example, the 1987 supernova was observed from NSF's 4-meter telescope at La Sereña, Chile, and is not visible in the northern hemisphere. Studies of the universe's structure and evolution also require full-sky coverage.

South Pole Telescope Complex: Funding has been authorized to establish the Center for Astrophysical Research in Antarctica, which will explore the South Pole's advantages as a site for infrared and submillimeter astronomy.

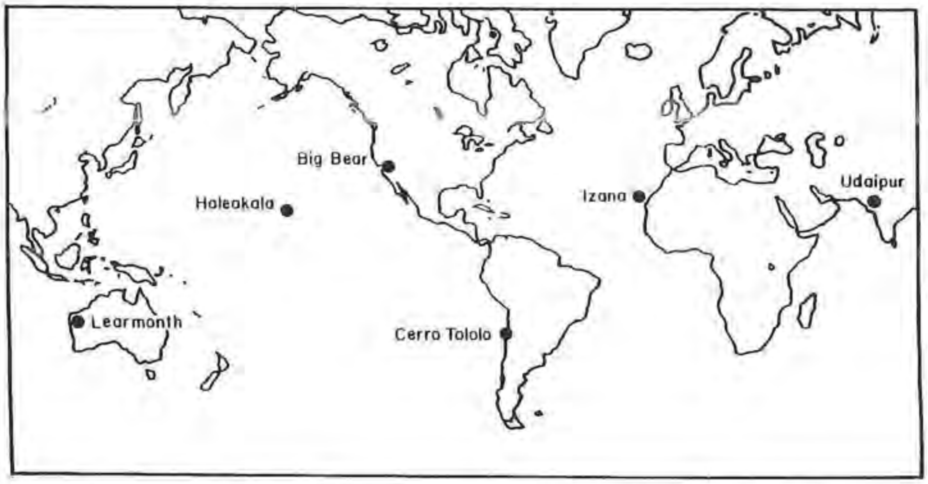
NSF partners in the project include the University of Chicago's Yerkes Observatory, with collaborators at Princeton University, AT&T Bell Laboratories, Rockwell International Corp., Boston University, Haverford College, the University of Illinois, George Williams College, the University of Colorado, the Smithsonian Astrophysical Observatory and Adler Planetarium.

Three initial Center experiments, covering a spectral range from 2 to 3,000 microns, will observe primeval galaxies, investigate the processes by which stars form from interstellar gas, and measure lack of homogeneity in the distribution of matter and energy in the early universe. In a fourth effort, the Advanced Telescope Project, Center researchers and a group of astronomers from other U.S. and foreign institutions will develop plans for a more powerful telescope that could be built in the second half of the 1990s.

The Global Oscillation Network Group: We now know that the surface of the Sun shows oscillations, similar to those seen in other stars. Studies of these oscillations will enable astronomers to determine physical conditions in the Sun's interior. Six observatory sites make up NSF's Global Oscillation Network Group (GONG), whose goal is to obtain the best and most continuous data on these internal vibrations. A prototype instrument, a Fourier tachometer developed for this application, has been tested at Arizona's National Solar Observatory in Tucson. The network will begin collecting data in 1994 and operate for at least three years. The instruments will be as electrically, mechanically and optically identical as possible.

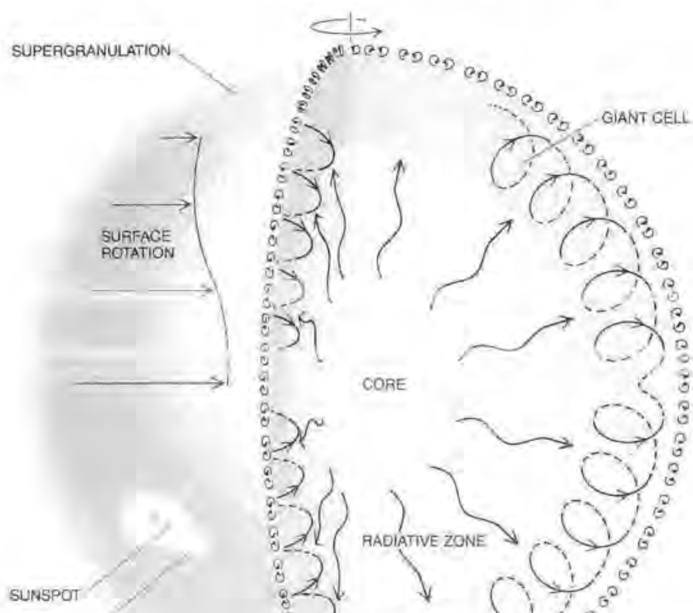
GONG sites are located so that three always are in daylight, and at low latitudes where seasonal variation in hours of daylight is not as great. Project scientists expect to be able to collect data 93 percent of the time. Their findings may help to refine ideas about particle physics and the age of the universe.

