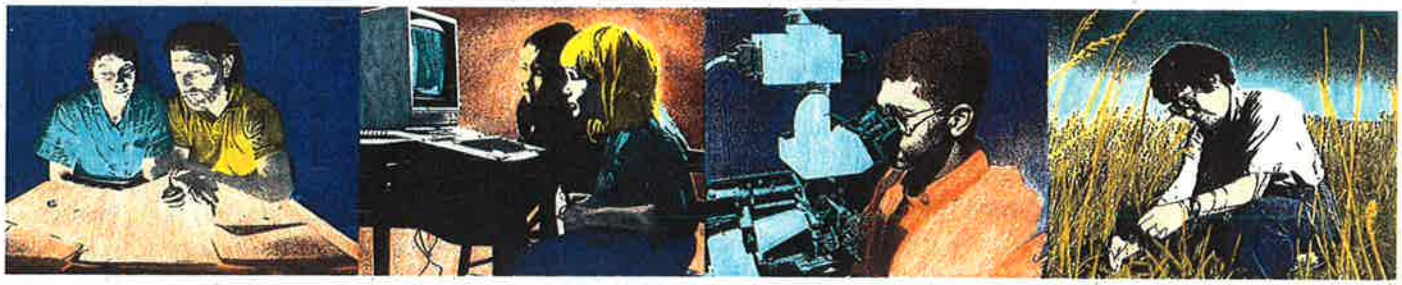
ANNUAL REPORT 1989

NATIONAL SCIENCE FOUNDATION



"Bear in mind that the wonderful things that you learn in your schools are the work of many generations. . . .

All this is put into your hands as your inheritance in order that you may receive it, honor it, add to it, and one day faithfully hand it on to your children."

Albert Einstein

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). It's 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.

NSF receives more than 37,000 proposals each year for research, graduate and postdoctoral fellowships, and math/science/engineering education projects: it makes more than 17,000 awards. These typically go to universities, colleges, academic consortia, nonprofit institutions, and small businesses. The agency operates no laboratories itself but does support National Research Centers, certain oceanographic vessels, and antarctic research stations. The Foundation also supports cooperative research between universities and industry and U.S. participation in international scientific efforts.

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

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

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

* * * *

NSF welcomes proposals on behalf of all qualified scientists and engineers and strongly encourages women, minorities, and persons with disabilities to compete fully in its programs.

In accordance with federal statutes and regulations and NSF policies, no person on grounds of race, color, age, sex, national origin, or disability shall be excluded from participation in, denied the benefits of, or be subject to discrimination under any program or activity receiving financial assistance from the National Science Foundation.

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

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

National Science Foundation (U.S.)

Annual Report,

1989

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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 1989 of the National Science Foundation, for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

Erich Bloch
Director, National Science Foundation

The Honorable
The President of the United States

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DIRECTOR'S STATEMENT

Erich Bloch

Into Our 40th Year

As this decade ends, the National Science Foundation will begin its 40th year of existence. Although still a relatively young federal agency, we are much different from the small foundation launched in the post-World War II era. Our first budget, in 1951, was $151,000; for Fiscal Year 1990, the appropriation passed $2 billion for the first time. In 1952 we awarded 28 research grants; now we receive more than 37,500 proposals annually and make more than 16,000 awards a year.

Our nation's place in the world and in science, engineering, and technology also has changed greatly. Forty years ago, the United States was secure in its technological lead and the competitive power of its industries. Today more and more of our industries find it difficult to compete in the world market. We face not only tough economic competition, but also technological and scientific competition. Indeed, some observers assert that we are in a new Sputnik era, a time when the United States must again keep pace with the achievements of other nations in science, technology and education.

Because of this new environment, we stress the need for cooperation in the science and technology community: across science and engineering disciplines, between large and small projects, across international boundaries, between groups and individuals, among federal agencies, and among universities, industry, and government. This report describes some of those collaborations; they take place through such NSF programs as Engineering Research Centers, Materials Research Groups, Supercomputer Centers, and Long-Term Ecological Research sites. This philosophy is also embedded in the Presidential Young Investigator program and in many individual investigator grants, which are and will remain the mainstay of NSF's activities.

We also stress science and engineering education—not a new theme, to be sure, but once again a critical one. That's why we have made it one of two "Special Focus" sections in this annual report, along with another current important topic, Geosciences/Global Change.

At NSF, we think that one of the best ways to boost education is to foster new talent in science and technology, and especially to tap underused human resources such as minority groups, women, and disabled persons. Focusing on those groups is not only a question of equity, but a step to satisfy a nation need: As we face a smaller supply of college-age youth, the pending retirement of older scientists and engineers, and the return home of many U.S.-educated foreign students—all this at a time when we are more reliant on technology and need technically trained people more than ever—we need to mobilize *all* of our human resources.

We must also improve the level of understanding of the larger public about science and technology, so that all our citizens can be better informed in this technology-dominated age. From the National Science Board's biennial report, *Science and Engineering Indicators*, we know that public support for science is high, even when science literacy is not. We also know from other sources that people are going to museums in growing numbers and watching television programs that convey the excitement of science, engineering, and mathematics. NSF is proud to be a supporter of museums and media efforts, as described in the later chapter on education and outreach.

And who could fail to be impressed by achievements like the ones described in this report: ocean-bottom and celestial discoveries, work with superconducting materials, advances in mathematics, robotics, supercomputers, and many others. How these discoveries will affect our lives is hard to fathom. Just as the now-common medical diagnostic technique of magnetic resonance imaging sprang from early work in physics, many of today's discoveries will find unforeseen applications.

As we move into the 1990's then, our aims are clear:

- To pursue vigorously the goal NSF has had since its founding in 1950: promoting the overall health of science. This means supporting the very best research in every field, the best methods of research, and the needed infrastructure, such as facilities and equipment.
- To continue our support for, and emphasis on, better science, engineering, and mathematics education in schools and colleges, and to develop this country's human talent base fully.
- To foster cooperation and partnerships in research and education. This includes cross-disciplinary, international, interagency, and other joint research efforts between the academic, government, and private sectors of our society. It also includes sharing the use—and possibly the funding—of the sophisticated, expensive equipment and instrumentation needed for modern research.
- To achieve a higher level of public literacy and public awareness about science and technology through media and outreach activities such as National Science and Technology Week and by sponsoring television presentations like "The Mind."

Our budget strategy and long-range plans reflect these aims. They are supported by the new Administration in its commitment to doubling the NSF budget by 1993. But these issues can only be addressed if our other partners—the academic community, industry and business, state and local government, nonprofit organizations, and other federal agencies—play their part in this important endeavor.

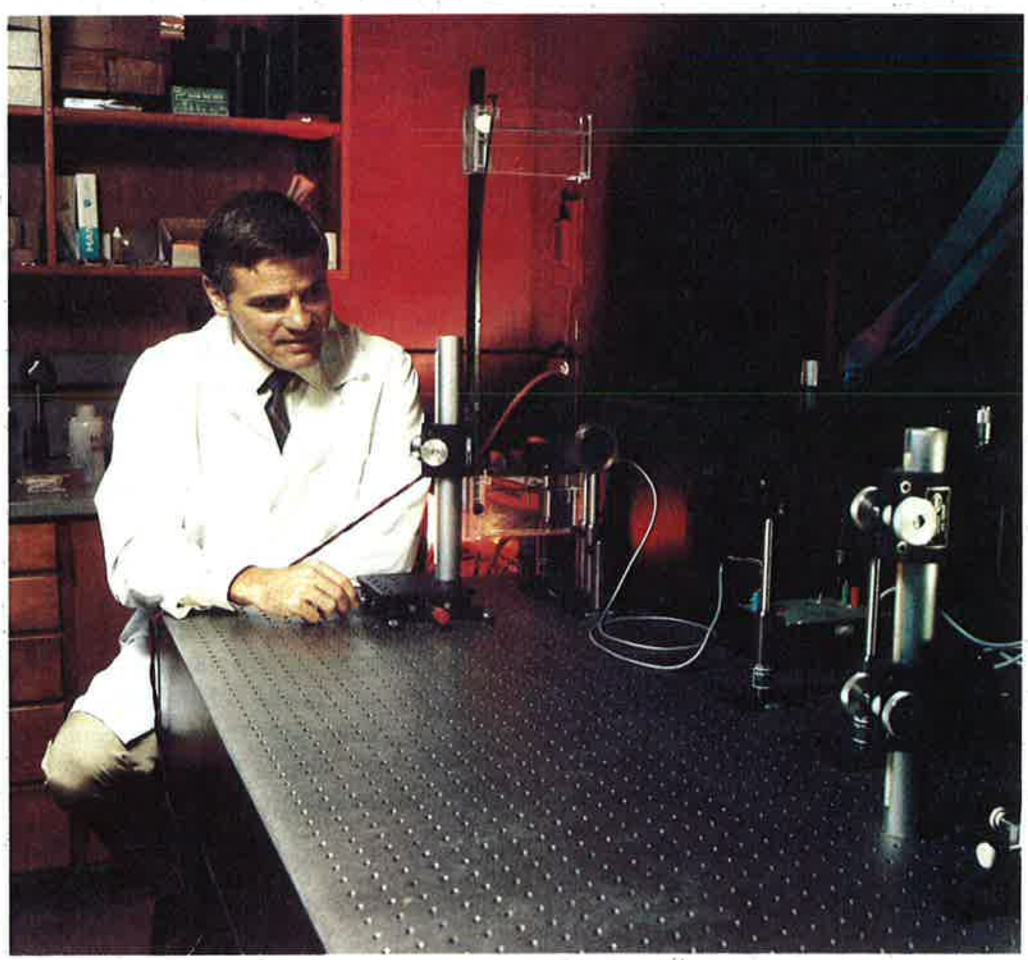
If we successfully marshall our resources and talent, the 1990's will be an age of unprecedented excitement and achievement, not only for science and technology but for the country's competitiveness as well. At NSF, we're ready for both the hard work and rewards that the new decade promises.

RESEARCH NOTES

Genetic Chip

In the world of genetics, a single mutation can have far-reaching consequences: A chance alteration may change eye color in a fly or can lead to a genetic disease such as sickle-cell anemia in human beings. To advance our understanding of biology—including how living systems work and why failures such as genetic disease occur—scientists aim to identify the unique sequence of chemicals called nucleotides that make up each DNA strand

Unravelling the genetic code. CalTech's Leroy Hood is shown with the prototype of a DNA sequencer, a machine that reads the sequence of repeating units in the genetic material of cells. Hood's team has developed a computer chip and software that greatly speed interpretation of such sequences.



on every chromosome. The entire genetic sequence, or genome, for humans is a daunting 3 billion nucleotides. But getting the complete DNA sequence is less than half the effort; deciphering its meaning and function is far more difficult. Thanks to a new computer chip and special software tailored at an NSF research center for molecular biology and biotechnology, that mammoth analytical task has become easier to tackle.

The chip enables scientists to detect similarities and patterns in the burgeoning data on genetic sequences hundreds of times faster than had been possible with the most advanced supercomputers. Until recently, state-of-the-art computers typically required an entire day to compare rigorously the nucleotide pattern of a typical 10,000-unit gene with the millions of nucleotide units stored in existing databases, according to *Leroy Hood.* He is director of NSF's Science and Technology Research Center at the California Institute of Technology.[1] But the new device, adapted at the center from a chip designed for pattern scanning by TRW, Inc., cuts analyzing time to 10 minutes.

The chip's power lies in an assembly-line approach to handling the large amounts of genetic data. Instead of waiting for separate operations to be performed one-by-one on the DNA sequences, it performs several analytical operations simultaneously at different points in the stream of data.

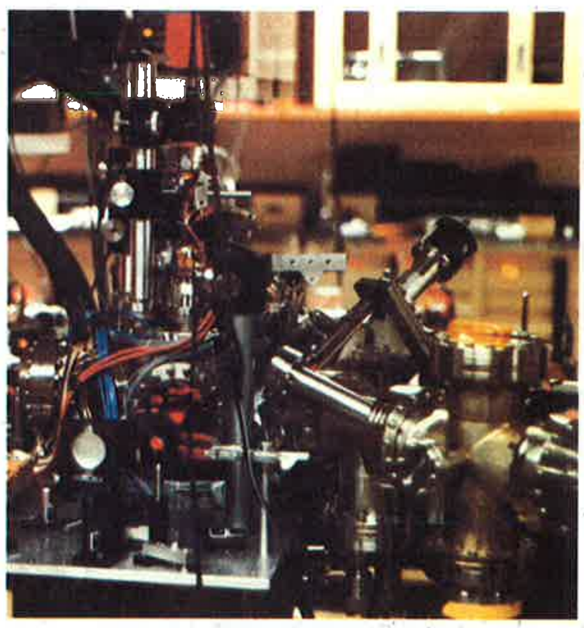
Hood's team, headed by computer scientist *Tim Hunkapiller,* has written software for the chip to identify similarities and patterns among DNA sequences in the database. Identification of such patterns can lead to the recognition of nucleotide sequences that govern life processes at a genetic level, permitting insight into how cells grow, divide, and become specialized. In turn, this information will contribute to our understanding of biological events ranging from photosynthesis to brain function. Sequence information also has important medical applications, since mutations in sequences may trigger disease.

Scientists believe the chip/software invention, in prototype form at this writing, will become critical for analyzing DNA data as the number of sequenced nucleotides, now totalling 30 million, increases several hundredfold over the next few decades. Listing each nucleotide sequence in the human genome, even though represented by a single letter, would fill up millions of pages of paper. A commercial version of the prototype chip, estimated to be available by the early 1990's, should enable molecular biologists to perform at their small computer work stations the kind of complex analysis of DNA data once limited to supercomputers.

[1]See "First S&T Research Centers" later in this section. The CalTech center is one of these.

Atomic Fountain Created; Decay of Z Particle

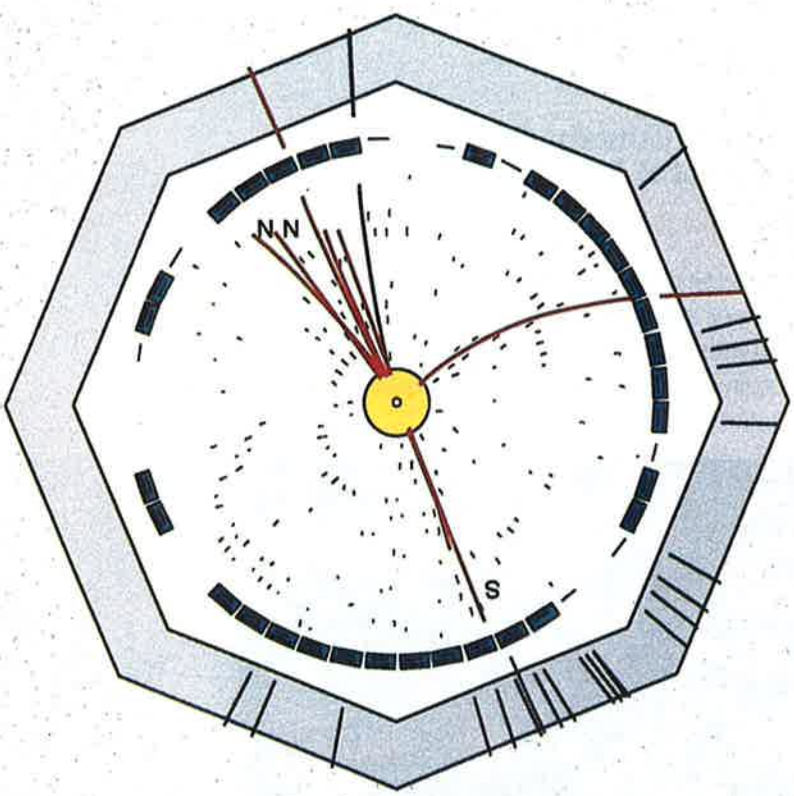
Relying on pulses of laser light to push a stream of atoms up and the force of gravity to bring them back down, physicist *Steven Chu* and his colleagues at Stanford University have created



Atom manipulation. In physicist Steven Chu's lab, this vacuum can is used to laser cool and trap sodium atoms, which are then launched upwards to create an "atomic fountain."

an atomic fountain. The fountain enables scientists to measure for more than a quarter of a second the energy levels of excited atoms as they return to lower energy states. According to the laws of quantum mechanics, such long-term measurements yield extremely precise determinations of the frequency difference between atomic energy levels—data which form the basis for establishing a newer, more accurate atomic clock for time standards.

To create the fountain, the Stanford team used a laser to slow down a stream of sodium atoms. They then confined the atoms in a trap formed by laser beams and magnetic fields. After cooling the atoms, the researchers turned off the trap and launched the atoms upwards with a single laser pulse. The atoms, momentarily excited to a higher energy level by the laser pulse, make a transition to a lower energy level as they fall back down. In a later version of the experiment, the scientists were able to keep the trap going continuously, constantly collecting new atoms for the fountain and increasing by a thousand the number of measurements possible in a given time period. Chu believes his fountain has the potential to create an atomic clock several times as accurate as the standard atomic time keeper.



The stuff of matter. In this computer image, researchers at the Stanford Linear Accelerator capture a Z particle (center) decaying into eight subatomic particles that fan out along the red lines. (The view is looking through a barrel-shaped detector. N indicates particles leaving the north end; S indicates particles leaving the south end of the detector.)

In other physics research, NSF-funded teams at Stanford University's Linear Collider (a Department of Energy facility) and the Large Electron-Positron Collider in Geneva, Switzerland, helped confirm that only three families of elementary particles exist. They did so in making precise measurements of the decay of Z particles—massive elementary particles created when electrons collide at high energies with positrons, their antimatter counterpart. The short-lived Z is one of three messenger particles that carry from one subatomic particle to another the weak force, which governs certain types of radioactive decay.

The results of this research help confirm the so-called standard model of elementary particles, which assumes that matter consists of two types of particles—quarks and leptons. A third group, called bosons, acts as messengers to carry the forces of nature between particles in the other two groups.

Protogalaxy. Astronomers Martha Haynes and Riccardo Giovanelli examine data from a hydrogen cloud that may be a galaxy forming. The cloud is 65 million light years away.

Possible Unborn Galaxy; Giant Solar Flare

Astronomers believe they have found for the first time a galaxy still in its birth throes, some 10 billion years after galaxies such as our Milky Way were believed to be born. A rare new "protogalaxy," or unborn galaxy, was sighted by radio astronomers *Martha P. Haynes* of Cornell University and *Riccardo Giovanelli*, who heads the radio astronomy group at the NSF-supported radio telescope in Arecibo, Puerto Rico. The discovery is doubly exciting, noted Haynes, because the protogalaxy--made of hydrogen gas that has not yet condensed to form stars or planets--is a relatively close 65 million light years away, making continuing observations from earth relatively easy.

For years astronomers had searched unsuccessfully for such unborn galaxies, and Haynes had been looking since her 1976 doctoral dissertation. But 13 years later, she and Giovanelli made their discovery of a hydrogen cloud by accident. They had focused the 1,000-foot dish of the Arecibo telescope at a presumably empty region of sky in order to calibrate the instrument. Instead, the astronomers unexpectedly detected radio emissions that signalled the presence of two huge clumps of hydrogen inside a large, isolated gas cloud.

A few other gas clouds had been discovered before the Arecibo finding, but all were closely associated with existing galaxies. "This cloud seems to have formed independently, in a pocket of space isolated from other galaxies," said Giovanelli.

Although the cloud, a slowly rotating disc of hydrogen located south of the Virgo Cluster, is about 10 times the size of the Milky Way, it appears to contain few stars and has far less mass than our own galaxy. Because it has not yet condensed and collapsed to form a large number of stars, the cloud may challenge our theories of galaxy formation.

Astronomers knew immediately that the giant solar flare erupting on March 6, 1989, was the largest in a decade. But observations over the following weeks showed that the flare heralded even greater things to come--the appearance of record-breaking activity on the solar disk. Telescopes at Sacramento Peak, New Mexico (part of the National Solar Observatory, supported by NSF) contributed to the observations of brilliant flares, shadowy sunspots, and showers of charged particles bursting from the sun.

Both sunspots and flares result from the distortions and stretching of huge bands of magnetic fields within the sun. Magnetic distortions on the sun are commonplace, and most of the time they do not cause an electrical storm. But occasionally the distortions become too intense and the magnetic fields snap like rubber bands, releasing vast amounts of energy that concentrate into a solar flare. Sunspots occur when the same distortions cause the magnetic bands, usually contained inside the sun, to break through the surface, leaving on the solar circumference telltale dark spots 100 times the width of earth.

Such activity is of intense interest to solar researchers on several counts. Ordinarily invisible magnetic field lines may become spotlighted by the hot plasma of a solar flare, and the blasts of X-rays and showers of electrically charged particles that strike the earth give a new keyhole for peering into the sun's interior. The dramatic observations in early 1989 may have signalled the coming of a banner year for sunspots and solar flares. (Sunspot activity follows an 11-year period expected to peak in 1991.)

Sun activity. A giant solar flare erupts from the sun.

National Solar Observatory

Supercomputers: Flame Behavior, Surface Research

From the beginning, fire has fueled civilization, providing warmth and protection for our ancestors half a million years ago. But today we still know relatively little about the structure and dynamics of the flame. Because of fire's complexity, scientists have developed computer models to describe its fluid dynamics and chemistry. Most models emphasize either dynamics or chemistry, but rarely both. Now mechanical engineer *Mitchell Smooke* and his colleagues at Yale University have used the Cornell National Supercomputer Facility, an NSF-supported center, to explore the effects of both fluid flow and chemical structure in four types of flames. Better understanding of the behavior of certain flames can help researchers identify how air pollution forms while they also learn about the flame's structure

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The study of surfaces and how they evolve--be they soap bubbles or the facets of a growing crystal--has prompted collaborations among mathematicians, physicists, and computer scientists. And the graphic imagery generated by such research seems to meld art with science.

An international collaboration of mathematicians--coordinated by the University of Minnesota--has developed a computer program that maps the surface of clusters of crystals, soap bubbles, and other solids and liquids, given the forces that act on them (such as gravity and pressure) and such constraints as volume and their surroundings. The program, developed by University of Michigan mathematician *Kenneth A. Brakke* as part of NSF's Geometry Supercomputer Project, relies on similarities between materials as seemingly different as crystals, capillary surfaces, and soap films.

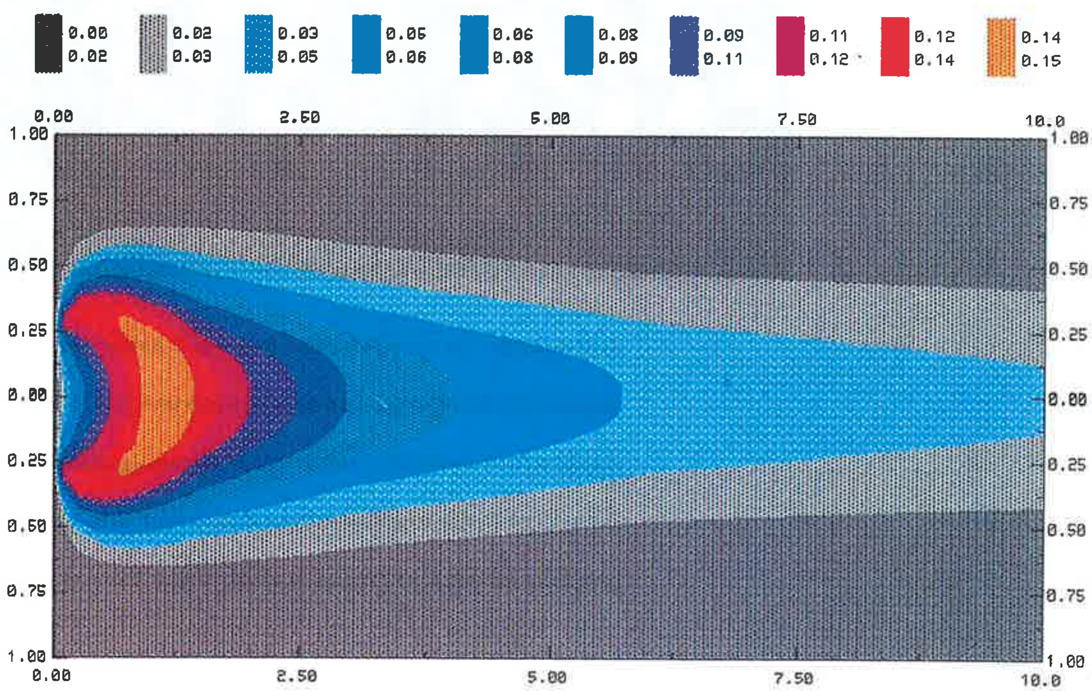
In other surface research, probing the microscopic structure of solids is also a challenge. But in the scanning tunneling microscope, researchers have a powerful device that can make atom-by-atom portraits of a surface.

Such intricate images have revolutionized materials research, because surface atoms play a special role in determining many properties of solids, such as chemical reactivity, resistance to corrosion, and electronic behavior.

Unlike an optical or electron microscope, the scanning tunneling microscope (STM) does not actually "see" the surface it probes. Instead, the instrument uses a quantum phenomenon called tunneling. A very sharp metal tip is brought extremely close to the surface, leaving a gap only a few angstroms wide. A small voltage between the tip and the surface forces a very small electrical current across the gap. This tunneling current is extremely sensitive to small variations in the width of the gap--so sensitive in fact that in scanning the tip over the surface, atom-size features show up as large changes in the tunneling current. Thus the tip's scan generates a precise topographic map of the surface.

University of Minnesota

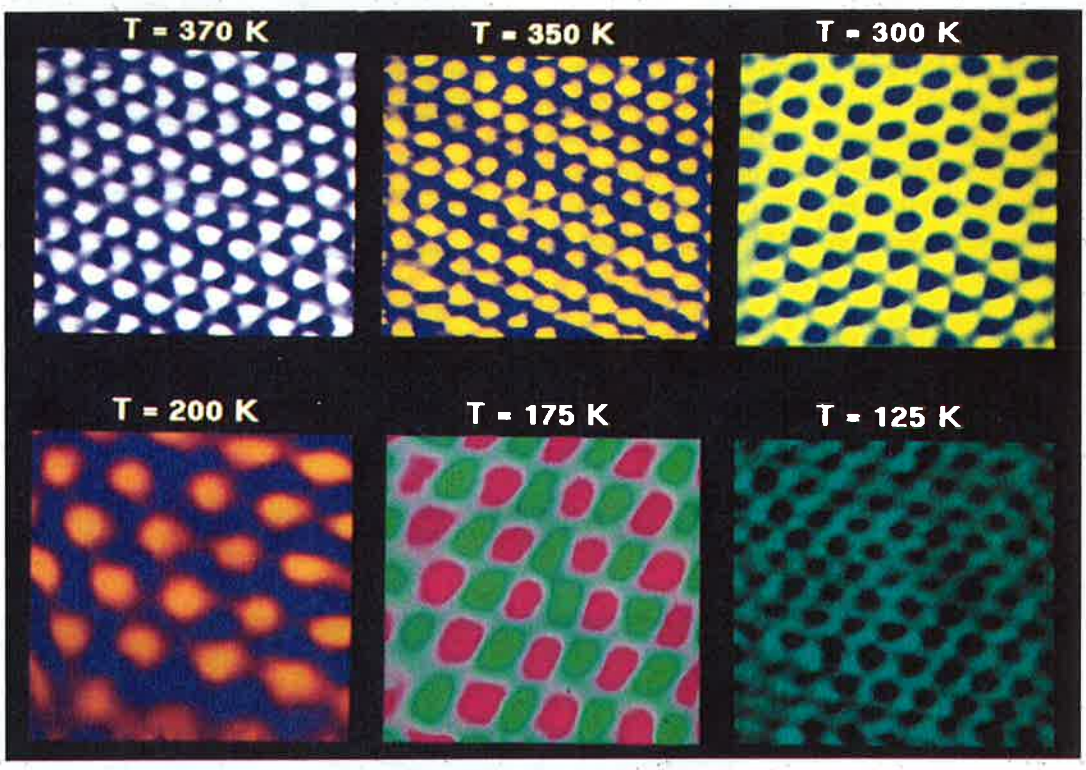
Soap bubble cluster. As discovered in surface research, this group of six bubbles is the smallest number that can share surfaces that are not spherical in shape.



Model flame. In this supercomputer-generated image, the hottest sections of a flame have the hottest colors.

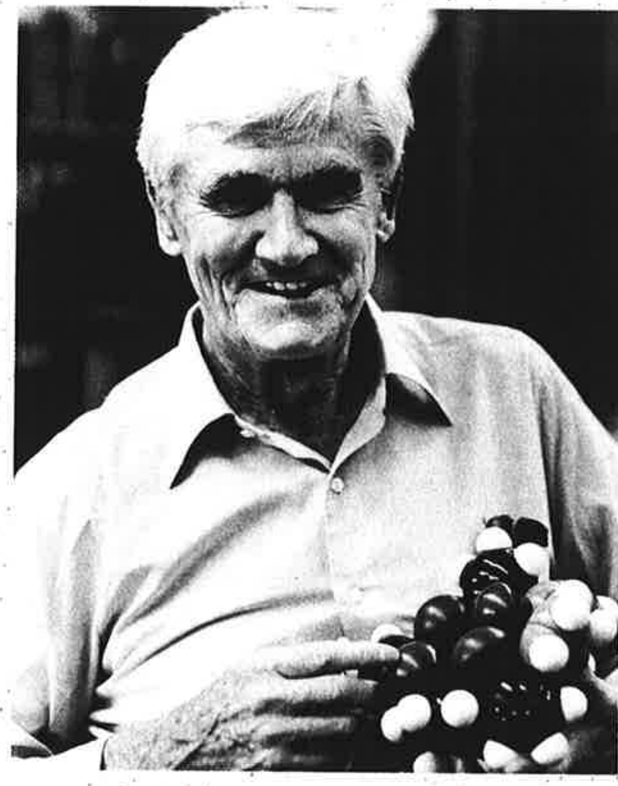
Cornell Supercomputer Facility

The microscope's tip has also been used to make atom-sized dents in materials and as a miniature transporter, picking up a mere molecule of material at one spot and putting it down someplace else. Because the microscope relies on detecting electrical current between the tip and the surface, it works best with materials that are good electrical conductors. But more recently, researchers have used the instrument to probe the surface structure of DNA and other molecules of life.



***STM results.** In the Materials Research Laboratory at the University of Illinois at Champaign-Urbana, researcher Joseph W. Lyding has developed the world's first variable-temperature scanning tunneling electron microscope (STM). This illustration shows false-color STM images of carbon atoms on a graphite surface at temperatures from 370K (207F) to as low as 125K(-234F).*

T. O'Donnell, UCLA



New phase of matter. Nobel laureate Donald Cram holds the type of molecular model he uses to design "carceplex" molecules.

Chemists Create New State of Matter, Advance in Study of Transition States

Trapping one molecule inside another like a Tinker Toy prison, a UCLA research team led by *Donald J. Cram* says it has created a new state of matter. Possible applications for the discovery might one day include new types of liquid crystals, new catalysts to promote chemical reactions, improved techniques for imaging the body, and new methods for delivering anticancer and other drugs.

Cram, who received the 1987 Nobel Prize in chemistry, calls the new molecules "carceplexes," from the Latin word for prison. Each carceplex contains a "carcerand," or hollow molecule that forms the jail cell walls for the "guest" molecule it traps inside. The guest molecule, Cram says, possesses a state of matter different from solids, liquids, gases, or plasmas.

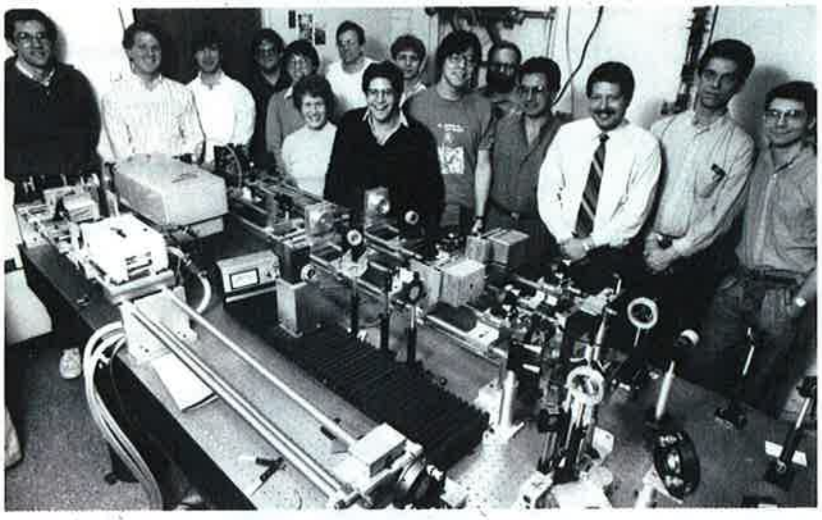
Cram and his co-workers have worked on carceplexes for several years, but in 1989 they succeeded in making purified crystals of the compounds, enabling the researchers to perform detailed structural studies. The crux of these compounds relies on carbon atoms, which chemically bind to other atoms in shapes resembling flexible Tinker Toys. Cram's team members formed molecular cages or prisons by fitting together several of these carbon-based shapes; they found that they could trap a smaller molecule inside while chemically constructing the Tinker-Toy-like prison walls.

Surprisingly, the group found that the trapped molecule, although locked into a rigid crystal structure, appeared free to rotate or change direction at random, depending on its shape and size relative to its prison walls. By applying magnetic fields, the researchers discovered they could control the orientation of the trapped molecules. For example, cylindrical prison molecules could rotate only around their long axis, while short molecules could rotate in several directions, presumably because their smaller size allowed more mobility within the chemical prison.

While Cram notes that his group invented the carceplexes to understand basic principles, the research may eventually have several dramatic payoffs. For example, a radioactive molecule that is chemically poisonous in the free state might be placed as a prisoner inside a larger molecule that attaches to a cancer cell. This would allow the imprisoned radioisotope to kill the cancer cell without harming healthy cells nearby.

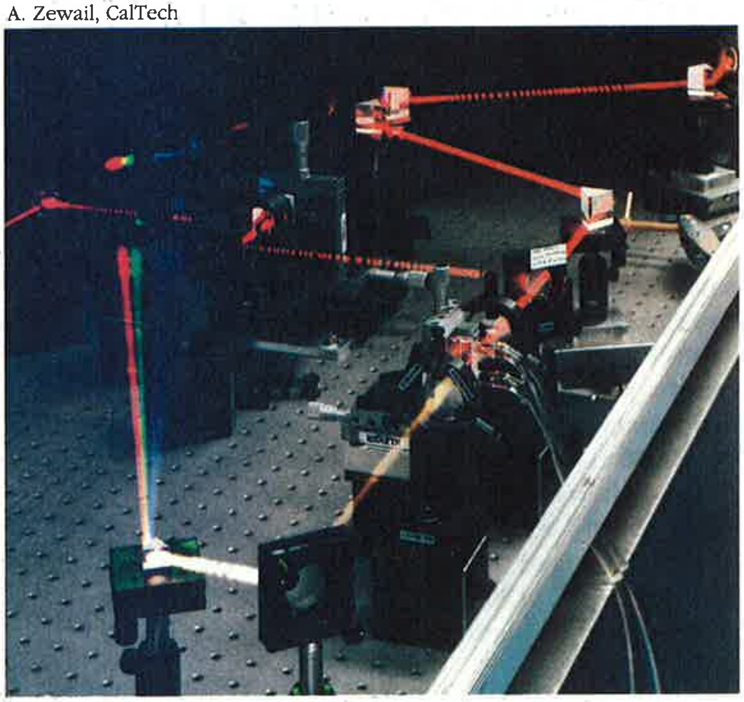
In studying transition states, scientists for years determined many details of chemical reactions by analyzing before-and-after pictures of the initial reactants and the final products. But there were no eyewitness accounts of the actual reaction. That scenario changed when NSF-backed researchers, using ultrashort pulses of laser light, glimpsed for the first time how atoms change partners in a chemical reaction--even one that is shorter than a millionth of a millionth of a second. This work was done at CalTech, the University of Chicago, the University of Pennsylvania, UC-Berkeley, and AT&T Bell Labs.

Scientists say the laser technique provides a groundbreaking first look at the birth of molecules formed as intermediate or transition compounds when two substances begin a chemical reaction. When molecules in a reaction encounter each other, they usually form high-energy, loosely bound complexes of molecules--the transition states--before forming products. Usually the



Ultrafast chemistry. Ahmed Zewail (wearing tie) and members of his CalTech research group gather around a laser set-up designed to measure ultrafast chemical reactions.

A. Zewail, CalTech



Laser table. A pencil-thin beam of laser light travels through prisms and lenses, then bounces off mirrors, illuminating equipment used to measure ultrafast chemical reactions.

transition state lasts for so short a time that it is impossible to study. But by adding pulsed laser light at just the right moment, the transition state can be detected directly or converted to a stable state with a similar geometry.

Chemists also use laser pulses to break up single molecules or bimolecular compounds into fragments. Transition states are observed as they lose energy and decay into the final products, emitting a characteristic pattern of radiation in the process.

The new information on transition states tells chemists such things as how energy is distributed inside isolated molecules or between molecules sharing a common bond. In addition, the laser technique holds the potential for directing chemical reactions to produce specific products.

Biodegradable Plastics; Bacteria That Secrete Polymers

Researchers have developed new biodegradable plastics and novel methods for recycling conventional, long-lasting plastics. The findings are welcome news because synthetic plastics have an estimated lifetime of hundreds of years in soil, harming both soil and wildlife. A study conducted for the Environmental Protection Agency showed only about 1 percent of plastics are recycled, even though they account for about 76 percent by weight of trash dumped in U.S. landfills.

At the Center for Plastics Recycling Research at Rutgers University, an NSF Industry-University Cooperative Research Center, scientists have developed and licensed an economical large-scale recycling system. It detects certain types of plastic soft drink bottles and high-density polyethylene containers and separates them from other plastic debris. The containers can then be reused. A new plant at Logan Township in southern New Jersey will be the first to use the recycling system. And what about other, noncontainer plastics? The research center also has a model system that extrudes materials mixed from the remaining plastics; those materials can be used to make park benches or parking lot blocks.

At the University of Massachusetts, Amherst, polymer chemist *Robert Lenz* and biochemist *R. Clinton Fuller* study bacteria that produce plastics when fed different hydrocarbons. Lenz and Fuller focus their efforts on coaxing bacteria such as *Alcaligenes eutrophus* to create new polyesters. The idea may sound surprising because most polyesters are human-made; nevertheless, just as plastics are long chains of repeating carbon compounds, polyesters contain subgroups of "ester" groups like those found in animal and vegetable fats and oils. The researchers have already obtained new polymers with unusual and desirable properties, and they have worked intensively with a bacterium that has the potential to produce a compound of major benefit to the environment--biodegradable rubber.

N. Romanenko, Rutgers

Reclaiming plastic. At Rutgers University's Center for Plastics Recycling Research, Darrell Morrow poses next to equipment that detects and separates certain types of plastic for recycling.

World's Oldest Known Rocks Found

U.S. and Australian scientists say they have discovered the world's oldest known rocks, two 3.96 billion-year-old specimens gathered from the Slave Province, a remote region of Canada in the Northwest Territories. The oldest rocks previously known were found in Greenland (3.82 billion years old) and Antarctica (3.87 billion years old).

Samuel A. Bowring, an earth and planetary scientist at Washington University in St. Louis, reported these findings in the fall of 1989, upon returning from the laboratory of his Australian collaborators in Canberra. After hauling some 4,000 pounds of rock to that lab, the team had used the most advanced technology available to date the specimens. That technology was the Sensitive High Mass Resolution Ion Microprobe (SHRIMP), a highly sophisticated isotope-measuring instrument.

From 1983 through 1989, Bowring and his students, along with *Janet E. King* of the Geological Survey of Canada, searched for and collected samples from the western Slave Province.

"We've now pushed 100 million years farther back in terms of rock we can study, into a period of earth's history about which we know almost nothing," said Bowring. The rocks found by his group are apparently unchanged since they formed in that little-known epoch.

Scientists believe the earth formed approximately 4.5 billion years ago, but they know very little about its earliest development. These well-preserved rocks should help them learn more about that ancient period.

First S&T Research Centers

In December 1988, NSF selected the first awardees for its new Science and Technology Research Centers program, funding 11 centers in 8 states for a total of nearly $25 million. Researchers ranging in focus from cosmology to storm prediction and from biotechnology to superconductors began to make their visions reality at university-based centers in California, Illinois, Michigan, New Jersey, New York, Oklahoma, Texas, and Virginia.

NSF established these basic research centers to encourage exploration of problems that are large scale or may require extended time and special facilities or collaborations to tackle. The Foundation required applicants to shape their proposals around a unifying theme, to include a strong educational component, to provide methods of transferring basic research ideas to those interested in applying them, and to establish collaborations with government, industry, states, or other interested parties.

Foundation support comes through a cooperative agreement with the university managing the center. A review after each center's third year will determine whether funding will be extended or phased out.