LIGO: Probing the Universe: Gravitational waves generate ripples in the fabric of space-time, as predicted by Einstein's theory of gravitation. They are produced by accelerations of bulk matter, or by oscillations of strong gravitational fields, and are expected to distort space as they pass. Gravitational waves can be detected by measuring the small oscillations they produce between sep-



Measuring solar vibrations. Sites in the Global Oscillation Network Group (GONG), which monitors internal solar vibrations, are Caltech's Big Bear Observatory; the University of Hawaii's Mees Solar Observatory (Haleakala); Australia's Learmouth Solar Observatory; India's Udaipur Solar Observatory; Instituto de Astrofisica de Canarias El Tiede Observatory (Izaña, Canary Islands, Spain), and the Cerro Tololo Inter-American Observatory in Chile.

Understanding our star. "GONG" models propose that nuclear energy radiating from the sun's core is connected to oscillations on its surface.



National Optical Astronomy Observatories (NOAO)

arated masses, but doing so calls for instrumentation of unprecedented sensitivity.

The new measurement technology comes from 20 years of research and development in the United States and Europe. Scientific teams spent the past decade building prototypes to demonstrate the scientific feasibility of a laser interferometer system. In the United States, physicists and engineers at the California and Massachusetts Institutes of Technology—joined by physicists from the University of Colorado, and Stanford and Syracuse Universities—planned the construction of a new national research facility: the Laser Interferometer Gravitational Wave Observatory (LIGO). This facility will consist of two receivers, widely separated within the continental United States—each of them L-shaped, with 4-kilometer-long arms.

Locating the direction of astronomical sources of gravitational wave signals requires four geographically separate, technically compatible detectors. In Europe, collaborators in France, Germany, Italy and the United Kingdom are developing plans for LIGO-like facilities. Two European detectors are expected to be approved in 1992. This would provide the geographical dispersion needed for an international network to begin astronomical research in the next century, using gravitational waves as a probe of the entire universe.

Green Bank Telescope: A new NSF radio telescope at Green Bank, West Virginia, will be the world's largest fully steerable telescope. After the collapse of an aging 90-meter (300 foot) telescope at Green Bank in November 1988, NSF's National Radio Astronomy Observatory proposed to replace it with a state-of-the-art, fully steerable 100-meter telescope. In 1989 Congress appropriated $75 million for the project. Assembly and installation near the old instrument's location should be complete in 1994, with astronomical observations scheduled to begin in 1995. This will be the first large telescope with an unblocked aperture, a feature that eliminates much internal and local ground interference.

Studies of radio emissions permit astronomers to learn about astronomical objects and phenomena that cannot be well understood through optical astronomy alone. The Green Bank instrument will have a reflecting surface that can be adjusted to optimal shape during operation, using a computer to control the position of individual reflecting panels. The new instrument will contribute to astronomers' understanding of the timing and regularity of pulsars and the chemical content and evolution of young galaxies. The telescope also will be used to study radio emissions from the sun's surface and throughout its corona, providing observational data for testing theories of solar physics.

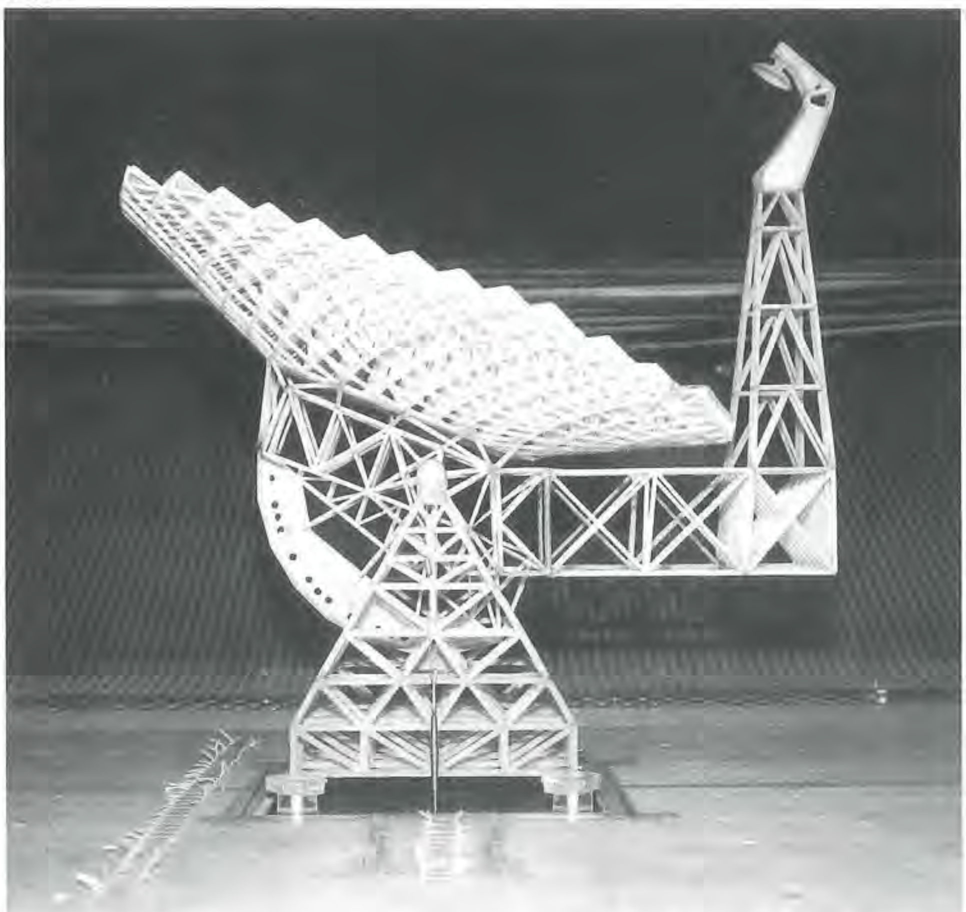
National Magnet Laboratory: A panel of scientific experts advised the National Science Board in 1991 to approve continued NSF support of the Francis Bitter National Magnet Laboratory through September 1995. At that time, the new magnetic field laboratory now being built with NSF funds is expected to become fully operational. The four-year, $23 million MIT award is helping to ensure that scientists who use powerful magnets in their research have access to this sophisticated technology. The Board's action also helps to maintain the U.S. position in high magnetic field technology.

The Bitter Lab was used in 1990 by nearly 400 scientists, engineers and students who conducted research in condensed matter physics, materials science and engineering, chemistry, biological sciences, and other disciplines. In addition to providing services to the user community, part of the MIT funding is earmarked to design, develop and build a 45-Tesla-class hybrid magnet. This magnet, achieved by combining superconducting and water-cooled magnets, would achieve a magnetic field 900,000 times the strength of the Earth's magnetic field.

The magnet project is a joint venture between the Bitter Lab and the new National High Magnetic Field Laboratory in Tallahassee, Fla. Funded by NSF and the state of Florida, the High Magnetic Field Lab is being established by Florida State University, the University of Florida and the Los Alamos National Laboratory in New Mexico.