The first S&T centers include these three:

• University of Illinois, Champaign-Urbana--Center for High-Temperature Superconductivity

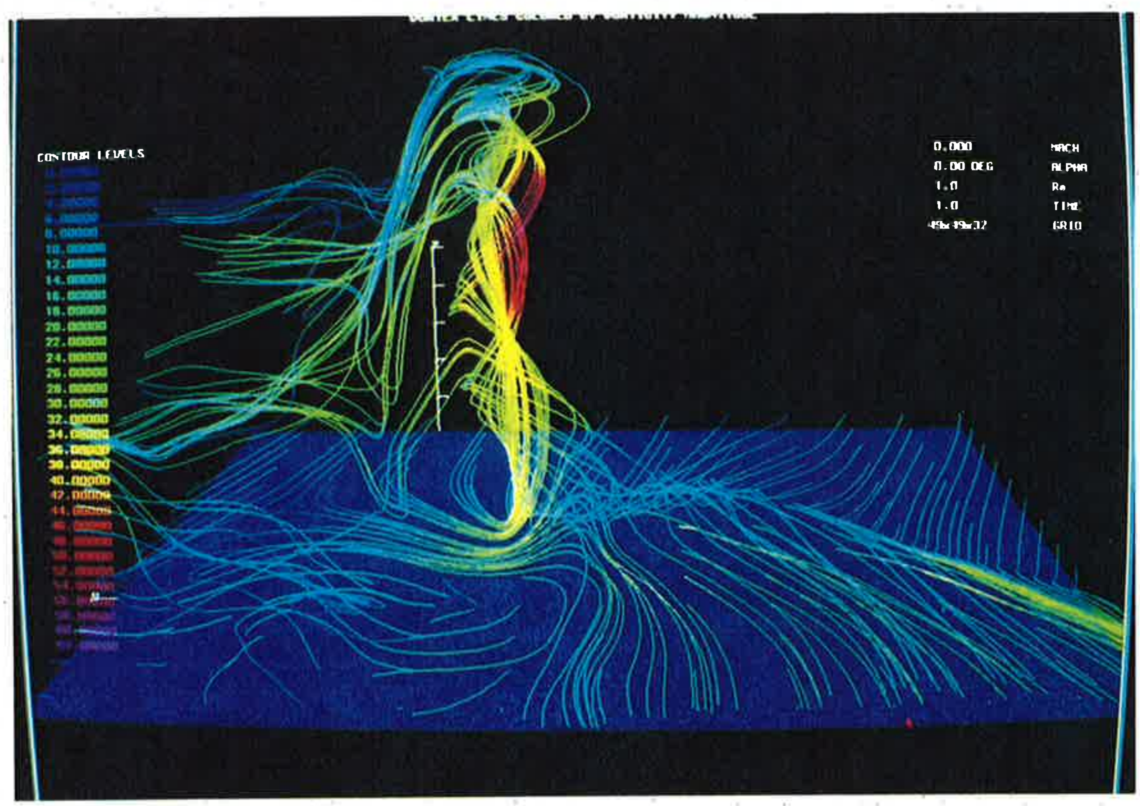
Investigators emphasize the understanding of interactions that give rise to high-temperature superconductors--materials that at a certain temperature lose all resistance to electric current. Scientists probe superconducting materials to learn more about their structure and chemical properties, how they conduct electricity, and how to shape them into thin films and other usable forms for circuitry.

• Michigan State University--Center in Microbial Ecology

Beneficial microbes that digest unwanted or contaminating materials may reduce groundwater pollution, improve control of plant pests, enhance the recycling of organic material, and perfect the products of biotechnology, fermentation, and other industrial processes. This center draws together microbiologists, soil scientists, geneticists, chemists, engineers, and mathematicians in an effort to study microbes and how they are affected by the environment.

• University of Oklahoma--Center for Analysis and Prediction of Storms

Focusing on better models for predicting tornados, flash floods, and severe thunderstorms, this center fills a gap in understanding weather phenomena that arise on a scale too small to be



Air inside a thunderstorm. Oklahoma's Center for Analysis and Prediction of Storms created this computer model of an air vortex inside a mature thunderstorm. Like water going down a drain, the rising air spins around each line — with warm colors representing faster rotation rates.

K. Droegenmeier, University of Oklahoma

K. Droegenmeier, University of Oklahoma

Warm air rising. This computer image, created by Oklahoma's Center for Analysis and Prediction of Storms, simulates a bubble of warm air rising through the lower atmosphere. Warm colors correspond to the warmest temperatures.

accounted for by current techniques for data collection and analysis. Using new ground-based radar and advanced supercomputers, meteorologists, mathematicians, and computer scientists work to develop and test new computer models. Their aim is to understand more about--and ultimately predict--regional weather systems that give rise to storms causing widespread damage.

Research on Cracks

A small crack in a 50-year-old tanker suddenly expands, ripping the container open from top to bottom and spilling three-quarters of a million gallons of diesel fuel into the Monongahela River, the source of drinking water for thousands of people in Pennsylvania. A 19-year-old airplane suddenly ejects the upper half of its fuselage in mid-flight between Hilo and Honolulu, hurling a flight attendant to her death and injuring 61 other people. And an 85-year-old bridge, a major thoroughfare in New York City, closes for six weeks because officials fear years of neglect have brought the structure to the brink of collapse.

Aging, overloading, insufficient maintenance, and exposure to the elements have taken their toll on the nation's multi-trillion dollar public works, which include bridges, airports, harbors, and buildings. As a result, efforts and expenditures to repair and rehabilitate these structures have increased. But to avert disaster, engineers and other researchers need to know about potential problems before they occur. Exactly how much stress is too much for a concrete bridge? What type of sensors are best to detect cracks in specific construction materials? How can scientists accurately measure the remaining life of an office building or suspension bridge? These research questions are the domain of an NSF initiative that supports development of instruments to probe the health of wood, concrete, masonry, and steel construction materials without disturbing or destroying a structure.

Although some detectors already exist, they often require removal of a sample, leaving a small but noticeable structural gap that usually requires repair. Nondestructive methods to probe metals and materials used in defense are common; the NSF program, a collaboration among three sections in NSF's Engineering Directorate, focuses on developing such nondestructive methods and instruments for the key but often overlooked field of construction.

Some of these methods use sound waves or other probes to detect flaws or weaknesses in concrete and wood. The collapse of several highway bridges has prompted *Frank D. Defalco* and *John A. Orr* at the Worcester Polytechnic Institute in Massachusetts to investigate the use of sensing devices and electronic equipment that could warn motorists of a bridge failure before it happens. In collaboration with engineers at Purdue University, *Thomas E. Fenske* at the University of Louisville in Kentucky used special detectors on 62 highway bridges to measure the displacement and vibration induced by different types of cars, trucks, and trailers. The study compared the stability and strength of several types of bridges, including those supported by steel beams and reinforced concrete.

At Cornell University, engineer *Mary J. Sansalone* and co-workers tap concrete slabs with a special hammer to detect structural flaws. The pattern of vibration echoes generated by the hammer clues the researchers about defects in the material. Comparison of echoes before and after stressing the material tells the investigators the impact of various forces on the concrete. Also at Cornell, *Alan T. Zehnder* uses infrared detectors to measure the increase in heat generated by crack formation in materials. Such measurements may give an early warning sign for defects in many types of infrastructures.

In separate but related work, this time supported by NSF's materials research program, chemists and physical scientists examine defects in simple materials in the hope of modelling flaws in more complex structures. Even these simpler studies involve structural behavior more complex than meets the eye. The types of materials that resist cracks differ from those which are best at slowing the spread of cracks once they form. *Yip-Wah Chung* at Northwestern University studies the effect of chemical environment on crack behavior in gold, gold-silver alloy, and silver-aluminum alloy crystals. Chung and his collaborators use a scanning tunneling microscope to image microscopic cracks and follow the jagged pattern created as cracks propagate through the crystals.

Such basic studies may help pave the way for engineers to routinely lace building materials with electrical, fiber-optic, and other sensors that continuously monitor structural health.

Innovative Small Business Research

Tractor-trailers, or "big-rig" trucks, may be able to save up to a billion gallons of fuel per year, thanks to a device developed under an NSF small business grant.

The device, called an aerodynamic boat tail, was developed with a Small Business Innovation Research (SBIR) grant to Continuum Dynamics, Inc. (CDI), of Princeton, New Jersey. The tail underwent tests in NASA's Ames Wind Tunnel, the world's largest. Those tests, conducted by NASA engineers, showed that drag on the test rig was reduced by about 10 percent, resulting in the potential fuel savings. (Drag is a ubiquitous problem with large trucks; the greater the vehicle's speed, the greater the pull or drag on it.)

The CDI device consists of fins attached to the rear of a truck. The fins work by causing the air flowing over the top and sides of the truck to turn inward at the back, creating a smoother flow that is shaped like a boat tail. By turning the air flow inward, drag on the truck is reduced.

A key feature is the ability to stow the device against the rear door or trailer sides.

SBIR grants have fostered other recent success stories. A grant to Charles Evans & Associates, Inc. of Redwood City, California, helped the firm develop and market its advanced imaging detector system for ion microscopes. This system was on the market within one year after Phase II of the grant ended. Sales now exceed $6 million, with 60 percent exported. Customers include such major companies as IBM, AT&T, Xerox, Toshiba, and Nippon Telephone and Telegraph. Another grant to Radiation Monitoring Devices of Watertown, Massachusetts, helped introduce an analyzer critical to quality control of mass produced, glass-reinforced plastics—used in automobile panels, computer cases, and telephones.

In FY 1989, NSF awarded 229 grants to small high-technology companies, in an effort to promote this kind of pioneering research.

S. Ember

Presidential Teacher Awardees

Each year two outstanding high school or middle school teachers from every state, the District of Columbia, Puerto Rico, and the U.S. territories receive this award. It is intended to encourage high-quality math and science teachers to enter and remain in the field. NSF established the award, in cooperation with the White House and scientific and professional organizations, in 1983. Some 1989 winners are shown below; these photos were taken during awards week in Washington, DC (October 1989).

Award-winning teachers. Shown here are some of the 1989 winners of the annual presidential awards for math and science teaching.

Chapter 1

RESEARCH COLLABORATIONS

Without the right tools and up-to-date laboratories, even the most talented scientists cannot hope to conduct cutting-edge research or keep abreast in their fields. But the costs of replacing and renovating equipment have skyrocketed. Thus a continuing coordinated effort by academia, industry, and government is needed to help finance the repair and renovation of scientific laboratories.

At NSF, a new facilities office has produced a report addressing this issue (see chapter 4). Beyond that, the recognition that research institutions often cannot afford to buy and maintain the tools and facilities of modern research has already forged new collaborations between universities, industry, and government (both federal and state). And, as modern research blurs the boundaries between disciplines, the pooling of resources becomes welcome and inevitable. For several years, NSF has pioneered such collaborations by supporting research centers in astronomy, atmospheric science, materials research, and (more recently) engineering, supercomputing, and other areas. NSF also has funded instrumentation shared by several research groups. What follows are some recent examples of these efforts.

Supercomputers

Predicting thunderstorms more accurately, tracking the changing structure of a newborn star, designing a better artificial leg--these are some of the applications of supercomputers. But just five years ago few universities had access to these multimillion dollar machines, which enable scientists to tackle in a few hours complex problems that might be otherwise impossible to solve or would require a year's running time on a conventional computer.

Today, the Foundation estimates that more than 11,000 professors, students, and other researchers in diverse fields use supercomputer facilities--thanks to the establishment of NSF campus centers nationwide. This program has the active cooperation and financial support of industry, states, and universities. An NSF-supported communications network, NSFNET, links users from across the nation to these centers and provides campuses nationwide with access to the supercomputers.

During 1989, NSF began to upgrade four of the supercomputer centers--at Cornell University, the University of Illinois at Champaign/Urbana, the University of Pittsburgh-Carnegie Mellon University, and the University of California at San Diego. The five-year grants will help develop more efficient software and expand education and training in supercomputing--all efforts that make it possible for scientists to explore new problems using computers.

As part of its upgrade, Cornell will receive a special grant for a second IBM supercomputer. The second machine furthers the center's study of parallel processing--a technique in which complex scientific problems are divided into pieces run simultaneously on different processors in the same computer, speeding results. The Cornell center already uses parallel processing to analyze such topics as:

- How the AIDS epidemic is spreading in New York City;
- The environmental, political, and engineering aspects of acid rain;
- How sound waves penetrate eye tissues (in order to plan better ultrasound treatment for eye cancers).

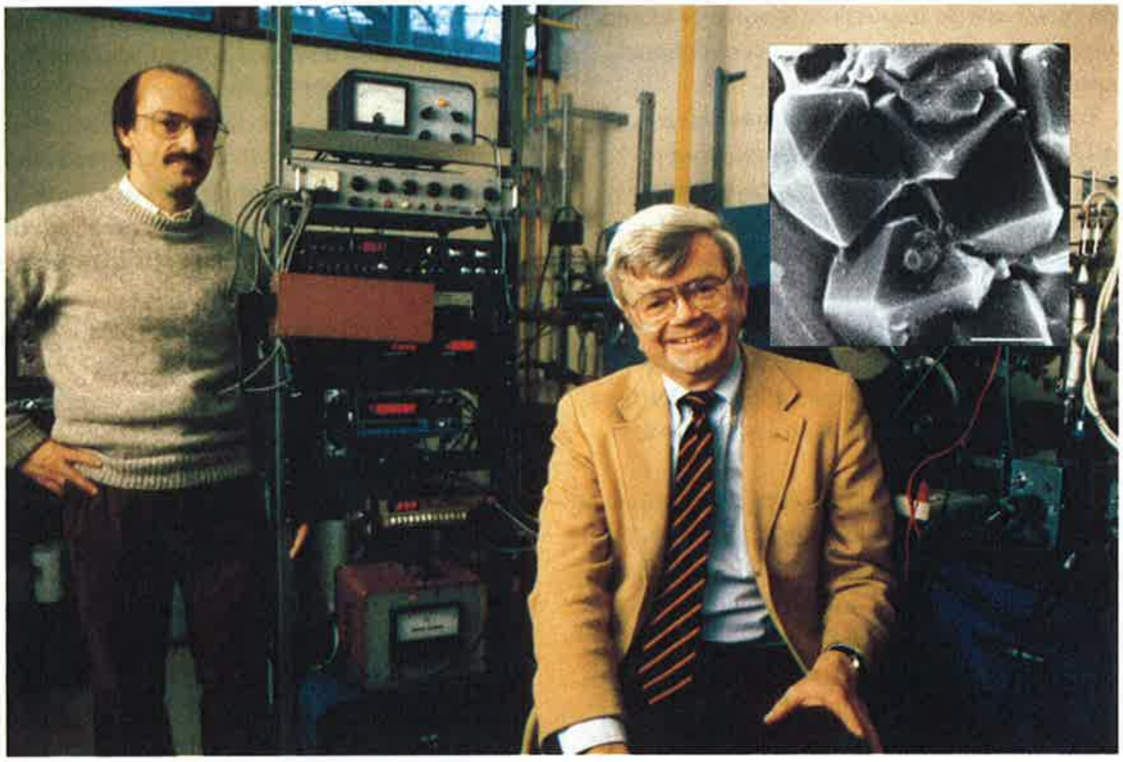
Science and Technology Research Centers

The first 11 S&T Research Centers funded by NSF (see "Research Notes") include the Center for Research on Parallel Computation. Awarded to Rice University, this center is a four-way partnership between Rice, CalTech, Los Alamos National Laboratory, and Argonne National Laboratory.

Site of supercomputer at UC-San Diego

Robert Muller

inset: Lawrence Staikoff



New materials. At Case Western Reserve University, Cliff Hayman (back) and John Angus are investigating synthetic diamonds like the ones magnified 10,000 times in the inset.

Scientists from all four institutions are cooperating to develop software and algorithms that can better recognize and take advantage of the emerging parallel architectures to be used in scientific applications requiring high-performance computing. In addition to equipment available at Rice and CalTech, facilities at the Advanced Computing Laboratory at Los Alamos and the Advanced Computing Research Facility at Argonne will be available for use by center participants.

A donation by Cray Research, Inc. of 2,800 hours of supercomputer time (valued at $4 million) helped boost research at many of the Science and Technology Research Centers during 1989. Many investigators at the centers use supercomputers to run models of complex phenomena, ranging from the motion of light through molecular clumps deposited on photographic films to the large-scale structure of the universe. The donation gave scientists access to a Cray-2, a supercomputer that has the largest memory of any commercially available computer. (For more on S&T centers, see "Research Notes.")

New Materials Research Groups

NSF established three new materials research groups[1] during 1989, bringing the total to 16 at 14 different universities. Investigators at Case Western Reserve are studying ways in which carbon atoms nucleate to form ultra-hard diamond and diamond-like thin films. Two groups, one at the University of Minnesota, the other at the University of Wisconsin-Madison, explore different aspects of high-temperature superconductors. The Minnesota group focuses on the physical properties of thin films fabricated from these materials; the Wisconsin group is concerned with the small grains present in these materials and how the links between these grains limit the amount of current that can be carried. Both areas pose fundamental problems that must be overcome before widespread use of high-temperature superconductors becomes possible.

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[1]NSF also sponsors a separate program for materials research *laboratories*.

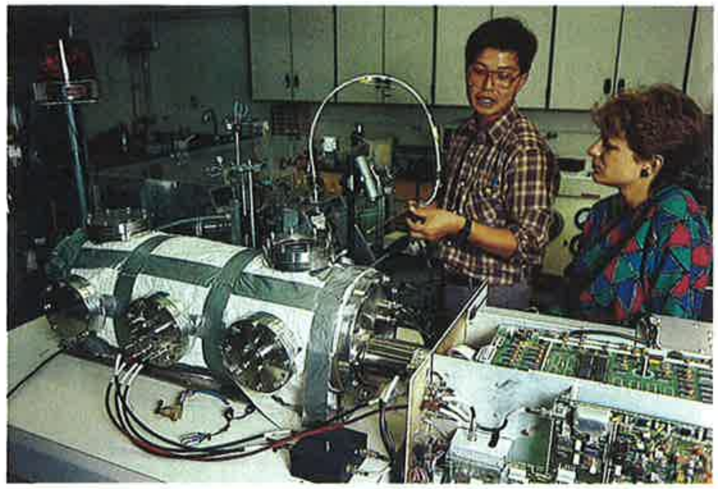
Long-Term Ecology Projects

Three research institutions were awarded six-year grants by NSF to undertake intensive studies of widely different ecological systems. These systems include a rain forest in Puerto Rico; a New Mexico site combining deserts, grasslands, and forests; and an experimental forest in Massachusetts (see chapter 2 for details).

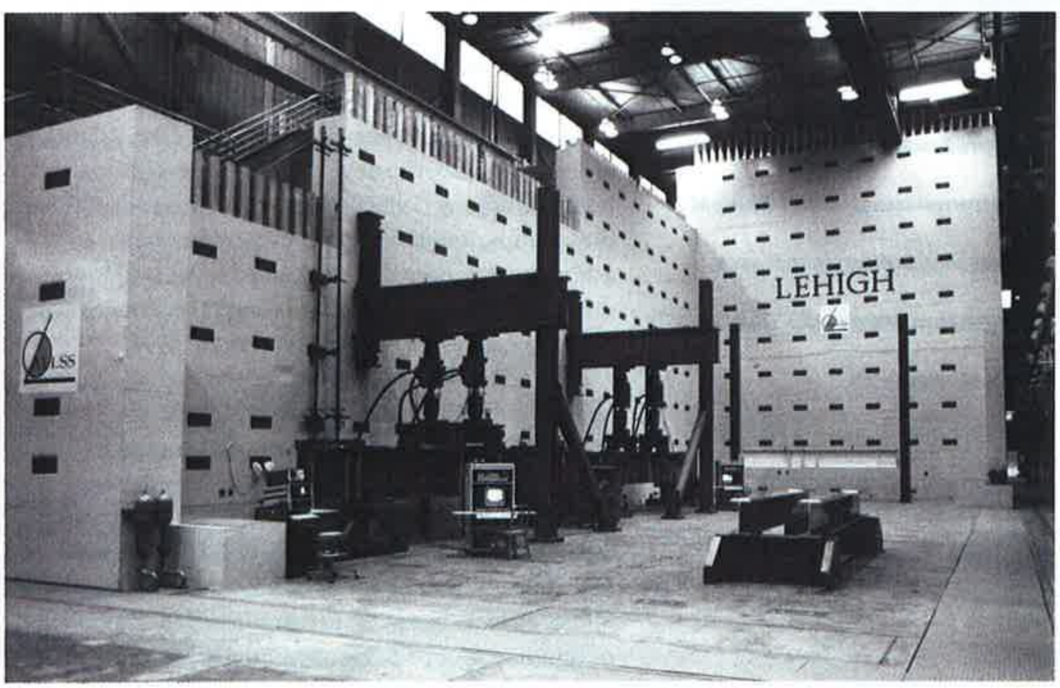
Five Engineering Centers Renewed

NSF renewed for five years Engineering Research Centers at Carnegie Mellon University, the University of Illinois, Lehigh University, Ohio State University, and Brigham Young University jointly with the University of Utah. The first of these 18 cross-disciplinary centers were created in 1985. Each brings together faculty, students, and industry professionals to focus on fundamental research and education in design, materials processing, manufacturing, telecommunications, and engineering systems--areas vital to maintaining U.S. industrial competitiveness with other nations. The centers also focus on new approaches to engineering education, to prepare students thoroughly for engineering practice.