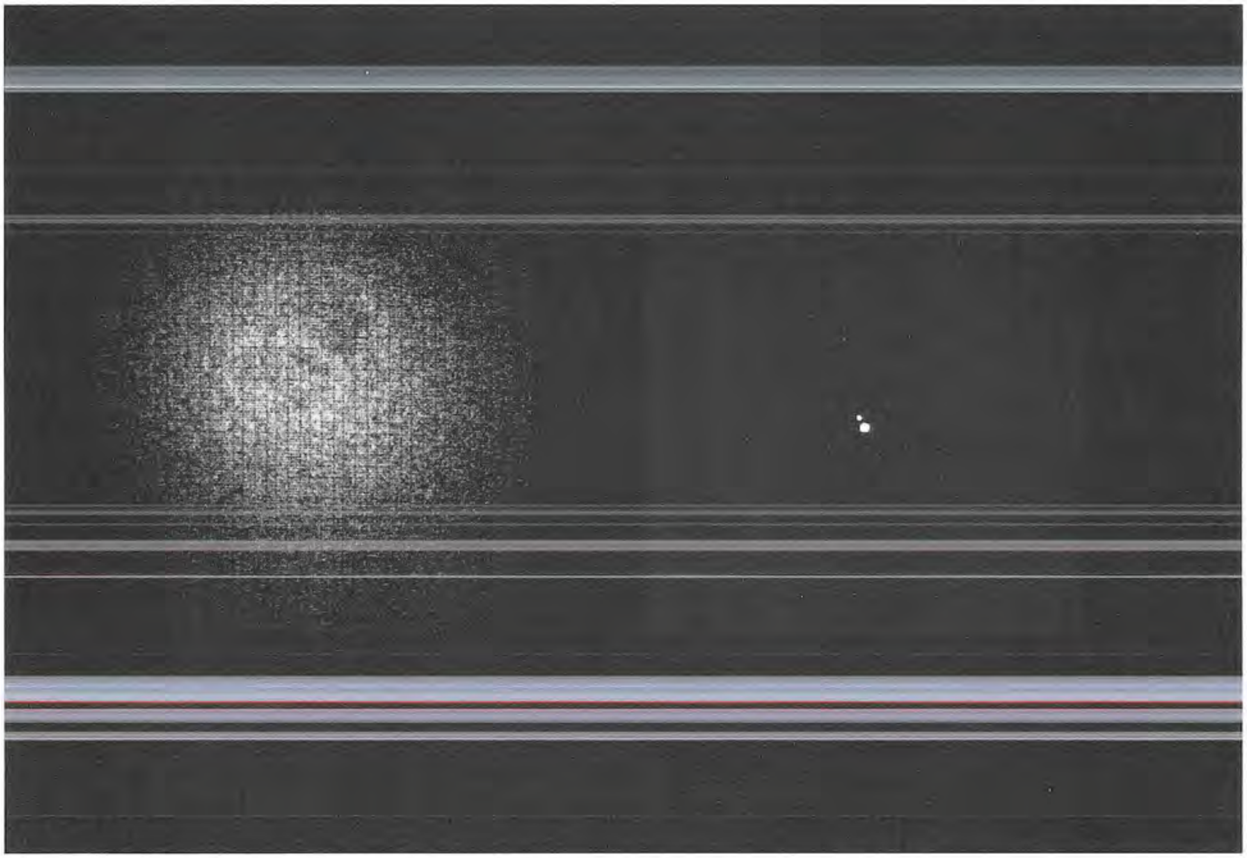
The hybrid magnet, to be completed by 1995, will provide the highest steady-state magnetic fields

NRAO



Starry listener. Model of a proposed new NSF instrument at Green Bank, West Virginia. It will be the world's largest fully steerable telescope.

T. Readhead, Palomar Observatory



Stellar clarification. These images of the star Sigma Hercules through our atmosphere and with image corrected for earth's atmospheric distortions show how a technique known as adaptive optics can aid astronomers.

Adaptive Optics from the Strategic Defense Initiative

Astronomers will be able to see stars and galaxies more clearly, a result of the declassification of *adaptive optics* technology and equipment developed through a research effort of the Strategic Defense Initiative Organization (SDIO). This equipment has been transferred to NSF.

Atmospheric turbulence, which causes the twinkling of stars, degrades the performance of ground-based telescopes. Adaptive optics employs "deformable" mirrors to remove the blurring effect and correct images of astronomical objects. This correction must be performed every few hundredths of a second. The technique was developed over the past decade through classified research under Defense Department (DoD) sponsorship.

In a March 1991 report, the National Research Council (NRC) suggested that adaptive optics should be the highest priority for the next decade among moderate-cost, ground-based astronomy projects because of its potentially huge impact on many branches of astronomy. With adaptive optics and the latest telescope mirrors and detectors, ground-based astronomers may be able to observe the evolution of other solar systems in the galaxy, and detect Jupiter-sized planets. Researchers will be able to refine their search for evidence of black holes—incredibly dense objects whose gravitational field is so strong that not even light can escape—and for quasars, stellar objects as bright as entire galaxies. With the new technology, it should prove easier to measure the distribution of stars in galaxies and of galaxies in the universe. Moreover, according to the NRC report, reducing background noise with adaptive optics could improve the limited sensitivity of ground-based telescopes by up to a factor of 50.

available, enabling scientists to make major discoveries in disciplines closely connected to competitive high-technology fields. For example, physicists and materials researchers will be better able to understand and develop high-temperature superconductors, semiconductor multilayer structures used for high performance computers, liquid crystals, novel magnetic materials and biomolecular materials.