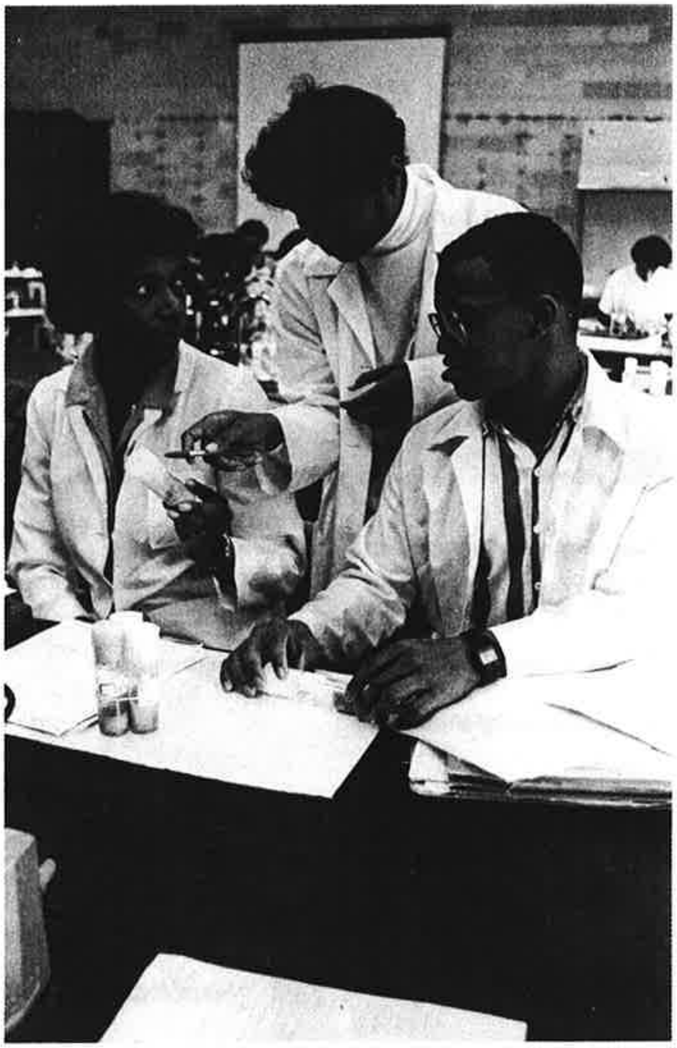
T. Newfarmer



Engineering research center (ERC). Graduate student Yongsenng Yun and chemical engineering professor JoAnn Lighty investigate coal combustion at the University of Utah.



Lehigh ERC. The Multidirectional Experimental Laboratory, shown here, is at Lehigh University's Center for Advanced Technology for Large Structural Systems. Here full-scale structures are tested under multidirectional loads. The center is also investigating innovations in design concepts, fabrications and assembly techniques, and performance monitoring.



Comprehensive Regional Center for Minorities. At Florida A&M University, biology professor Lynette Padmore (left) directs student research.

Center research at Lehigh includes the study of design, construction, and safety monitoring of large structures such as buildings and bridges. This center has already developed self-aligning connectors that ease the joining of structural components, computer software "expert" systems that aid in designing structures that are easy to build, and corrosion sensors for long-term monitoring of structural stability. The center exposes students to a total systems view of structures. Students interact with representatives of construction firms, both at Lehigh and at construction sites.

The ERC at Brigham Young and the University of Utah will continue research and education on the fundamentals of combustion, including development of a model that industry uses to control burning in boilers, furnaces, and waste incinerators. Industry works closely with the ERC to test this model on a range of real-time situations. The goal is to pollute less and burn material more efficiently.

Minority Centers

During 1989, NSF expanded one of its programs to enhance minority participation in the scientific and technical work force. The Foundation established five new Comprehensive Regional Centers for Minorities in California, Florida, Missouri, Pennsylvania, and Texas; these centers encourage and support minority students in science and math programs from kindergarten through college. Along with sites in New York City, Atlanta, and Puerto Rico, the new centers emphasize partnerships among colleges and universities, community groups, and local and state governments--to address the nationwide scarcity of most minority groups in science and engineering. The Foundation plans to launch 15 of these centers by 1991.

In addition to these comprehensive regional centers, which operate primarily at the pre-college level, the Foundation also supports a program called Minority Research Centers of Excellence (MRCE). This program aims to increase the quantity, and strengthen the quality, of NSF-supported research at key minority academic institutions. The MRCE effort is based on the premise that members of minority groups presently underrepresented in

Minority Research Center of Excellence. At the University of Texas at El Paso, NSF supports a multidisciplinary center for materials science. This grant promotes rapidly advancing research areas at institutions with 50 percent or more minority students.

research careers will enter such careers if they are made more attractive and accessible. MRCE complements another NSF program called Research Improvement in Minority Institutions (which supports specific research projects) by encouraging some of these institutions to undertake long-term efforts to develop into major research and training centers.

New Program to Link Chemistry, Chemical Engineering, Materials Research

Novel chemical approaches to the preparation and processing of advanced ceramic compounds have led to ceramic materials that are stronger, lighter, and can withstand higher temperatures than metals. Such properties offer promise that ceramics may one day replace metals as components of airplanes and auto and aircraft engines.

Traditionally, ceramics have been made under high temperatures and often at high pressures, using a process that can sometimes cause impurities or cracks in the material. Catastrophic failure of the ceramic part can result from such defects. But a novel method of making ceramics, metalorganic chemical vapor deposition, has far fewer problems. The process, a subject of worldwide research, yields a composite material which, upon heating,

Research Improvement in Minority Institutions (RIMI). Supported under the RIMI program, a Chicago State University biology student examines the chromosomes of the Aedes *mosquito.*

***Interagency collaboration.* A technician works on a neutron guide tube for the new Center for High Resolution Neutron Scattering. The center was established by NSF and the National Institute of Standards and Technology (part of the Commerce Department).**

decomposes into a preformed ceramic, with vastly improved properties. Other applications of fundamental organometallic chemistry are also leading to breakthroughs in areas such as high-temperature superconductors and advanced electronic materials.

A recent NSF initiative on materials chemistry and chemical processing supports collaborative studies of these and other novel routes to forming ceramics, high-temperature superconductors, electronic materials, and other compounds with unique properties--research that requires the complementary expertise of chemists, materials scientists, and chemical engineers.

Continuing the theme of an interdisciplinary approach to materials research, the National Research Council—with NSF and other support—conducted a comprehensive three-year survey of the relationship between materials science and engineering.[2] The study found some striking contrasts—for example, the field has had a series of rapidly emerging discoveries and applications, but

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[2] *Materials Science and Engineering for the 1990's,* National Research Council, 1989.

researchers predict a shortage of educated personnel. In addition, limitations on the supply of raw materials have already hampered progress.

The central message of the study challenges materials scientists, engineers, and policy makers, noting that the relationship between materials science and engineering opportunities is vital. Federal programs have taken the lead in treating engineering and materials science as related entities, but industry, academia, and government institutions must find new ways to coordinate these programs.

Physics, Biology Collaborations

A new NSF-funded institute has been established at Harvard University to help provide a focus for theoretical atomic and molecular physics, and to address the severe shortage of U.S. academic theorists in this area of study. Intended to support and educate talented graduate students in this active but underpopulated field, the Harvard-Smithsonian Institute of Theoretical Atomic and Molecular Physics focuses on such phenomena as classical chaos, in which microscopic disturbances in the initial motion of an object grow enormously until they lead to huge, random changes later. Institute physicists also attempt to understand better the atomic processes that determine the properties of plasmas--highly ionized gases contained within stars and created on earth in fusion energy experiments.

There are other research questions at the institute. Are the laws of nature any different for particles that appear identical but move as mirror images of each other? Do the laws alter if time runs backwards? Can we explain the direction of time? Theorists at the institute ponder such fundamental issues, which may sound strange and somewhat unreal, but turn out to have a profound and practical effect on unifying and understanding the four known forces of nature.

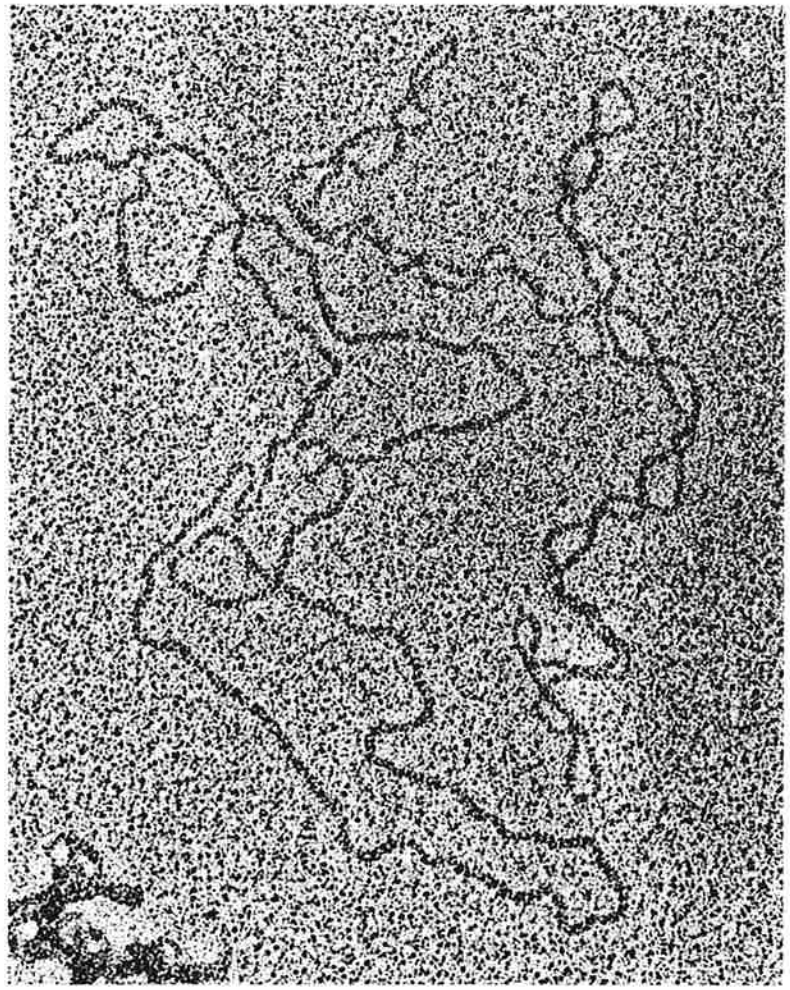
A new center for studying the atomic structure of materials using neutron beams was established by NSF and the Commerce Department's National Institute of Standards and Technology (NIST). Scheduled to open in 1991 at NIST headquarters in Gaithersburg, Maryland, the Center for High Resolution Neutron Scattering will use low-energy or "cold" neutrons to probe materials in a manner similar to X-rays. But because neutron beams penetrate to greater depths and interact differently with matter than do X-rays, they provide complementary information. The national center will feature two new state-of-the-art spectrometers to measure neutron scattering. It will be open to users from universities, industry, government, and nonprofit groups, both U.S. and foreign.

Industry and medicine both stand to benefit from a new national facility at Washington University in St. Louis, Missouri. This facility gives scientists the most advanced instrument available for determining the structure of biological molecules and experimental polymers. Researchers at the National Instrumentation Facility for Nuclear Magnetic Resonance of Biological Studies have been probing the atomic structure of biological molecules and living tissue with a magnetic system widely used for imaging the human body in medical diagnosis. The recent extension of the technique, known as nuclear magnetic resonance (NMR), for analyzing solids allows scientists to image insoluble biological molecules in their natural state.

By using NMR, biologists learn more about the structure of cell walls and membranes, and of skin and other tissues. Researchers then apply this knowledge to design more powerful drugs to treat cell disorders with fewer side effects. Investigators also rely on solid NMR to study experimental polymers, materials built up from repeating microscopic networks of organic chemicals. NMR allows scientists to determine whether the new polymers might be used as aerospace materials, electrical conductors, or biodegradable plastics.

New Radio Telescope at Green Bank

It took only minutes for a leading instrument in radio astronomy for 26 years to collapse suddenly on the evening of November 15, 1988. The 300-foot telescope in Green Bank, West Virginia, completed in 1962, was one of the world's largest single-dish instruments for detecting radio signals emitted from astronomical objects in our own Milky Way galaxy and beyond.



Untying DNA. Mathematicians and molecular biologists are working together to understand how knotted strands of DNA, shown here in an electron micrograph, untie themselves.

An independent study panel appointed by NSF and the Associated Universities, Inc., which manages the NSF-funded radio telescope, found that the fracture of a single, highly stressed steel plate was the likely cause of the collapse. The plate that failed was a key part of the telescope's support structure, and it was subjected to high stresses whenever the telescope swiveled to change direction. (The instrument was being rotated from one position to another when it collapsed.) The panel also found that stress on several other structural elements–including some rings and radial ribs of the telescope dish itself–was substantially higher than is permissible today.

Researchers recovered half of the plate from the wreckage; metallurgical analysis indicated that small cracks had developed in the plate even before it gave way. However, these cracks were in an area that could not be seen during regular visual inspections of the instrument.

Supplemental funds in NSF's FY 1989 budget are making possible the construction of a replacement telescope. Like its predecessor, this instrument is expected to further pioneering research and collaboration by astronomers throughout the United States and in many foreign countries.

X-Ray Snapshots from a Synchrotron

Using an intense beam of X-rays, biochemists at Cornell University's High Energy Synchrotron Source (CHESS) have made snapshots of an organic molecule in one ten-billionth of a second--an exposure time a million times shorter than had ever been achieved. The ability to take such fast pictures opens a new window on molecular structure and function, and could boost studies in such diverse areas as tracking enzyme reactions and custom-designing new drugs.

Keith Moffat, Wilfried Schildkamp, Donald Bilderback, and Marian Szebenyi used a special device to create a beam so powerful that diffraction pictures of organic compounds could be taken with a single burst of X-rays. Like a photographer's strobe, the bright beam enables scientists to make a snapshot using shorter exposure times.

The device used, a magnetic tool known as an undulator, is the product of work done in the academic, federal, and private sectors. It was designed by scientists from Cornell and the Argonne National Laboratory, a United States Department of Energy facility. The undulator was then built by Spectra Technology, Inc. of Bellevue, Washington. The tool is a prototype for several such devices planned for the new Advanced Photon Source at Argonne; when completed in the mid-1990's the facility will create X-ray beams 10,000 times brighter than are now commonly available.

Researchers tested the undulator by placing it in the Cornell Electron Storage Ring. They expect that the undulator-generated X-rays should help overcome the limitations of current X-ray imaging methods, allowing faster and more detailed pictures of proteins, viruses, and other large biological molecules. Researchers also plan to watch how enzymes rapidly change shape as they trigger chemical reactions. That knowledge may lead to development of compounds that are more effective enzymes than nature's own.

Mathematics and Biology: DNA Ties the Knot

In a novel collaboration made possible by a five-year, $2 million grant from NSF, mathematicians have teamed up with molecular biologists to study tangled features of DNA that have troubled life scientists for more than three decades.

Biologists have long been frustrated in their search for structural patterns hidden within the twisted coils that make up large DNA molecules. Problems arise in attempting to track the myriad knots and twists that occur within DNA strands, and in tracing the links and intertwinings between neighboring DNA strands. The geometry of these tangles helps trigger the biochemical reactions needed to translate the genetic blueprint into a complete plant or animal. But researchers have had great difficulty in classifying knots, distinguishing one shape from another, and answering the key question: Which life-sustaining reactions are associated with particular DNA tangles?

Using the language and equations of topology, a branch of mathematics that concerns itself with knots and links, mathematicians believe they may be unraveling the problem. Guided by topology, researchers hope to distinguish between DNA structures and to trace the thread between them and their associated biochemical processes.

If these efforts succeed, scientists should gain insight into cellular processes that together allow a microscopic egg to develop into an adult organism. Such events include the control of DNA reproduction during cell division, the ordering of genes on chromosomes, and mechanisms that control whether a particular gene is switched on or off.

Researchers in the NSF program also study proteins, the products of switched-on genes. Proteins possess structural features and functions that reflect little-understood patterns in the order of their molecular building blocks, amino acids. A better understanding of these relationships would aid scientists trying to decide which amino acids to string together to create new hormones and drugs.

This interdisciplinary NSF program, which initially involved scientists from nine research institutions, marked the first time that the Foundation's divisions of mathematics and molecular biosciences co-funded a large project. The program's primary goal, extending far beyond current projects, is to enable mathematicians and biologists to learn each other's language, setting the stage for mathematical techniques to be applied more and more to important biological questions.

International Collaboration: Ties with Soviets, Japanese

A Memorandum of Understanding between the NSF and the Soviet Academy of Sciences has created new opportunities for cooperative research in the basic sciences between the two nations.

Under the agreement, American and Soviet researchers may take advantage of the scientific expertise, facilities, and research sites of the two countries to address basic research problems of special mutual interest. The agreement targets specific areas of opportunity for mutual benefit in mathematics, theoretical physics, Arctic research, geosciences, chemistry, life sciences, basic engineering research, and science policy. This NSF-

Japan program: long-term visitor. Physicist Craig Van Degrift, National Institute of Standards and Technology, conducted research for a year at Japan's Electrotechnical Laboratory.

Soviet Academy program offers U.S. and Soviet researchers for the first time a means to submit jointly initiated research proposals for competitive review.

In other work with the Soviets, the United States responded to an invitation by the Soviet Academy of Sciences for American scientists to help in the wake of the devastating 1988 earthquake in Armenia. With major funding from NSF, 16 American engineers, seismologists, architects, and social scientists toured the disaster area in late 1988 in hopes of learning how to limit injury and loss of life from future earthquakes. The U.S. research team included experts from several government agencies, universities, and private industry.

Among the leading industrialized nations, growth in R&D expenditures has been particularly impressive in Japan. A recent NSF report presents an indepth comparison of U.S. and Japanese science and technology resources.[3] One of the more interesting findings is that, contrary to popular belief, less than 2 percent of industrial R&D funding comes from the Japanese government, compared to 35 percent in the United States. The government does, however, use various indirect mechanisms to support the R&D activities of Japan's industries. The ratio of Japan's company-funded R&D to gross national product has exceeded that of U.S. firms every year since 1970. In fact, in the industrial areas of ceramics, electrical equipment, textiles, iron and steel, and nonferrous metals, Japanese companies spend more than the U.S. firms even in absolute amounts.

To increase collaboration between American and Japanese researchers and improve U.S. access to Japanese laboratories and facilities, NSF--in cooperation with the Japanese government--has expanded opportunities for American scientists and engineers to do long-term research in Japan. During the period May 1988 to October 1989, NSF supported 20 Americans with Japan-U.S. Fellowships to spend six months or more in Japan. An additional 47 American scientists and engineers were nominated by NSF for 6-24 month postdoctoral awards supported by the Japanese government, for work at Japanese university or government laboratories.

In order to gain further access to Japanese scientific and technological information, NSF and Japan's National Center for Science Information (NACSIS) have established a telephone link between computers at NACSIS and the NSF offices in Washington, D.C. Through this link and computer equipment provided by NACSIS, U.S. researchers will be able to access several important Japanese scientific databases, including results of research grants, doctoral dissertations, and conference proceedings. This link, also providing an electronic mail system, should help to draw Japanese and foreign researchers closer together.

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[3] *The Science and Technology Resources of Japan: A Comparison with the United States,* NSF 88-318.

Chapter 2

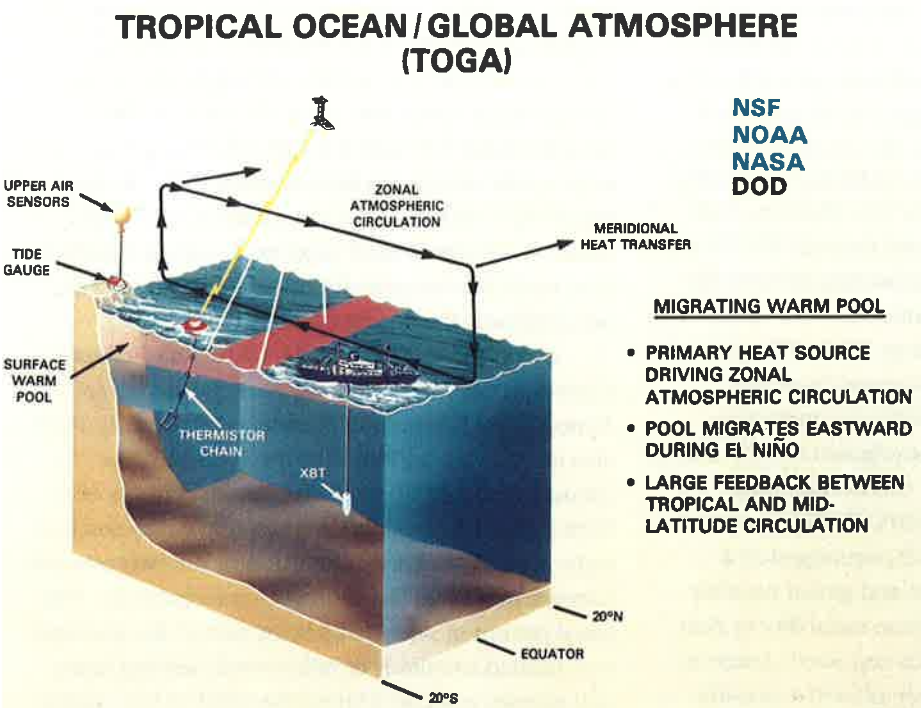
SPECIAL FOCUS: GEOSCIENCES/GLOBAL CHANGE

If the earth's changing weather patterns and variability in climate are our tutor, then researchers today have an unprecedented opportunity to learn more about our planet's processes and systems—and the links that inextricably bind them to our own activities. Global change is an ongoing process and many of its patterns are harmless, but some recent events may be grounds for concern. For example, periodic depletion of the protective ozone layer over Antarctica was greater than ever during 1989, the possible threat of global warming was highly publicized in the wake of a summer 1988 drought, and an NSF-sponsored report highlighted the ongoing loss of biological diversity in forests and wetlands.

These are some of the many phenomena investigated by the scientific community, with NSF help. Funding two-thirds of all basic research in atmospheric, ocean, and earth sciences at U.S.

Ocean research—one of the many geoscience areas supported by NSF

Woods Hole Oceanographic Institution



TOGA project: Investigating how the tropical Pacific Ocean influences global climate. Both the thermistor chain and the expendable bathy thermograph (XBT) profile water temperature.

universities, the Foundation supports such efforts as Greenland ice core drilling that can potentially predict future climate changes, analyses of ocean currents and their effect on weather patterns around the globe, and long-term ecological research at sites ranging from Arctic tundra to tropical forests. With the wealth of data collected, researchers are gaining more predictive power, increasing their ability to model future climate conditions and their impact on the planet. Such research is paramount for both understanding and protecting our environment.

NSF-supported research projects in global change have these main objectives:

• To advance knowledge of the earth's upper and lower atmosphere, including its chemistry and general circulation.

• To improve knowledge of the physical, chemical, geological, and biological processes in the world's ocean and at its interface with the atmosphere, the shoreline, the sea floor, and the earth's crust beneath.

• To improve understanding of the earth-system cycling of the key nutrient elements—carbon, nitrogen, oxygen, sulfur, and phosphorus.

• To advance knowledge of ecosystems and their dynamics, through better understanding of internal cycles and interactions among terrestrial, freshwater, and marine biota.

• To encourage, in the Antarctic and the Arctic, multidisciplinary research that explains regional and global climate phenomena.[1]

• To provide further insights into the physical, chemical, and geological characteristics and processes that produce such features as hydrocarbon and ore deposits and such cataclysmic events as earthquakes, volcanic eruptions, and landslides.

WOCE, TOGA: Two Global Change Projects

These goals lie at the heart of an extraordinary effort to study global change, an effort spearheaded by NSF along with several other federal agencies. Among the research projects is the World Ocean Circulation Experiment (WOCE), which has been planned since the mid 1980's and formally begins in 1990. Researchers from the United States and at least 20 other countries will examine the patterns of ocean currents and their effect on how the oceans absorb heat and store gases.

[1]See also chapter 4 for discussion of NSF's safety, environment, and health initiative in Antarctica.

Combining observations from satellites, ships, and instruments that drift in the water or are fixed to stationary moorings, WOCE will help gather the data needed to build reliable computer models of such processes as the accumulation of carbon dioxide in the atmosphere and ocean. In addition to providing new data and fertile ground for new theories, state-of-the-art instruments developed through WOCE will help generate a network of monitoring systems for future international experiments.

Another program, known as TOGA (Tropical Ocean/Global Atmosphere), focuses on ocean phenomena in the tropical Pacific that influence global climate conditions. Coordinated by NSF and three other federal agencies,[2] this decade-long international study began in 1985. TOGA comes at a time when the tropical Pacific has emerged as a profound influence on climate and global weather patterns—ranging from monsoon variability in Asia and Africa to droughts in Africa and South America. TOGA researchers have already offered a possible explanation for the summer 1988 drought that devastated crops in the U.S. midwest.

El Niño and La Niña. The drought's chief sources, some researchers have proposed, were naturally occurring climatic forces in the tropical Pacific Ocean, rather than global warming caused by atmospheric pollutants. These same forces may also account for the 1988 record floods that killed more than a thousand people in Bangladesh. Researchers have found that the tropical Pacific is the source of two turbulent global weather phenomena: El Niño, a system that transports warm water and wind from the western Pacific, and its counterpart, La Niña, which brings unusually low temperatures to the eastern Pacific. The two phenomena are the chief components of a giant weather system known as the Southern Oscillation, which links the ocean and atmosphere in the Pacific.

The system is part of a giant heat pump, taking energy from the equator and distributing it to higher latitudes through storms over the warm western Pacific. La Niña, researchers believe, exaggerates the normal functioning of the Southern Oscillation, creating extremes in weather. Stronger than usual easterly trade winds that occur during a La Niña episode cause the eastern Pacific off South America to be colder and ocean temperatures in the western equatorial Pacific to be warmer than normal. As a result, investigators have proposed, coastal deserts in Peru and Chile became drier than usual and floods occurred near the equator during 1988.

According to *Kevin Trenberth*, chief of climate analysis at the NSF-supported National Center for Atmospheric Research in Boulder, Colorado, La Niña also may have contributed to the 1988 summer drought in the midwest. When the cold fronts of La Niña crossed the path of an unusually warm patch of water near Hawaii, the interaction of the two weather patterns may have had dramatic consequences: The usual pattern of storms that bring rain to the midwest was pushed hundreds of miles north, leaving farms and prairies to sizzle without the relief of rain during the summer of 1988.

Carbon Fluxes Increase

Yet another type of pattern underscores the link between the atmosphere and the oceans. Although scientists have confirmed that burning oil and other fossil fuels, along with the destruction of forests, has increased the amount of carbon dioxide in the atmosphere—causing less energy to radiate into space and more back toward earth—much remains to be learned about the removal of excess carbon from the atmosphere. For example, a group of one-celled organisms on the ocean surface may exert a more powerful influence on the carbon cycle than human activity does.

With the annual spring bloom of algae and other phytoplankton, carbon dioxide is absorbed from the atmosphere as these organisms undergo photosynthesis, the energy-producing process on which they thrive. After the bloom, the plant cells that haven't been eaten by predators succumb to the dwindling sunlight and reduced nutrients on the ocean surface, sinking to the bottom and taking with them large amounts of carbon. The feces of marine plant eaters also contain carbon and sink to the bottom as well.

[2]Department of Defense, National Oceanic and Atmospheric Administration (NOAA), and National Aeronautics and Space Administration (NASA)

Simply put, ocean sediments are a giant storehouse for the world's carbon, and changes in the annual bloom and later decline of phytoplankton that contribute to this deposition of sediments might profoundly affect the world's climate by slowing or increasing the removal of carbon from the atmosphere. Such phenomena offer a particularly striking example of what scientists call a biogeochemical cycle—the sequence of events involving the movement of chemical elements, such as carbon, through the atmosphere, the land, the oceans, and their sediments.

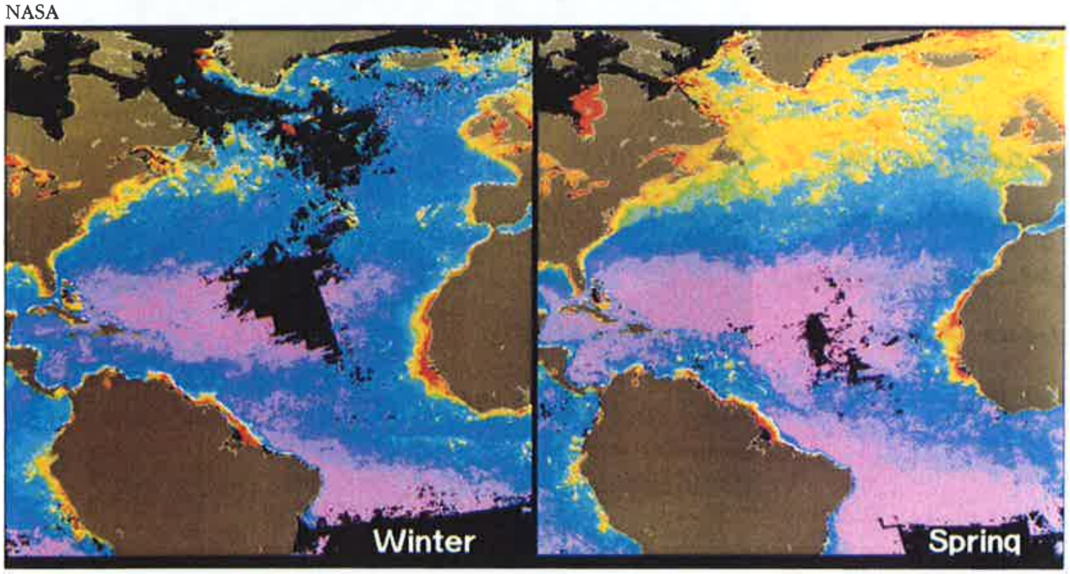
These and related studies are the focus of the Joint Global Ocean Flux Study, an NSF-sponsored international research project that has reported preliminary results of a pilot study. For eight months during the winter, spring, and summer of 1989, teams of researchers from the United States, Great Britain, Holland, Germany, and Canada converged on a region of the North Atlantic Ocean 600 miles off the Azores to study the annual cycle of marine plants. Winters in the North Atlantic are frigid and the winds are merciless, but the processes heralding the spring bloom of marine plants are simplest to understand there. The stage is set during these coldest months, when the surface water temperature matches the normally colder layers of the ocean below. Water layers of equal temperature mix easily, and nutrients hidden below rise to the surface. In spring, the winds abate, the sun's rays intensify, and the "seeds" of the ocean—diatoms and other single-celled plants—reproduce and bloom, tingeing the blue of the winter waters with specks of green.

Using ships, satellites, and aircraft to monitor the spring bloom—along with both moored and drifting instruments to measure the amount and rate of sediment accumulated as the phytoplankton died—scientists found some surprising results in preliminary experiments. The North Atlantic bloom lasted longer than expected, and it appeared to be driven by several varieties of single-celled plants, according to biologist *Hugh W. Ducklow* at the University of Maryland's Horn Point Environmental Laboratories. Investigators found that diatoms (phytoplankton that thrive on silica) led the bloom's beginning in late winter, and the scientists succeeded in measuring rates of photosynthesis as it occurred—a challenging feat in open waters.

Atmospheric Research Projects

At the National Center for Atmospheric Research (NCAR), scientists have been using coupled global models of the atmosphere and oceans to investigate climate change due to increased carbon dioxide

NASA



***Spring bloom.** Satellite images measure seasonal changes in phytoplankton growth in the North Atlantic. Red and orange indicate high concentrations, yellow and green represent moderate levels.*

concentration. In using more realistic ocean models, they have found that the regional patterns of climate change are much more complex than previously thought. For example, they note that the North Atlantic and North Pacific Oceans can cool and the continents can warm—a scenario not unlike the climate change patterns presently observed. Thus, the simple picture of global warming evident in earlier studies may be far from correct. Obviously, NSF-supported researchers must continue to work toward more realistic and more interdisciplinary climate models.

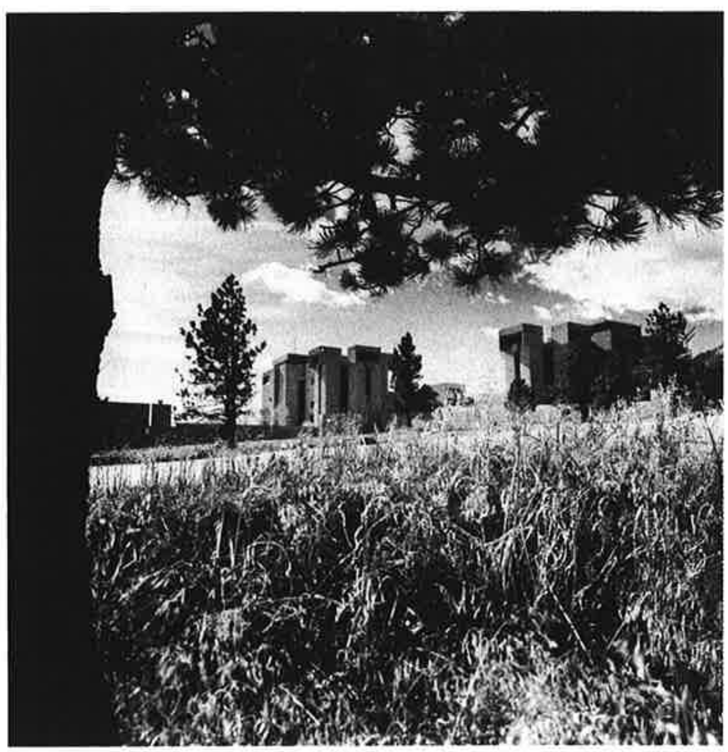
The Global Tropospheric Chemistry program (GTCP) is a high priority under the NSF Global Geosciences Initiative started in FY 1987. An immediate goal of this program is the effort to measure, understand, and predict changes over the next century in the chemistry of the global atmosphere, with particular emphasis on changes affecting the oxidizing capacity and radiative properties of the atmosphere and the biogeochemical cycles of elements through the atmosphere.

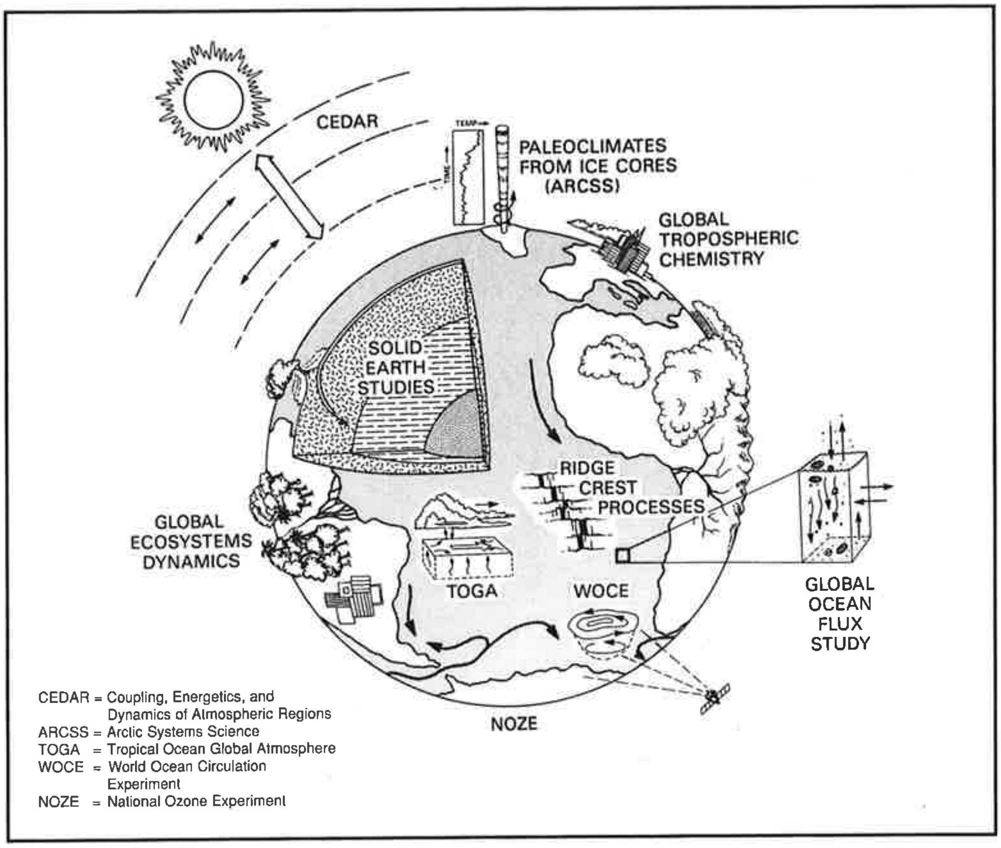
Recent GTCP research has led to improved instrumentation and models for describing and studying atmospheric chemistry. Such research also has provided new insights about how the chemistry of the global atmosphere may respond and contribute to changes in the earth's climate system. A series of special studies in the Atlantic and Pacific, carried out in recent years, suggests that anthropogenic sources of reactive compounds such as the nitrogen and sulfur oxides can influence, on a hemispheric or global scale, the chemical oxidation processes through which the atmosphere cleanses itself of waste products—both natural and human in origin.

Yet another NSF effort in atmospheric sciences is the CEDAR program (Coupling, Energetics, and Dynamics of Atmospheric Regions). CEDAR combines observations, theory, and modelling activities to link the various regions of the upper atmosphere (above 4 miles) in terms of coupling, energetics, and dynamics on regional and global scales.

Recent CEDAR modelling studies have suggested that stratospheric changes due to increases/decreases in some of the greenhouse gases will have a major impact on the density altitude distribution of

The National Center for Atmospheric Research–site of global modelling efforts and other NSF-supported research





Examples of NSF-backed projects in global change and the geosciences

the major atmospheric constituents above 6 miles. The study of this impact may lead to a more definitive determination of the incidence of global change than is obtainable from measurements of trace gases at lower altitudes. (There the gases are small fractions and their changes are masked by more localized effects.)

Drilling into Ice; Listening to Quakes

In other studies expected to add knowledge about global processes, researchers dig into the earth to uncover clues to our planet's early history and climate. U.S., French, and Soviet researchers, for example, studied ancient gases trapped in segments of an Antarctic ice core. The trapped gases in this core from the Soviet Vostok Station provide a record of the earth's atmosphere from 160,000 years ago and may yield information to develop models of future climate changes.

In central Greenland, NSF-supported researchers have launched the most ambitious U.S. drilling effort ever to recover in ice cores a history of the earth's climate spanning more than 200,000 years. Ice core samples collected from the Greenland site, which eventually will reach some 10,000 feet down, have already revealed remnants of past volcanic eruptions. From the deposit of sulfates in snow layers near the surface, researchers have traced annual winter increases in North American and northern European fossil-fuel burning.

Researchers in 1989 brought to 18 the number of state-of-the-art seismological systems that can listen to the earth's rumblings over a wide range of frequencies. As the major funder of a university consortium of seismologists known as the Incorporated Research Institutions of Seismology (IRIS), NSF supports the group's goal of establishing a network of 100 stations worldwide. Such a network may provide new details of the process that triggers an earthquake, and would help to locate its epicenter and predict the intensity of aftershocks.

Within hours of the San Francisco earthquake of October 17, 1989, IRIS scientists flew sophisticated instruments to the site; others recorded shock waves from the quake at research stations in the west and midwest. These scientists helped determine that the quake (which killed 67, injured more than 2,800, and caused an estimated $7 billion in damage) had not relieved stress stored in the ground there, leaving the region vulnerable to even more upheaval in the coming decades. But while short-term predictions of earthquake activity are still uncertain, new measuring techniques and devices can determine the likelihood that a particular section of a fault is earthquake prone.

Paul Mayewski

***Ice research.* Sleeping quarters in Summit, Greenland for scientists studying ice cores**

***Frozen record.* Measurements of chemicals trapped inside Greenland ice cores are revealing the earth's past history.**

Earlier, following the devastating Armenian earthquake in the fall of 1988, NSF had dispatched a team of scientists to the Soviet Union to work with scientists there on gathering data that perish quickly in the aftermath of a quake. Those data may help to predict and locate future earthquake activity.

Polar Research

Since the mid-1980's, NSF has led an interagency committee that directs U.S. research efforts in the Arctic. These efforts, outlined in a 1989 report,[3] increasingly emphasize the global impact of regional phenomena in the Arctic. These include the effect of sea ice and seasonal snow cover on global radiation, the consequences of atmospheric carbon dioxide stored in Arctic land and waters, the effect of transferring heat from the ocean to the atmosphere, and how the shift in mass between regional glaciers and ice sheets might change global sea levels.