Instrumentation and Laboratory Improvement (ILI): Future scientists and engineers, teachers, leaders in business and government and literate citizens need strong undergraduate instruction in science, mathematics and engineering. Laboratory or field experiences with suitable instruments are crucial elements of that instruction. The Foundation's ILI program supports the acquisition of those instruments for laboratory courses. "Laboratory" is defined as any setting where students actively participate in learning subject matter; the setting can be an observatory, the field, a computer room or a traditional laboratory.

ILI objectives include the use of modern instruments, equipment sharing via consortia or centers, and development of new experiments or applications that extend the instructional capabilities of equipment. Projects that will produce models for the future are especially valued. In 1991, awards included grants to:

- *LaRhee Henderson* at Iowa's Drake University—for both a program and instrumentation to teach biochemistry.
- *George MacRitchie* at Owens Technical College, an Ohio community college—for a state-of-the-art Metrology Data Center.
- *Kate Lajtha* at Boston University—for innovative laboratory exercises for students in an interdisciplinary environmental studies program.
- *James Beall* at St. John's College in Annapolis—for the purchase of a telescope to be installed in a permanently mounted dome on campus. A faculty study group has been developing manuals and collecting original papers to guide the use of astronomical telescopes in a liberal arts setting.

Academic Research Facilities

In 1991 NSF announced awards to 78 colleges, universities and nonprofit institutions for the repair and renovation of their science and engineering facilities. These funds are being combined with institutional, state and local government funds to provide more than $100 million in total support for projects in 37 states.

These were the first awards made under NSF's Academic Research Facilities Modernization Program, established by Congress as part of the Academic Research Facilities Modernization Act of 1988. Recipients include 26 baccalaureate and master's degree-granting institutions, three museums and one consortium.

Projects typically involve renovating laboratories and facilities; upgrading or replacing plumbing, heating, ventilation, air conditioning and electric power systems; and replacing fume hoods, laboratory benches and other equipment. Tennessee's Fisk University, for example, is upgrading a 60-year-old chemistry and physics building. Other grants are aiding renovation of Morgan State University's Baltimore Science Complex, MIT's water resources and environmental engineering lab, the University of Kentucky's chemistry and physics building and California's Point Reyes Bird Observatory.

Awards and Organizational News

Vannevar Bush Award

J*ames A. Van Allen*, an internationally known pioneer in space science research and education, received the National Science Board's (NSB) 1991 Vannevar Bush Award. Given periodically, this award acknowledges outstanding contributions in science and technology. Van Allen, Regent Distinguished Professor of Physics at the University of Iowa, received a medal struck for the occasion and a citation at the Board's annual dinner. The 24-member NSB is the Foundation's policymaking body.

Van Allen was recognized for a long, productive career in space science, including his discovery of the radiation belt around Earth that bears his name. The Board also cited his longtime advocacy of using satellites to explore the planets; his role as an advisor to the U.S. government on space science policy; and his contributions as an educator and mentor of young scientists. Van Allen has been an advisor on atmospheric and space exploration and science since 1946, using improvements in rocketry to expand research horizons. He also was a pioneer in cosmic ray and geophysical studies at high altitudes and over a range of latitudes.

In 1956, Van Allen made the proposal that led to his most famous discovery. After conducting productive cosmic ray experiments for several years with balloon-launched rockets, he suggested using a satellite to conduct such research as part of the 1957-58 International Geophysical Year. In January 1958, the NSF-funded Iowa Experiment rode into space aboard an Army rocket. The payload, dubbed *Explorer I*, was the first placed into orbit by the United States.