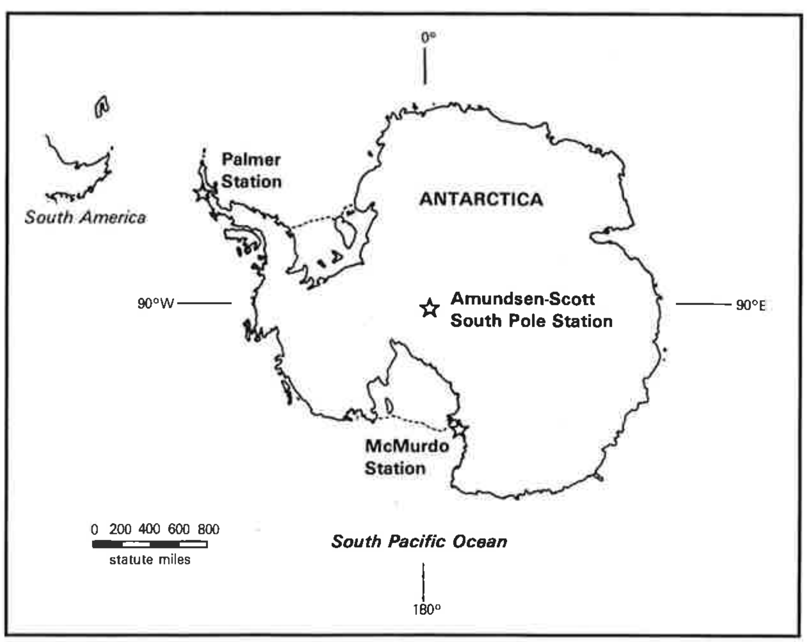
NSF also manages all U.S. research activities in Antarctica, the coldest of continents. Perhaps the biggest and most disturbing piece of research news from the frozen continent during 1989 was the severe ozone depletion in the Antarctic stratosphere, rivalling the "ozone hole" of 1987.[4] Stratospheric ozone protects life by absorbing harmful ultraviolet radiation from the sun; ozone depletion allows more ultraviolet light to reach earth.

Four years of expeditions supported by NSF, NASA, and NOAA have demonstrated that industrially produced chlorofluorocarbons (CFC's)—used mainly in refrigeration, air conditioning, and solvents—cause the annual Antarctic ozone hole, which has occurred each September and October since the late 1970's. More recently, a research team led by *Philip Solomon* and *Robert de Zafra*, from the State University of New York at Stony Brook, pinpointed the process through which CFC's destroy Antarctic ozone. The group reported it had confirmed that a single chemical mechanism involving chlorine from CFC's dominates the process of ozone depletion; bromine from CFC's, which scientists had thought was also important, actually plays a minor role. This work verifies the hypothesis of *Mario Molina*, at the Jet Propulsion Laboratory in Pasadena, California, that the molecule chlorine monoxide, formed when chlorine destroys ozone, combines with other identical molecules to speed ozone depletion.

Polar research

[3]*Arctic Research of the United States*, Fall 1989, vol. 3, Interagency Arctic Research Policy Committee

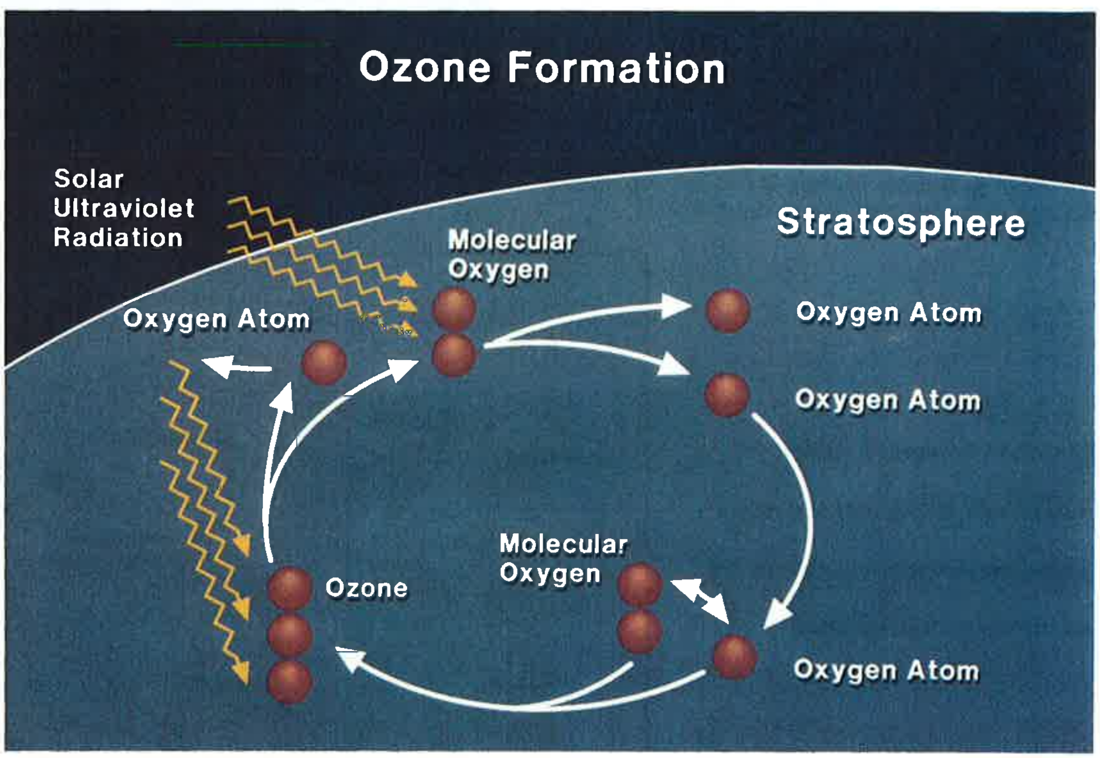
[4]In contrast, an ozone hole that appears over the Arctic region near the end of its winter is far smaller; only 3 percent of the usual ozone supply is depleted. Scientists believe the shallower Arctic hole occurs because the polar air mass there mixes far more with the surrounding atmosphere, causing ozone-depleting chemical reactions to start and stop instead of building up continuously as at the South Pole.



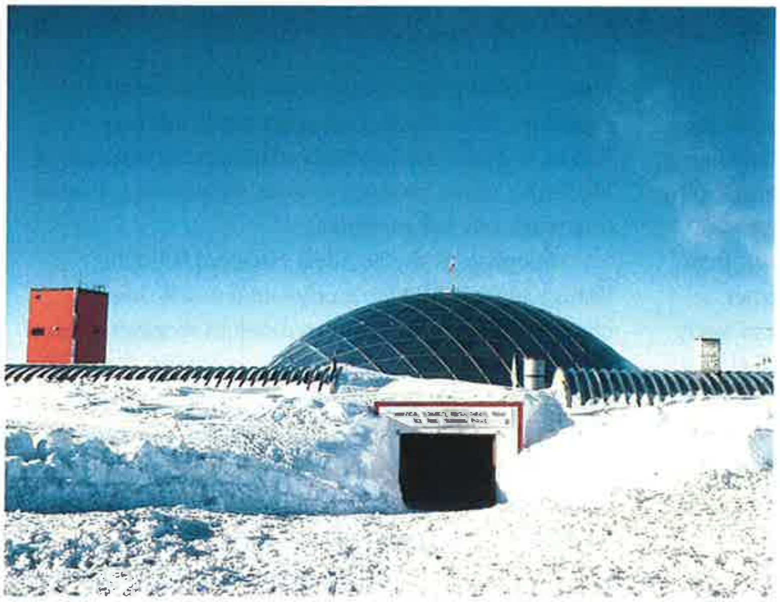
Antarctica–the world's coldest continent and site of a broad range of global geoscience research (map shows three NSF stations)

The Antarctic ozone hole, which lasts for only two months out of the year, begins at an altitude of 12 miles and extends to 20 miles.

Research on ozone depletion is just one of more than 95 projects that drew some 340 scientists and technicians to the Antarctic region in 1989. Atmospheric research, astronomy, biology, earth sciences, and studies of the nearby oceans remain the broad topics of U.S. research in both the Antarctic and Arctic. During 1989, investigators in the two regions examined the impact of oil spills on marine populations, continued their efforts to understand how nutrients sustain life in frigid waters, and carried on long-term research to understand natural processes and phenomena in both polar environments.



***Protective layer.* Complex chemical reactions form and destroy ozone in the upper atmosphere.**



Polar research at the Amundsen-Scott South Pole Station

Cornelius Sullivan, USC

Cold crustacean. Unusually large numbers of shrimp-like krill thrive during the frigid Antarctic winter. They are a major food source for other animal life in the region.

Craig Peterson, U.S.Navy

Young Scholar at South Pole. Catherine Anne Blish participated in polar research under NSF's Young Scholars program. Its aim is to further an interest in science and engineering careers among high-potential or high-ability students in secondary schools. Blish is from Saratoga, CA.

Biology's Role

Biological studies in polar and other environments highlight the roles that diverse organisms and ecosystems, such as forests, deserts, and tundra, play in global climate and evolution. Through international cooperation, for example, NSF support gives U.S. scientists access to ecological sites in other regions of the world. And through support of such programs as Long-Term Ecological Research (LTER) sites, begun in 1980, the Foundation fosters studies of coastal pollution, deforestation and tree death, sea-level rise, and acid rain—projects that require years of research and follow-up in order to measure ecological change. At LTER sites, scientists study the effects of climate change on ecosystems, the processes underlying how biological systems control the concentration of atmospheric gases, and the interactions of plants, animals, and microorganisms in a given environment.

During 1989, NSF established three new LTER sites. These included a rain forest in Puerto Rico; a New Mexico site encompassing deserts, grasslands, and forest; and a forest in Massachusetts. The Luquillo Experimental Forest in Puerto Rico is the first tropical rain forest under the LTER program. Research at this lush 28,000-acre area focuses on the impacts of hurricanes and other weather-related disasters. In addition, biologists study the way plants, animals, and bacteria maintain the balance of life in this richly productive area, despite heavy rains that wash out soil nutrients.

Scientists at the Sevilleta National Wildlife Refuge in New Mexico study—in a much drier climate—the way yearly variations in weather affect deserts, grasslands, and high piñon forests. Because the region receives little rainfall and has poor soils, it is acutely sensitive to weather changes. Researchers plan to use data gathered from this huge, 250,000-acre region to model, by computer, ways in which climatic changes might alter these ecosystems.

Investigators have studied the ecology of the Harvard Forest of central Massachusetts since 1907. The current NSF-supported study examines the forest-wide impact of trees blown down by high winds, such as hurricanes. By cutting trees in a pattern characteristic of a major storm, researchers study the processes of tree decomposition, nutrient recycling, and regeneration that would be expected to follow a tree blowdown. Ecologists also examine the impact of fertilizer runoff and pollutants on the flow of nutrients through this hardwood forest.

Other ecosystem studies supported by NSF ex-

Long-Term Ecological Research site. University of New Mexico biologist James Gosz collects insects and small animals in this trap at the Sevilleta National Wildlife Refuge.

Prairie research. Biologist Kathleen Keeler, from the University of Nebraska/Lincoln, has studied the Konza Prairie, a Long-Term Ecological Research site in Kansas.

amine specific research issues in global change, such as contributions to the greenhouse effect of atmospheric warming, caused by the accumulation of gases that trap the sun's heat. *Paul Steudler, Richard Bowden,* and *Jerry Melilo* at the Marine Biological Laboratory in Woods Hole, Massachusetts—along with their colleague *John Aber* at the University of New Hampshire—have reported that nitrogen fertilizers may add to the greenhouse effect because they prevent soil microbes from absorbing atmospheric methane, one of the most important greenhouse gases. The scientists found that soil bacteria treated with nitrogen fertilizer took up far less methane than untreated microbes.

Methane, which accounts for about one-fifth of the greenhouse gases that trap solar heat, constantly accumulates in the atmosphere from decaying vegetation in wetlands and swamps and from termites, among other sources. The Woods Hole-New Hampshire researchers, who did their work in yet another Massachusetts forest, also found that temperate forests in the Northern Hemisphere may play a much larger role than do tropical forests in removing methane from the air.

Many NSF-supported research projects in the biological sciences examine the loss of biodiversity and the conservation and restoration of natural ecosystems. These studies were underscored by a task force report that called on NSF and other U.S. institutions to lead an international research effort to save the world's ecosystems and halt rapid species extinctions. The report,[5] issued by the National Science Board (NSF's policy-making body) and internationally known experts, highlights proposed NSF efforts to educate the public about the decline in biodiversity; it also emphasizes the need for international cooperation in this research.

"Unless the international community can reverse the trend," the report states, "the rate of extinction over the next few decades is likely to rise to at least 1,000 times the normal background rate of extinction, and will ultimately result in the loss of a quarter or more of the species on earth."

The report concluded that NSF should lead efforts to identify and classify the world's animals, microbes, plants, and fungi, to understand better the complex ecosystems in which they live, and to expand human resources to carry out these tasks. The report also recommended more funding throughout the federal government to strengthen the scientific knowledge that underlies research efforts, along with better public education about the issues. Schools and museums should emphasize awareness of biological diversity. Teaching young students about biological and environmental subjects "is now as important to the national interest as early education in mathematics and other sciences," the report noted.

Hand-in-hand with such recommendations comes the realization that issues of biodiversity and global change are both a scientific concern and a public policy issue of far-reaching importance. In recognition of this dual role, NSF has launched a new program, Human Dimensions of Global Environmental Change. Using the insights and perspective of social scientists, this program helps identify human and institutional actions that can cause changes in our environment. Research supported by this initiative may also suggest ways to moderate and manage the environmental consequences of actions already taken.

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[5] *Loss of Biological Diversity: A Global Crisis Requiring International Solutions,* August 1989

Chapter 3

SPECIAL FOCUS: EDUCATION AND OUTREACH

Bear in mind that the wonderful things you learn in your schools are the work of many generations....All this is put into your hands as your inheritance in order that you may receive it, honor it, add to it, and one day faithfully hand it on to your children.

Albert Einstein in a talk to school children

Educating both students and the general public about science and engineering is one of the Foundation's chief missions. Through a broad range of education programs--some of them highlighted in this chapter--NSF works to strengthen the quality, diversity, and number of U.S. scientists and engineers. The Foundation also aims to improve the overall quality of science and math education for *all* U.S. students. And, through its outreach efforts, the Foundation strives to inform the public about science and technology in our increasingly complex age.

Facing Education Issues

Just one week after the National Research Council issued an NSF-funded report[1] calling for a complete overhaul of U.S. math education (see "Math Focus" below), another study highlighted problems in both math and science skills. An international comparison of those skills showed that American 13-year-olds scored far worse than their South Korean counterparts. U.S. students also performed worse or no better than students from the three European countries and four Canadian provinces that participated in the study.

In mathematics, for example, 40 percent of South Korean students showed an understanding of measurements and geometry concepts, compared to just 9 percent of the Americans. In science, more than 73 percent of the South Korean students could use scientific methods to analyze science data, including designing experiments and drawing conclusions. But only 40 percent of the American students had these skills, according to the study, which was co-funded by NSF and the Department of Education and administered by the Educational Testing Service.[2]

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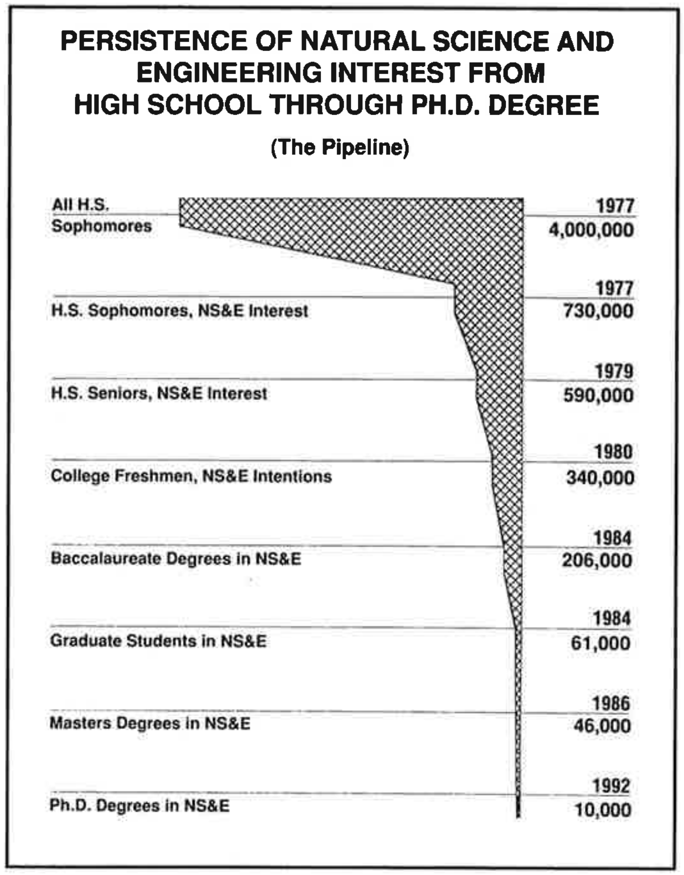
[1] *Everybody Counts,* 1989, National Research Council
[2] *A World of Difference,* 1989

NSF



Persistence of U.S. student interest in natural science (NS) and engineering (E) from high school (HS) through Ph.D. degree (Numbers rounded to nearest thousand, 1992 figure estimated)

Another concern, this time at the university level, is the *quantity* of graduates in science and engineering. An annual NSF survey[3] found that U.S. universities awarded a record 20,257 doctorates in science and engineering during 1988. However, that number reflects only a small (2 percent) increase in U.S. citizens earning doctorates, compared to a 9 percent rise for foreigners. Moreover, an unprecedented 13 percent jump in engineering degrees was primarily fueled by foreign citizens, who accounted for 54 percent of those doctorates.

Although scientists and engineers comprise only 4 percent of the U.S. workforce, they contribute enormously to our nation's strength, vitality, and economic competitiveness. Thus our nation continues to face the challenge of attracting more U.S. students to science and engineering.

Finally, in an increasingly technological society, the scientific literacy of the general population is important to ensure necessary job skills and continued support for scientific research. Literacy and public attitudes toward science and technology are monitored in the National Science Board's series of reports, *Science and Engineering Indicators*. Recent data from that series show that, although a significant number of Americans believe that the world is better off because of science, many still believe that the sun circles the earth (21 percent) and that humans lived at the time of the dinosaurs (37 percent). By comparison, significantly higher percentages of citizens from 12 European communities were better informed on those topics.

One Response: Project 2061

Several of the nation's largest scientific organizations have unveiled a sweeping project to revamp school curricula. The goal of this project is to overcome serious deficiencies in the science and mathematics skills of U.S. students. Supported by NSF and several private and government groups and coordinated by the American Association for the Advancement of Science, Project 2061 began in 1985, the last time Halley's comet approached the earth, and is named for the year in which the comet will return.

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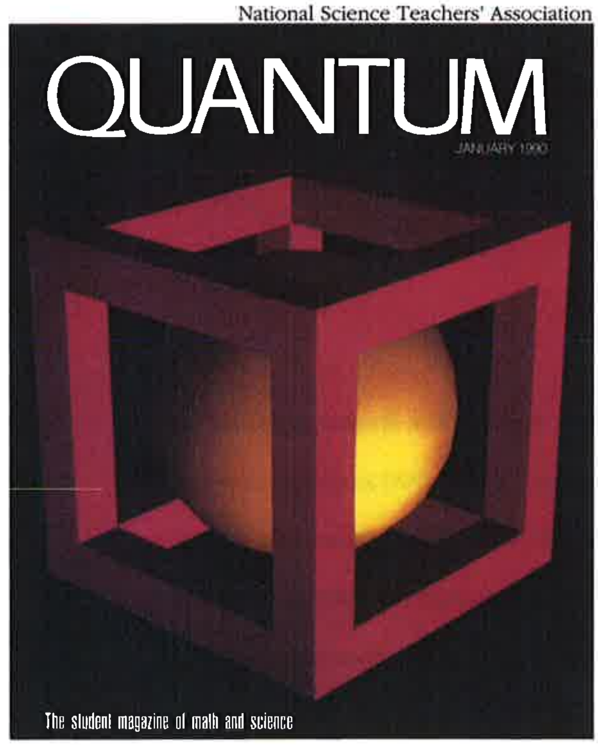
[3]*NSF Survey of Earned Doctorates,* NSF/Science Resources Studies, 1988



Quantum leap. The first issue of* Quantum, *a magazine for high school students in science and mathematics

The plan outlined by Project 2061 differs from previous attempts to address school system problems by simply rewriting textbooks or training teachers, such as occurred after the 1957 launch of the Soviet satellite Sputnik. Instead, the project seeks to develop a new approach to teaching, including the possibility of eliminating regular subjects and ending standardized tests. Teachers would guide students through projects that include not only science and mathematics, but related aspects of literature, economics, and history.

Under Phase I of Project 2061, scientists spent four years writing a detailed outline on the kind of knowledge about science and nature that a student should have by the end of high school.[4] Researchers announced in 1989 the beginning of a second four-year phase of the project, in which teams of teachers from 12 school districts in 5 states are outlining new curricula, tests, and student schedules. Under Phase III, to begin in 1993, scientific societies and educational organizations will begin a nationwide effort to make the educational blueprints developed in Phase II part of the backbone of U.S. school systems.

Math Focus

The year 1989 also saw major efforts to focus on mathematics and to revise the way this subject is taught. Working through two mathematics panels of the National Research Council (the research arm of the National Academy of Sciences), more than 70 educational organizations recommended less rote learning and a stronger emphasis on problem solving and understanding fundamental concepts, as well as more use of calculators and computers.

Dovetailing with this ambitious initiative, the National Council of Teachers of Mathematics provided a detailed set of teaching standards for the proposed new curriculum, and a report by the Mathematical Sciences Educational Board spelled out suggested course revisions.