With the data collected, Van Allen demonstrated that Earth is surrounded by a massive, intense radiation belt. He called it "a huge region of space populated by energetic charged particles [principally photons and electrons]


Vannevar Bush awardee James A. Van Allen

trapped within the external geomagnetic field." Beginning with *Explorer I*, Van Allen was a scientific leader on 24 missions involving Earth and lunar satellites and planetary spacecraft. These include the continuing journeys of *Pioneer 10* and *Pioneer 11*, which are still returning data after passing beyond the planets and into the outskirts of the solar system.

Alan T. Waterman Award

H*erbert Edelsbrunner*, professor of computer science at the University of Illinois at Urbana-Champaign, received NSF's 1991 Alan T. Waterman Award. Given annually since 1976 to outstanding young researchers in science, mathematics or engineering, this award includes grants (up to $500,000) for up to three years of scientific research. Edelsbrunner, the 16th Waterman Award recipient, was chosen from among 97 nominees.

The selection committee recognized Edelsbrunner for his work in computational geometry, a field that links mathematics and computer science. In his research, Edelsbrunner combined geometry with algorithms—a finite series of pro- gramming steps needed to represent and manipulate geometric shapes and patterns. This has made it easier for computer programmers to write software for complex applications such as modeling airplane design, airflow and surface tension. Many consider his book, *Algorithms in Combinatorial Geometry*—published in 1987 before he reached age 30—the best textbook and reference in computational geometry.

Alan T. Waterman awardee Herbert Edelsbrunner

Distinguished Public Service Award

Lindy Boggs, a former U.S. Representative from Louisiana who advocated programs to support the education of women and minorities throughout nine terms in Congress, received the 1991 Distinguished Public Service Award from NSF. The award is given periodically to those who distinguish themselves through leadership, public service and dedication in support of U.S. science, engineering, and education in those fields.

Beginning in the 95th Congress (1977), Representative Boggs became a member of the House Appropriations Committee, serving on the subcommittee that has oversight of the NSF budget. In this capacity she became an advocate of the Foundation's research and education efforts. Representative Boggs was, for example, an early supporter of the agency's Experimental Program to Stimulate Competitive Research (EPSCoR), created to help research institutions in designated states overcome barriers to successful competition for federal research support.

Distinguished Public Service awardee Lindy Boggs

National Medals of Science and Technology

National Science Board member and current chairman *James J. Duderstadt*, president of the University of Michigan, was among 18 engineers and industrialists to receive the National Medal of Technology. President George Bush conferred these honors at a White House ceremony in September 1991. Duderstadt received his award for contributions to engineering education and efforts to bring women and minorities into the engineering profession.

At the same ceremony, President Bush also awarded the National Medal of Science to 20 scientists, including former NSF Director H. Guyford Stever.

New NSF Director

Walter E. Massey became Director of NSF in March 1991. He is the former Vice President at the University of Chicago for Research and for the Argonne National Laboratory. Earlier in his career, the new NSF Director was a physics professor at the University of Chicago; both associate and full professor of physics at Brown University (where he was also Dean of the College); and assistant professor of physics at the University of Illinois. His research in physics centered on the many-body theories of quantum liquids and solids.

Dr. Massey also has been a member of the President's Council of Advisors on Science and Technology, a former member of the National Science Board and President of the American Association for the Advancement of Science.

New Assistant Directors [1]

Joseph Bordogna, dean of the University of Pennsylvania School of Engineering and Applied Science during the past decade, became NSF's Assistant Director for Engineering in September 1991. In his new position, Bordogna is responsible for 23 programs representing eight major engineering research areas—among them electrical/communications, chemical/thermal, mechanical/structural, and design/manufacturing systems. Bordogna oversees the engineering portfolio of NSF-supported research, which totaled more than $237 million in fiscal 1991.

Joseph Bordogna

A. Nico Habermann, dean of Carnegie Mellon University's School of Computer Science since 1988, became Assistant Director for Computer and Information Science and Engineering (CISE) in October 1991. In this position, Habermann is responsible for 25 programs in six divisions, representing computer and computation research; information, robotics and intelligent systems; advanced scientific computing; microelectronic information processing systems; networking and communications research and infrastructure; and cross-disciplinary activities. Habermann oversees the CISE portfolio of NSF-supported research, which totaled $189.5 million in fiscal 1991.

A. Nico Habermann

NSB News: Science and Engineering Indicators

Science and technology are beginning to reflect the effects of extraordinary global, political and economic changes. In its 10th edition, the National Science Board's *Science and Engineering Indicators 1991* examined trends in research and development (R&D) expenditures, science and math education, and other areas. Highlights include:

Science and Engineering (S&E) Personnel: The S&E work force in the United States continued its long trend of growth through 1989 at an annual rate of about four percent. Expansion of science and engineering employment continued at a faster rate in the larger nonmanufacturing sector than in manufacturing.

During the 1990s, the number of S&E jobs in manufacturing increased by one-third to 993,000 in 1989, even though total manufacturing employment declined. In nonmanufacturing industries, S&E jobs increased even more rapidly—by nearly half—to a total of 920,000. By 1989, 5.1 percent of manufacturing jobs and 1.7 percent of nonmanufacturing jobs were in science and engineering.

[1] In FY1992, NSF established a new Directorate for Social, Behavioral and Economic Sciences and chose its first Assistant Director. She is Cora Bagley Marrett, professor of Sociology and Afro-American Studies at the University of Wisconsin since 1974. Programs under the new directorate were formerly in the Directorate for Biological, Behavioral, and Social Sciences (now called Biosciences), and in the now-disestablished Directorate for Scientific, Technological, and International Affairs. Marrett is responsible for four divisions representing social and economic science, behavioral and cognitive sciences, international cooperative scientific activities, and science resources studies.

Supply and demand indicators suggest that, during the 1990s, there will be relative stability in these labor markets, in which lower demographic growth will be matched by generally slower economic growth.

Public Perceptions of Science and Technology: As measured in NSF's biennial survey of public perceptions of science and technology, U.S. adults strongly support the scientific enterprise and federal support for basic research, even if it brings no immediate benefits. However, there is increased concern about the use of animals in research and about the quality of science and mathematics education in U.S. schools. The proportion that felt too little is being spent on education increased from 60 percent to 71 percent between 1985 and 1990.

Comparative data from the United States, Canada and the 12 European Community countries on public knowledge about science and technology show strikingly similar degrees of knowledge. These new data also indicate that Americans and Canadians view science and technology more positively than do Western Europeans.

Senior Foundation and Board Officials, Fiscal Year 1991

Walter E. Massey, NSF Director

Mary L. Good, Chairman, National Science Board

Frederick M. Bernthal, NSF Deputy Director

Thomas B. Day, Vice-Chairman, National Science Board

NSF Senior Staff and National Science Board Members (FY 1991)

NATIONAL SCIENCE FOUNDATION SENIOR STAFF

(as of September 30, 1991)*

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Deputy Director,
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 Infrastructure,
Nathaniel Pitts

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,
Joseph Bordogna

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, (Acting)
Kurt G. Sandved

Assistant Director for Administration,
Geoffrey M. Fenstermacher

** NSF was reorganized in the early part of fiscal 1992. That reorganization affected several of the offices listed above.*

NATIONAL SCIENCE BOARD

(as of September 30, 1991)

Terms Expire May 10, 1992

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Chapel Hill, NC

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W.T. Doherty-Welch Foundation Distinguished Professor of Chemistry and Director,
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JOHN C. HANCOCK,
Retired Executive Vice President,
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Consultant,
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JAMES L. POWELL,
Chief Executive Officer,
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Philadelphia, PA

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

(2 Vacancies as of 9-30-91)

Terms Expire May 10, 1994

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Pennsylvania State University,
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Rensselaer Polytechnic Institute,
Troy, NY

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

Member Ex Officio

WALTER E. MASSEY
(Chairman, Executive Committee),
Director,
National Science Foundation,
Washington, DC

Terms Expire May 10, 1996

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Chancellor Emeritus and Regents Professor,
Department of Entomology,
Texas A&M University,
College Station, TX

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

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

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Rowland Pettit Centennial Professor of Chemistry and Director,
Center for Fast Kinetics Research,
Department of Chemistry,
University of Texas,
Austin, TX

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Institute for Advanced Study,
Princeton, NJ

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Vice Chairman,
Coronado Communications Corporation,
Los Angeles, CA

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Vice President for Central Research and Development,
E. I. DuPont DeNemours & Co.,
Wilmington, DE

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

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

Patents and Financial Tables for Fiscal Year 1991

Patents and Inventions Resulting from NSF Support:

During fiscal year 1991, the Foundation received 218 invention disclosures. Allocations of rights to 124 of those inventions were made by September 30, 1991. These resulted in dedication to the public through publication in 29 cases, retention of principal patent rights by the grantee or inventor in 90 instances, and transfer to other Government agencies in 5 cases. Licenses were received by the Foundation in 42 patent applications filed by grantees and contractors who retained principal rights in their inventions.