The current reforms allow and encourage schools to have great flexibility in designing programs. Moreover, much of the new approach was written by and in consultation with math teachers who experience daily the travails and triumphs of reaching out to students.

NSF Responses: Precollege Activities

New Children's Magazine. High school students interested in science and mathematics now have their own magazine, *Quantum,* published by the National Science Teachers Association with funding from NSF. Modelled after a popular Soviet science magazine that features physics and mathematics articles and many problem-solving activities for teenagers, *Quantum* is intended to attract students to science careers by sparking their natural curiosity and tapping their creative thinking. Editors from the Soviet magazine contribute translated articles and original illustrations so that U.S. students can learn about research in the Soviet Union. The magazine's first issue appeared in late 1989.

Chemicals in the Classroom. How would you demonstrate the concept of one part per million? Never mind the chalkboard. At the

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[4] *Science for All Americans,* Project 2061, American Association for the Advancement of Science

University of California at Berkeley's Lawrence Hall of Science, they use food coloring, water, and a medicine dropper. Youngsters from nearby middle schools add 10 drops of a watery solution of food coloring into the first paper cup. Into the second cup goes one drop of food coloring from the first cup and nine drops of pure water—already a 1 in 10 dilution. Eventually, the students achieve for themselves a one part per million concentration of the food dye.

This activity is an example of the Chemical Education for Public Understanding Program operated at the university. The program, which receives NSF support, also involves development of middle school curriculum modules that include hands-on chemical analyses and exercises in risk assessment.

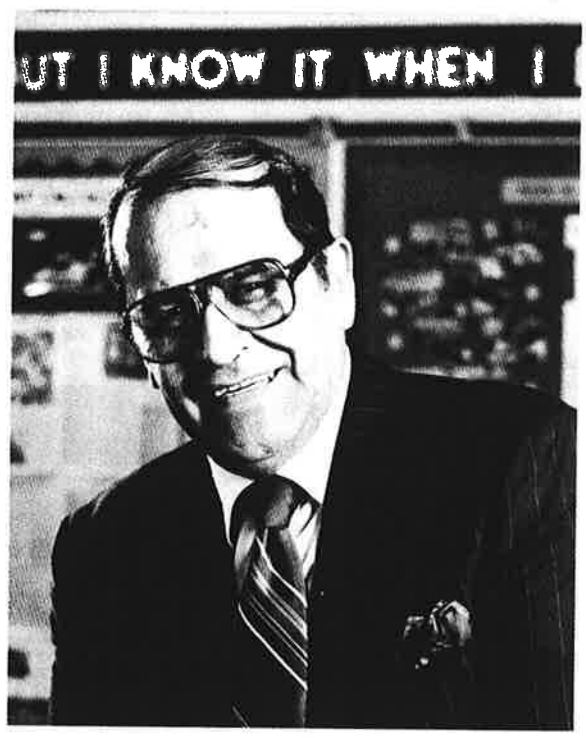
Escalante's Work Expands. NSF is supporting a project to expand the pioneering work of high school math teacher Jaime Escalante, who motivates inner-city minority students to become involved in science and mathematics. Escalante's highly successful calculus program at Garfield High School in east Los Angeles has won national acclaim and was the subject of *Stand and Deliver,* a 1988 feature film. The new three-year award from the Foundation builds upon the calculus activity to include additional mathematics programs.

This project also enables Escalante to be a role model for other teachers in physics, chemistry, and computer science. Under the direction of Escalante and five other instructors whom he has trained, 27 teachers will receive special instruction at Los Angeles Community College during summers, after school, and on weekends. Some 700 middle and senior high school students will benefit from classes taught by these teachers, and they will earn academic credit for their participation.

Detroit Youngsters Prepare for Careers. Since 1976, a coalition of Detroit-area public schools, local businesses, parents, community groups, and universities has worked to ensure that minority students who show a special interest and ability in math and science receive the training, guidance, and support they need to succeed in college-level engineering studies. Through special courses that bolster their understanding of basic

E. Christelow

Learning activity. At the Lawrence Hall of Science, students learn about chemistry through the Chemical Education for Public Understanding Program.



Master teacher. Jaime Escalante motivates Los Angeles high school students to learn mathematics.

math and science concepts, after-school tutoring, a mentor program that draws community leaders into the school system, and a summer job program for seniors, some 1,800 middle and high school students learn about engineering both as a course of study and as a career.

Another key element of the program, known as the Detroit Area Pre-College Engineering Program (DAPCEP), is the Parents Advisory Committee. This group of volunteer parents met every Wednesday evening and Saturday morning for five months to develop a proposal for NSF funding. The $621,000 grant that NSF awarded in 1985, the largest in DAPCEP's history, has helped develop a middle school curriculum guide and related videotapes, along with mathematics materials that supplement standard courses for eighth and ninth graders. The materials help the students to close knowledge gaps critical for success in algebra. An additional NSF grant helped produce videotapes that feature master teachers presenting key concepts in mathematics.

The numbers speak well of DAPCEP's success. More than 128 of the program's students have graduated college, and 12 have pursued post-graduate study. More than 570 students have

Nicholas Wilhelm

Detroit's pre-college program: Fostering interest in engineering careers. Here a middle school student works on a science fair project.

enrolled in college, 70 percent of them in science, mathematics, or engineering programs. And a 1988 report from the U.S. Department of Education cited DAPCEP as one of the most effective pre-college education programs in the country.

Eyes on Arkansas. NSF awarded the state of Arkansas a $1 million grant to upgrade the way mathematics is taught and learned in grades two through six of the state's public schools. Sponsored jointly by the Arkansas governor's office and the University of Arkansas at Little Rock, the undertaking, known as Project MAST (Mathematics and Science Together), aims to enhance students' understanding of the ways that science studies relate to mathematics.

Under Project MAST, 120 elementary school teachers attend summer training institutes that stress techniques for integrating math and science courses rather than teaching them as separate, unrelated subjects.

This project began as a privately funded, four-year program for gifted students in three school districts in and around Little Rock. Thanks to the NSF grant, the program is expanding over a four-year period to 15 Arkansas school districts, with a special focus on sparking the interest of students who are minority or female. These two groups will make up an estimated 85 percent of entrants into the workforce by the year 2000, yet they often stop studying math and science long before career choices are made.

University-Level Activities

An Experiment in Engineering Curriculum. With the support of NSF, Drexel University and eight other universities have become part of an experiment that promises to improve significantly the quality of education for undergraduate engineering majors. The experiment involves revising the standard courses taken by engineering students during their first two years of study, to show more clearly the way different disciplines of science relate to engineering. The goal, according to Drexel officials, is "integrating the teaching of engineering fundamentals with math, basic sciences, engineering sciences, and lab work."

Faculty members tie together subjects such as physics, calculus, materials research, circuit theory, and chemistry rather than treating them as separate entities. In the process of viewing a variety of courses in relation to engineering, students gain insight into how engineering subfields fit to make up the field as a whole. Others taking part in this project are Texas A&M, Purdue, the University of Michigan, MIT, the University of Pennsylvania, West Virginia University, the University of Texas, and California Polytechnic State University, along with the American Society of Mechanical Engineers.

Undergraduate Research Opportunities. Hands-on participation in research supported by NSF has increasingly become an integral part of the undergraduate experience in such fields as physics, astronomy, biology, chemistry, and engineering. Supervised research introduces college students to the world that lies ahead and gives them the chance to learn one-on-one from a faculty mentor. And a little experience can go a long way, noted one undergraduate who spent a recent summer working at Indiana University's cyclotron. "My view of physics and the world has widened so very much," the University of Chicago student wrote. "My life has truly been altered. I know now what I have to learn for graduate school and what I can expect there. I've seen what research is...."

Training Across Boundaries. The biological, behavioral, and social sciences have undergone great changes in approach and research methods during the past decade. Increasingly, frontier research in these fields overlaps with other disciplines such as engineering, physics, chemistry, or computer science. An NSF program begun in 1989 recognizes those changes by encouraging scientists at Ph.D.-granting institutions to devise new or enhanced training programs for students in the biological, behavioral, and social sciences. In applying for funds from the program, known as the Research Training Group awards, universities must propose projects that stress multidisciplinary research training. The goal is to ensure that new generations of researchers—undergraduates, graduate students, postdoctorals—can skillfully apply a variety of approaches to research problems that increasingly cross traditional academic boundaries.

Minority scholars. At Jackson State University, NSF supports student research in the ocean sciences through its Research Careers for Minority Scholars program.

These two electrical engineering students (seated) and their professor (standing) are at Texas A&M University. They are studying under NSF's Research Careers for Minority Scholars program.

Minority Scholars. Minority groups are underrepresented among the ranks of scientists and engineers, and NSF has a number of programs to address this deficit. One of them assists 10 colleges and universities in enriching academic and research opportunities for minority undergraduate and graduate students. The program, Research Careers for Minority Scholars, emphasizes innovative projects that can significantly increase the chance of minority students pursuing science and engineering research.

A grant to Jackson State University in Mississippi, one of the few historically black universities that has an environmental and marine sciences program, emphasizes research opportunities in the ocean sciences. The Jackson State project involves off-campus research during the summer, training in technical writing, and courses that focus on independent study and an introduction to research and how it is done.

An award to Clark College/Atlanta University established a program to increase the number of minorities who wish to pursue a doctoral degree in the geosciences. Activities include a precollege summer workshop, four-year scholarships for six freshmen, and a revised curriculum that includes research opportunities.

Minorities who receive a doctorate in the biological, behavioral, or social sciences may get further help from a new fellowship program for minority postdoctoral students. The three-year fellowships, which carry an annual stipend plus possible funding later for start-up research, are awarded to U.S. citizens in minority groups that are underrepresented in the biological/behavioral/social sciences. Students may conduct their work at any U.S. academic or nonprofit institution, including government laboratories and privately sponsored institutes.

Supplemental grants to three NSF-supported Materials Research Laboratories (MRLs) at the University of Pennsylvania, Cornell University, and

Other Educational Activities Supported by NSF

Northwestern University enabled 25 minority undergraduates to conduct research at these centers during 1989—the first time MRLs have had such a program.

Fellowships. The Women in Engineering Awards represent a new component of NSF's Graduate Research Fellowship Program. These awards, announced in the fall of 1989, are designed to encourage women to enter or continue careers in engineering.

The 80 awards are part of approximately 1,050 total new graduate fellowships for advanced study that will be announced in the spring of 1990. Included are 850 NSF Graduate Fellowships, 150 NSF Minority Graduate Fellowships, and approximately 50 NATO Postdoctoral Fellowships (for advanced study outside the United States in a NATO member country).

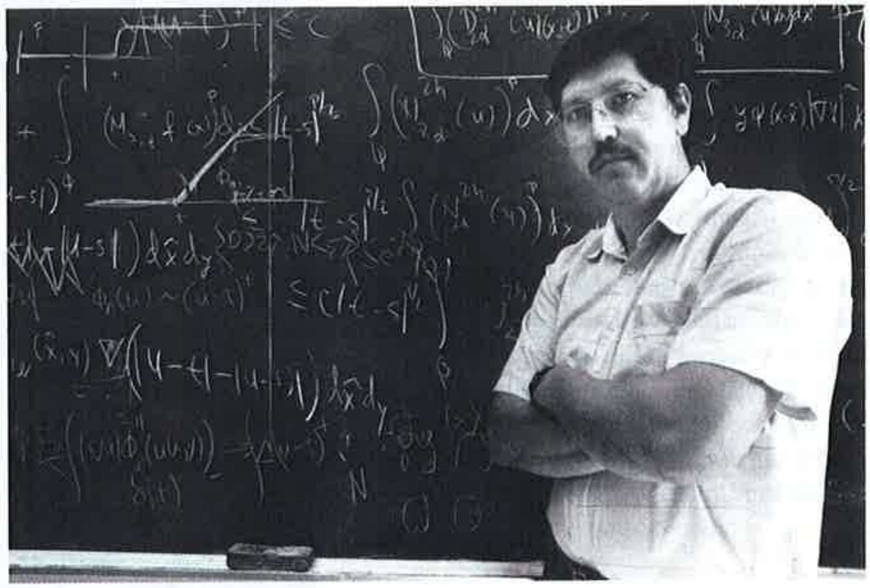
G. Mobley, C. 1988, National Geographic Society

Science broadcast.* *Students in satellite-linked science museums were able to talk with scientists while viewing TV images transmitted from an underwater robot. Marine geologist Robert Ballard is seen here inspecting the TV images.

On the road.* *In this van, Pennsylvania's Juniata College transports a teacher and a classroom of chemical equipment to 25 area high schools. As a result, both teachers and students gain hands-on experience.

Chemistry researchers.* *The American Chemistry Society's Project Seed offered these minority students in Montana a summer of directed research.

Staying informed. *Undergraduate faculty enhancement grants keep teaching faculty informed of new developments in their fields. Clemson University engineer Vera Anand, shown here, presented a computer graphics workshop under one of these grants.*



Presidential Young Investigators (PYI's). *Mathematician Rodrigo Banuelos (above) studies Brownian motion at Purdue University. Oceanographer Cengiz Ertekin (center) and 1988 PYI Anthony Kuh (left) are at the University of Hawaii in Manoa. PYI grants help universities attract and retain promising young researchers.*

Career advancement award. *Susan DeMesquita at Marshall University in West Virginia studies a neurotransmitter in rats. Her NSF award comes under a program to expand research opportunities for female scientists and engineers.*

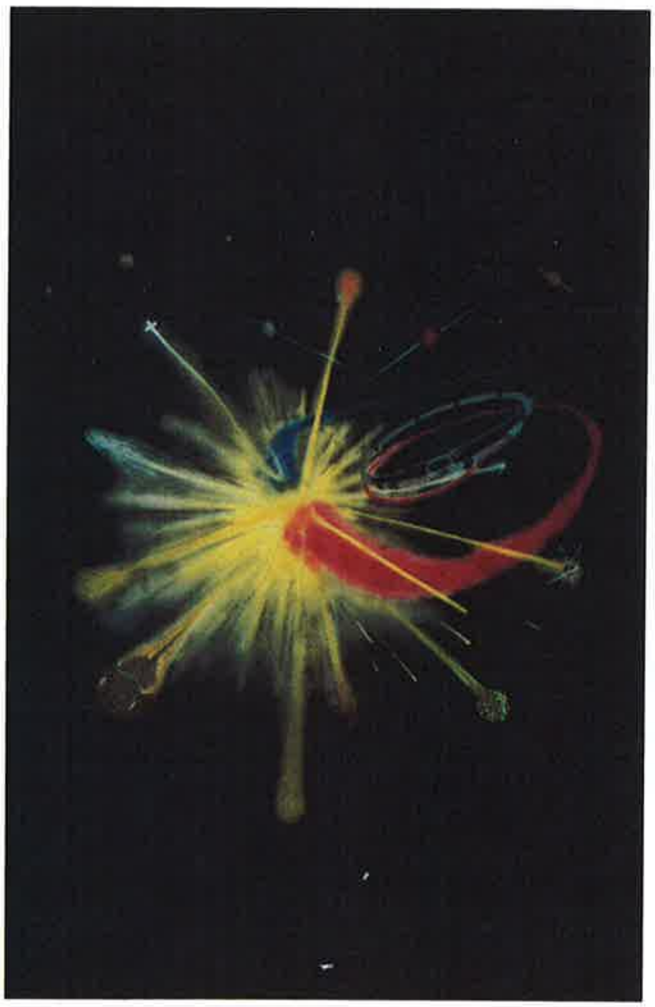
Education and Outreach to the Public

National Science and Technology Week. Begun in 1985, this NSF event is held each April to give people throughout the nation a sense of the excitement of science and technology. Through this project, NSF—aided by several industry donors—works to promote the general public's interest in science, math, and engineering, and to encourage young people to pursue S&T careers. The Week serves as a vehicle to mobilize a wide range of activities by local school systems, businesses, universities, and educational organizations as well as students, their families, and their teachers.

Hugh Moore & Associates

NATIONAL SCIENCE & TECHNOLOGY WEEK '89
APRIL 23-29
Sponsored by National Science Foundation
1800 G Street NW Washington DC 20550

Logo for National Science and Technology Week



Art of Science. This was one of 50 finalists in the 1989 Art of Science competition, held during National Science and Technology Week. The artwork—entitled "What Does It Matter?"—depicts nuclear fusion and the splitting of atoms. The artist is Robert Hogan, Jr., from Benjamin Banneker Senior High School in Washington, D.C.

Museums Plan S&T Exhibits. Eight U.S. science museums are part of a three-year NSF project to develop exhibits on science and technology themes. The grant, coordinated by the Oregon Museum of Science and Industry in Portland, helps each museum create permanent displays as well as versions that will tour the other seven sites. Planned exhibition themes include:

- Bug's-Eye View of the Environment--An illustration of the way insects perceive and deal with the world around them. (Oregon Museum of Science and Industry, Portland)
- The Secret House--An adaption of a book of the same title by David Bodanis, this display illuminates the everyday role of chemistry, as experienced in the familiar environment of the house. (Impression 5 Museum, Lansing, Michigan)
- Natural Inspirations--Technologies, inventions, and designs inspired by natural objects and phenomena--e.g., the fastening material Velcro, whose inventor got the idea from a burr stuck in his sock. (Science Museum of Charlotte, North Carolina).

The "Nature's Fury" exhibit of the Oregon Museum of Science and Industry

Outreach to the States

EPSCoR. Since 1978, NSF's Experimental Program to Stimulate Competitive Research (EPSCoR) has involved 16 states and Puerto Rico in a program designed to broaden the geographic base for science and technology. This will be done by expanding the number of regional scientists and engineers who can compete successfully for federal grants, and fostering long-term improvements in research and education in targeted regions of the country. The four newest grants went to the states of Idaho, Louisiana, Mississippi, and South Dakota.

The three-year grants to the four new states aim to strengthen academic science departments and support the research of individual scientists and engineers. The NSF awards are complemented by state, local, and private funds totalling $32 million.

Recent grants to Oklahoma and Kentucky highlight ways that EPSCoR stimulates and sustains research efforts in the states. When Kentucky received an EPSCoR award in 1986, its universities ranked 47th among the states in the amount of federal R&D funds given to research institutions. During Kentucky's first three years of participation, EPSCoR has supported 132 faculty, 14 post-doctoral students, and 113 graduate and undergraduate students in studies ranging from astrophysics to microeconomics. A project at Western Kentucky University included an innovative mentoring program that links faculty at the state's regional universities with professors at Kentucky's two Ph.D.-granting institutions.

In addition to direct funding of research and education efforts, the grant prompted Kentucky Educational Television to produce a one-hour documentary on scientific and engineering research in Kentucky. And NSF funds supported a legislative workshop on science and technology, attended by 55 state legislators and several university presidents.

In Oklahoma, an EPSCoR grant inspired that state to make one of its largest commitments ever to research and economic development. In May 1989 the Oklahoma Center for Advancement of Science and Technology (OCAST), which is modelled on EPSCoR projects in Arkansas and other states, became a permanent part of the state's efforts to promote research and development. Under OCAST, the state created centers for industry, academia, and government researchers to collaborate on studies in molecular medicine, integrated design and manufacturing, and laser development and applications.

NSF-NGA Agreement. A 1989 report by the National Governor's Association (NGA) noted that state governments are increasing their commitment to research and technology development. In conjunction with that report, the Foundation announced an initiative to increase coordination of state and federal S&T investments, and to increase collaboration between the states and NSF. This initiative enables states to capitalize on NSF's review of certain proposals.

Under an earlier agreement between NSF and the NGA, the Foundation provided information about highly rated S&T research center proposals[5] to the states through the NGA. The states had the opportunity to consider funding these proposals, which NSF had previously reviewed and identified as finalists but could not fund. As a result, several states launched new programs based on these proposals.

In 1989 NSF expanded this initiative to include information on highly rated proposals for Engineering Research Centers, another Foundation program. In both cases, proposers agree to share the information involved.

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[5]See "Research Notes" for more on NSF's first group of science and technology research centers.

Chapter 4

AWARDS AND OTHER NEWS

Linus Pauling:

1989 Bush Awardee

Vannevar Bush Award

Linus Pauling, twice a winner of the Nobel Prize, received the National Science Board's Vannevar Bush Award in acknowledgment of his outstanding contributions to science and society. Pauling, a seminal figure in the history of chemistry, has made major contributions in several areas of scientific study, including crystallography, molecular structure, molecular biology, genetic disease, antibodies, macromolecular evolution, and the nature of memory.

In 1954, Pauling was awarded the Nobel Prize in chemistry for his research on the nature of the chemical bond and its application to elucidating the structure of complex substances. He was also awarded the 1962 Nobel Peace Prize for his work on the international control of nuclear weapons, against nuclear weapons testing, and other efforts to promote the cause of peace.

Vannevar Bush, for whom this award is named, oversaw the federal research effort during World War II and was instrumental in establishing the National Science Foundation in 1950.