Financial Tables:

table 1. biological sciences

	(DOLLARS IN MILLIONS) Number of Awards	Amount
Molecular and Cellular Biosciences	891	$ 76.74
Integrative Biology and Neuroscience	998	72.36
Environmental Biology	678	68.33
Biological Instrumentation and Resources	217	37.72
Total	2,784	$255.15

SOURCE: Fiscal Year 1993 Justification of Estimates of Appropriation to the Congress.

table 2. computer and information science and engineering

	(DOLLARS IN MILLIONS) Number of Awards	Amount
Computer and Computation Research	348	$ 31.32
Information, Robotics and Intelligent Systems	335	23.59
Microelectronic Information Processing Systems	206	18.53
Advanced Scientific Computing	69	66.51
Networking and Communications Research and Infrastructure	189	29.80
Cross-Disciplinary Activities	132	19.76
Total	1,279	$189.51

table 3. engineering

	(DOLLARS IN MILLIONS) Number of Awards	Amount
Biological and Critical Systems	471	$ 36.02
Chemical and Thermal Systems	484	32.98
Electrical and Communications Systems	481	31.85
Mechanical and Structural Systems	397	23.43
Design and Manufacturing Systems	302	20.54
Engineering Education and Centers	248	70.06
Industrial Innovation Interface	253	22.78
Total	2,636	$237.66

table 4. geosciences

	(DOLLARS IN MILLIONS)	
	Number of Awards	Amount
Atmospheric Sciences	679	$117.35
Earth Sciences	745	70.84
Ocean Sciences	931	164.63
Arctic Research Program	143	14.89
Total	2,498	$367.71

table 5. mathematical and physical sciences

	(DOLLARS IN MILLIONS)	
	Number of Awards	Amount
Mathematical Sciences	1,424	$ 73.15
Astronomical Sciences	358	99.60
Physics	668	130.05
Chemistry	1,240	104.71
Materials Research	998	134.14
Major Research Equipment	3	22.50
Subtotal	4,691	$564.15
Green Bank W. Va. Telescope	1	69.58
Total	4,692	$633.73

table 6. social, behavioral and economic sciences*

	(DOLLARS IN MILLIONS) Number of Awards	Amount
Social and Economic Science	590	$ 35.94
Behavioral and Cognitive Sciences	399	20.66
International Cooperative Scientific Activities	563	12.76
Science Resources Studies	140	9.86
Total	1,692	$79.22

**New directorate created late 1991*

table 7.education and human resources

	(DOLLARS IN MILLIONS) Number of Awards	Amount
Systemic Reform	12	$ 16.41
Elementary and Secondary Education	787	149.04
Undergraduate Education	832	52.36
Graduate Education and Research Development	244	43.99
Human Resource Development	67	34.56
Research, Evaluation and Dissemination	106	25.60
Total	2,048	$321.96

NOTE: This table displays NSF's proposed new organizational structure for the Education and Human Resources directorate, as reported in the FY 1993 Budget Justifications to the Congress.

table 8. united states antarctic program

(DOLLARS IN MILLIONS)

	Number of Awards	Amount
U.S. Antarctic Research Activities	249	$100.12
U.S. Antarctic Logistics Support	6	74.95
Total	255	$175.07

table 9. academic research facilities and instrumentation

(DOLLARS IN MILLIONS)

	Number of Awards	Amount
Research Facilities Modernization	78	$ 39.02
Total	78	$ 39.02

table 10. experimental program to stimulate competitive research

	(DOLLARS IN MILLIONS)	
	Number of Awards	Amount
Experimental Program to Stimulate Competitive Research (EPSCoR)	45	$ 9.95
Total	45	$ 9.95

NOTE: FY 1991 and FY 1992: EPSCoR funded from the Research and Related Activities appropriation. In FY 1993 EPSCoR will be funded through the Education and Human Resources activity.

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Principal Writer: Cheryl Pellerin, *Editorial Experts, Inc.*

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