Waterman Award

Richard H. Scheller, a Stanford University neurobiologist, received the National Science Foundation's Alan T. Waterman Award, presented to one outstanding young scientist each year. Recipients receive a medal and up to $500,000 in research funding over a three-year period. Scheller has mastered diverse areas of modern biology, especially molecular genetics and neurobiology. This knowledge has enabled him to clarify the way regulation of gene expression, and the selective action of proteins encoded by these genes, control cellular physiology and even give rise to simple forms of behavior.

Mary L. Good, who chairs the National Science Board, noted that "Richard Scheller has remained at the frontier of modern recombinant DNA technology while becoming proficient in the physiological aspects of neurobiology. His basic studies should lead to a better understanding of the complex biological processes that underlie major psychiatric illnesses."

The Waterman Award, named in honor of NSF's first director, has been given annually since 1976 to an outstanding young researcher in any field of science, mathematics, or engineering.

Richard H. Scheller: 1989 Waterman Awardee

Jake Garn: Distinguished Public Service Awardee

Doug Walgren: Distinguished Public Service Awardee

Distinguished Public Service Awards

U.S. Senator *Jake Garn (R-Utah)*, ranking minority member of the Senate Appropriations Subcommittee on HUD and Independent Agencies, and U.S. Representative *Doug Walgren (D-PA)*, chairman of the House Subcommittee on Science, Research, and Technology, each received the Foundation's Distinguished Public Service Award. This award, which includes a gold medal and a citation, is given periodically to persons who have distinguished themselves through leadership, public service, and dedication in support of American science, engineering, and education in those areas. Senator Garn and Congressman Walgren were cited for sustained support on Capitol Hill of NSF and its budget.

Constance K. McLindon: Director, Office of Information Systems

P. Olmert

Donald Senich: Director, Division of Industrial Science and Technological Innovation, STIA

Presidential Awards

Four NSF executives received Presidential Rank Awards during FY 1989. They are *Constance K. McLindon,* director, Office of Information Systems; *Donald Senich,* director, Division of Industrial Science and Technological Innovation, STIA; *Judith Sunley,* director, Division of Mathematical Sciences, MPS; and *Margaret L. Windus,* director, Division of Personnel and Management.

McLindon received the award for *Distinguished Executive* at a Presidential ceremony on September 14, 1989. This award recognizes career Senior Executive Service (SES) members who have shown sustained extraordinary accomplishment during their executive careers. The rank award carries a stipend of $20,000.

Throughout her 30-year government career, Connie McLindon has consistently achieved outstanding success in both the operational and advanced research aspects of information systems. At the Defense Advanced Research Projects Agency (DARPA), for example, she participated in the development of ARPANET, an early forerunner of electronic mail.

In 1980 McLindon was appointed to her SES position at the Foundation. Since that time, she has revitalized NSF's information systems processing, with dramatic improvements in service quality, accountability, and organizational productivity.

Senich, Sunley, and Windus were each awarded the rank of *Meritorious Executive.* This award recognizes career SES members who have demonstrated sustained accomplishment during their executive careers and carries a $10,000 stipend.

Judith Sunley: Director, Division of Mathematical Sciences, MPS

Don Senich has long been instrumental in strengthening the Foundation's ties to industry. In 1977 he developed the prototype for NSF's Small Business Innovation Research (SBIR) program. In FY 1988, NSF received more than 1,500 SBIR proposals, a growth of over 60 percent since the program began.

Judith Sunley has made many contributions to the management of NSF and has shown outstanding leadership of the Division of Mathematical Sciences, both currently as director (since 1987) and previously as deputy director. Sunley also received the first NSF Director's Award for Equal Opportunity Achievement in 1986.

Margaret Windus: Director, Division of Personnel and Management

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

Margaret Windus has served in a wide variety of roles at NSF—as special assistant to the Director, as executive officer of the National Science Board, and as director of Personnel and Management (her position at this writing). She also has chaired an NSF Task Force on Bureaucracy and Control, which was widely credited with enhancing the electronic flow of information at NSF and streamlining grant awards and personnel processes.

Staff Notes

Linda G. Sundro became NSF's first permanent Inspector General in May 1989, after serving as Deputy Inspector General at the Department of Commerce. Inspectors General (IG's) are charged to uncover fraud, waste, abuse, and mismanagement in the operations of federal departments and agencies, their contractors, and their grantees. In 1988, amendments to the Inspector General Act required the appointment of IG's to 33 of the smaller federal agencies, including NSF. Sundro and her staff report to the National Science Board, to assure independence in their activities.

In January 1989, *Mary E. Clutter* became NSF's Assistant Director for Biological, Behavioral, and Social Sciences. Clutter first came to NSF in 1976 as program director for developmental biology under the Foundation's rotator program. Later in her career at NSF, she was division director of cellular biosciences and senior science advisor to NSF Director Erich Bloch.

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

Effective September 1, 1989, *F. Karl Willenbrock* became Assistant Director for Scientific, Technological, and International Affairs. An engineer, Willenbrock brings experience from the university, federal, and private sectors. He has been a faculty member and dean at Harvard University, SUNY-Buffalo, and Southern Methodist University.

Richard J. Green, formerly Assistant Director for the Scientific, Technological, and International Affairs Directorate (STIA), became director of NSF's new Research Facilities Office (see "Organizational Changes" below). *William B. Cole, Jr.*, previously director of NSF's grants and contracts division, is the executive officer.

Richard J. Green: Director, Research Facilities Office

Luther Williams, a molecular biologist and former president of Atlanta University, was named senior science advisor to NSF Director Erich Bloch. Before coming to NSF in June 1989, Williams was deputy director of the National Institute of General Medical Sciences at the National Institutes of Health.

Senior Science Advisor Luther Williams

William C. Harris became director, Office of Science and Technology Centers Development, effective November 20, 1988. He had served as associate (and later acting) director since this office was established in 1987 to coordinate the NSF-wide initiative in S&T centers development. Earlier, he served as a program director with NSF's chemistry division.

William S. Kirby was selected as the new director, Division of Grants and Contracts (DGC). Kirby was formerly head of the DGC policy office. While there, he founded the Grants Bulletin Board, a popular electronic communication link for NSF and many university grants offices and academic departments.

In making key staff appointments, NSF took the first steps toward implementing a new Presidential Initiative in Safety, Environment, and Health for the U.S. Antarctic Program (USAP). The initiative is a five-year effort; its goals are to (1) assure that USAP activities are in line with environmental regulations for the area, (2) achieve year-round operations at acceptable risk levels, and (3) improve the facilities and procedures that are vital to the general health and safety of USAP participants.

Among the appointments was that of *Gary T. Staffo* as Safety, Environment, and Health Officer. He is developing policy and overseeing this new aspect of the USAP effort.

Senior Foundation and Board Officials, FY 1989

Erich Bloch,

NSF Director

John H. Moore,

NSF Deputy Director

Mary L. Good,

Chairman, National Science Board

Thomas B. Day,

Vice-Chairman, National Science Board

LAWRENCE H. OLIVER

Directorate for Computer and Information Science and Engineering (CISE)

Tenure at NSF:
March 1966 to present

Special achievements:

In his long tenure at NSF, Larry Oliver has been responsible for a number of education and research programs. He has served in the Office of Science Information Services, the Office of Data Management Systems, and the Science Education Directorate (now the Directorate for Science and Engineering Education). He has been a part of the Foundation's programs in computing almost from the start, first in the Office of Computing Activities, later in the Division of Computer Research, and now in the Office of Cross-Disciplinary Activities in CISE.

In the last few years, Oliver anchored a number of new activities in response to the need for minority scientists and engineers. Working with the Minority Institutions Infrastructure program, he helped organize departments of computer science and engineering at minority institutions into a new professional society. Part of this effort resulted in three professional societies working together to assist in curriculum development and accreditation. Oliver is now applying the same formula to develop an effort, within CISE, to bring modern advances in computer technology to bear on the problems of persons with physical disabilities.

Outside interests:

Oliver relaxes through his activities in music, his church, and farming. He plays the organ for four choirs, chairs the Board of Deacons for his church, and grows heart- and palate-warming jalapeno peppers in his garden.

PETER E. YANKWICH

Directorate for Science and Engineering Education (SEE)

Tenure at NSF:
October 1985 to present

Special achievements:

In October 1985, Peter Yankwich, a physical chemist, came to NSF on loan from the chemistry department, University of Illinois at Champaign-Urbana. He became a permanent member of the NSF staff in June 1988 and is currently SEE's executive officer.

Yankwich says that "planning, budgeting, staff recruitment, quality assurance, representation, and responding--for SEE--are my principal activities." The directorate's programs cover a wide range--from kindergarten through postdoctoral levels, and across all NSF fields (mathematics, engineering, and the sciences)--and they touch almost every aspect of education. SEE's budget has nearly tripled since Yankwich has been executive officer; "This complex and interesting job," he says, "has become an exciting opportunity to develop the Foundation's education programming."

Outside interests:

Both Yankwich and his wife are ballet enthusiasts, and he is probably the only Arlington, Virginia resident who memorizes passages of Homer (in ancient Greek) while walking his English Springer Spaniel.

DELOISE WASHINGTON

Directorate for Biological, Behavioral, and Social Sciences (BBS)

Tenure at NSF:
1967 to present

Special achievements:

Deloise Washington joined NSF in 1967 as a program secretary in the Division of Biological and Medical Sciences. She progressed through the ranks from program secretary to section head secretary, division secretary, administrative officer, and then to her present position as Administrative Support Center manager in the Division of Molecular Biosciences. She has been employed continuously in the biology area and has worked for numerous visiting scientists and division directors.

Washington's service and contributions to the Foundation have been recognized by several achievement awards, including the Superior Accomplishment Award.

Previously employed by the Department of Health, Education, and Welfare (now Health & Human Services) and the Department of Labor, Washington has been a federal employee for more than 28 years. To advance her career she has taken many courses at George Washington University and other Washington-area schools.

Outside interests:

Washington is married and has one daughter. She especially enjoys family affairs and daydreaming on the beach. When she is not involved with activities for her daughter, she likes to read and experiment with new recipes.

CAROL A. ROBERTS

Directorate for Geosciences (GEO)

Tenure at NSF:
August 1988 to present

Special achievements:

In 1984, after competing for a slot on a nationwide basis, Carol Roberts was accepted in the NSF Senior Executive Service's Candidate Development Program. She completed the program in 1986 and was employed by NSF in August 1988. In the interim, she held a position with the Naval Air Systems Command.

As Deputy Division Director of NSF's Division of Polar Programs, she led the division effort to establish a five-year Presidential Initiative in Safety, Environment, and Health for the U.S. Antarctic Program. She also developed an Antarctic air safety plan with the DOD/U.S. Navy and the Department of State, for the Antarctic Treaty Consultative Meeting held in Paris in the fall of 1989.

Roberts' previous employment includes managerial positions with NASA and the National Transportation Safety Board (NTSB). She earned a Ph.D. in electrical engineering, is a registered professional engineer, and holds a commercial pilot's license with instrument rating. She received the 1987 Jerome F. Lederer Award for technical excellence in aircraft accident investigation from the International Society of Air Safety Investigators. This prestigious international award was for work performed while at the NTSB.

Outside interests:

Roberts and her husband enjoy travelling and reading, and she is an avid opera fan. Personal highlights of her job at NSF include the opportunity to visit Antarctica, New Zealand, and other faraway places. Her personal motto (borrowed from Louis Pasteur): "Chance favors the prepared mind."

LAWRENCE S. GOLDBERG

Directorate for Engineering (ENG)

Tenure at NSF:
October 1985 to present

Special achievements:

Following a career as a laser physicist with the Naval Research Laboratory, Lawrence Goldberg came to NSF as program director for the Quantum Electronics, Waves, and Beams program. In this position he has represented three very diverse research areas (lasers, plasmas, and electromagnetics) and has initiated a number of specialized NSF workshops on topics at the forefront of these fields.

In 1988, Goldberg was asked to prepare and present testimony on photonics research at NSF for two congressional subcommittee hearings exploring the state of this technology. He has encouraged researchers in engineering disciplines, particularly in critical technology areas, to conduct cooperative research abroad in Japan, and has organized a workshop and spoken at professional meetings on the subject. In the summer of 1989, he served as acting head of NSF's Tokyo Office; there he pursued discussions at Japanese industrial laboratories on opportunities for visiting American researchers.

Outside interests:

Goldberg speaks fluent German and has lived and travelled extensively abroad. He has three children and shares his wife's avocation as a ceramic artist in the design and construction of fountains and sculpture for garden settings. The family also enjoys its Bethany Beach house on the Eastern Shore of Delaware.

CARMELLA D. WILLIAMS

Directorate for Mathematical and Physical Sciences (MPS)

Tenure at NSF:
1977 to present

Special achievements:

Carmella Williams began her career in NSF's personnel office while attending high school in 1977. Upon her graduation in 1978, she went to the physics division as a clerk-typist, providing support to all programs in the division. From 1979 until 1989, she provided support services to the Elementary Particle Physics program, where she was known as a problem solver and as extremely efficient in helping to manage the program. She is held in high regard by high-energy physicists throughout the country. Early in 1989, Williams was selected for her current position as secretary to the Division Director for Physics.

During her association with NSF, Williams has received many performance awards, served as a counselor in the Equal Employment Opportunity program, and continued her education through NSF's After-Hours program. This program enabled her to attend Southeastern University in Washington D.C., where she obtained an associate degree in accounting. She is presently pursuing a bachelor's degree in finance at George Washington University in Washington, D.C.

Outside interests:

In addition to her continuing education, Williams' other interests include basketball, real estate for investment purposes, and volunteering her time at a local church to work with children and senior citizens. Her long-term goal is to become a Certified Public Accountant and establish an independent accounting practice.

JENNIFER BOND

Directorate for Scientific, Technological, and International Affairs (STIA)

Tenure at NSF:
September 1976 to present

Special achievements:

Jennifer Bond began her NSF career after serving in science policy positions in the Brazilian Space Research Institute, the National Academy of Sciences, the World Bank, and the Center for Policy Alternatives at MIT.

Since 1983, Bond has been highly successful in expanding NSF efforts to identify, acquire, and analyze international Science & Technology data from a wide range of domestic and foreign sources. Her extensive involvement with the international community has resulted in new and important additions to the international S&T database and has helped develop comparative analyses of international resources and activities. Early in her career, Bond made major contributions to the development of quantitative indicators incorporated into the biennial National Science Board report, *Science and Engineering Indicators*.

Outside interests:

Away from NSF, Bond devotes much time and energy to the Stanford Alumni Society, to church and other charitable activities, and to dancing.

CATHERINE HANDLE

Directorate for Administration (ADM)

Tenure at NSF:
1974 to present

Special achievements:

Catherine Handle began her career with NSF as a clerk typist in the Directorate for Administration. She progressed to secretary, administrative clerk, and then to her current position as personnel assistant in the Division of Personnel and Management.

Since 1976, Handle has been the principal administrator for all personnel activities associated with NSF's programs for rotational staff. Working closely with Visiting Scientists and employees on detail to NSF through Intergovernmental Personnel Agreements (IPA), she explains and implements the rules pertaining to travel, benefits, household moves, and reimbursements. Her personal concern is evident as she helps these new employees acclimate to NSF and the Washington, D.C. area.

Handle's responsibilities include assisting NSF managerial staff through her efforts to find and recruit scientific personnel by preparing vacancy announcements and advertising for these positions through various media, including professional journals. She has designed and created a customized database pertaining to rotational staff that has become invaluable to many NSF offices.

Outside interests:

Away from NSF, Handle enjoys activities with her family. Other interests include church activities, bowling, and needlework. She has recently realized a life-long ambition to study the piano.

Y.T. CHIEN

Directorate for Computer and Information Science and Engineering (CISE)

Tenure at NSF:
1982-83; 1985 to present

Special achievements:

After training as an electrical engineer and then teaching, Y.T. Chien came to NSF, on a one-year rotational assignment, as program director for intelligent systems. He then went to the Office of Naval Research to do robotics research, but returned to NSF to run the Robotics and Machine Intelligence program. When the new CISE directorate was established in 1986, he became the Division Director for Information, Robotics, and Intelligent Systems.

Chien has been the guiding force for this division through a period of growth and change. He initiated joint programs with other federal agencies to provide unique funding opportunities for research in computer vision and speech recognition. He helped organize a highly visible seminar series featuring technical presentations by NSF staff and external scientists. This biweekly series has become a widely recognized public forum by the Washington, D.C.-area CISE research community.

Outside interests:

In his spare time, Chien enjoys sports as a spectator. He is married and has two sons and one daughter. He serves on several professional society committees and publications boards as a volunteer officer.

BEVERLY DIAZ

Directorate for Scientific, Technological and International Affairs (STIA)

Tenure at NSF:
September 1980 to present

Special achievements:

Beverly Diaz has held a wide-range of support positions in the Division of International Programs (INT). She began her NSF career in 1980 as a secretary, first in the Saudi Arabian program; then in the Latin America and Pacific Section. Her duties broadened in the next several years to include participation in the U.S.-People's Republic of China program and as secretary to head of the Industrialized Countries Section of INT.

This diverse program experience, including additional duties in fiscal matters, prepared Diaz for advancement, and she returned to the Saudi Arabian program in the fall of 1984 as a program specialist. This office, which has been renamed the Science and Technology (SCITECH) Project Office, relies on Diaz to maintain and administer more than 20 key contracts. These contracts require extensive liaison with scientific and academic institutions which provide information and technical assistance to the Saudi scientific community. She assists in the review process of the annual competition that makes grants to Saudi Arabian scientists in basic and applied research.

Diaz also has served successfully as one of the Foundation's Administrative Support Center managers. In each position held, she has exhibited a high degree of competence and a great capacity to succeed.

Outside interests:

Diaz is an avid reader and enjoys listening to music and visiting with her two sons and their families. She also maintains close ties with family members living in Puerto Rico.

NINA MATHENY ROSCHER

Directorate for Science and Engineering Education (SEE)

Tenure at NSF:
June 1986 to present

Special achievements:

Nina Roscher began working for NSF on a part-time basis in June of 1986. Since September 1988 she has been on loan from American University's department of chemistry.

Roscher began her work at NSF with the chemistry portion of the Instructional Laboratory Improvement program. Since 1988, she has been director of the Undergraduate Faculty Enhancement program in the Division of Undergraduate Science, Engineering, and Mathematics Education (USEME).

Because student mentoring is one of her many concerns, Roscher has actively sought undergraduate students to work with the professional staff in the USEME division. And as a participating member of the American Chemical Society, she addresses another of her concerns through her frequent lectures on issues related to women in chemistry.

Outside interests:

The majority of Roscher's spare time is spent in the continuing construction, landscaping, and remodeling of a cabin shell she purchased several years ago in Lost River, West Virginia.

Operations: New Award Mechanism

The Foundation has launched a new effort called Small Grants for Exploratory Research (SGER). The aim of this new award mechanism is to fund small-scale, high-risk/exploratory work in the fields of science, engineering, and education supported by NSF. Only brief proposals are required, and they are not subject to the usual NSF external review.

Proposed work may include preliminary research on untested and novel ideas; ventures into emerging research areas; research requiring urgent access to specialized data, facilities, or equipment; or similar exploratory efforts likely to catalyze innovative advances. Grants are normally for one year, are not renewable, and are limited to $50,000. Any NSF program may spend up to 5 percent of its budget on SGER awards.

Simplified Grants

The Federal Demonstration Project (FDP) is the second phase of a 1986 effort to test standard, simplified terms and conditions for federal awards. When it began, FDP (then called the Florida Demonstration Project) involved NSF, four other federal agencies, the Florida State University system, and the University of Miami. Joining those original parties now are four more federal participants and 34 more grantee institutions from 14 states.[1]

The first phase of this project showed measurable success in streamlining much of the paperwork and regulations in government-sponsored university research. By spending less time on federal regulatory requirements and unnecessary paperwork, researchers spent more time on their research and increased their productivity.

The Foundation also launched a totally electronic timecard system for its personnel—the first of its kind in the federal government. And NSF eliminated more than 800,000 sheets of paper a year from its financial and administrative operations by doing more tasks electronically and otherwise streamlining paper requirements.

Organizational Changes

In December 1988, the Foundation established the Research Facilities Office (RFO) to provide leadership, coordination, and oversight in this critical area. The facilities office, reporting to the NSF Director, is assessing current and future needs, developing approaches to meet those needs, and helping to delineate the responsibilities of federal and state governments, academic institutions, industry, and others investing in and supporting research facilities.

This office is also developing NSF's implementation of the Academic Research Facilities Modernization Program, enacted as part of the National Science Foundation Authorization Act of 1988. The RFO submitted to Congress, in August 1989, a report[2] recommending that:

1. A combination of government and private funding mechanisms is needed to address the repair, renovation, and construction of research facilities.

2. The federal government should consider a number of possible initiatives, such as (a) targeted programs in various agencies, with appropriate funding; (b) modifying federal cost principles with regard to use allowances, depreciation, and other facility-related costs; (c) removing or increasing the $150 million cap on tax-exempt bonds; (d) additional tax and other incentives to encourage support of facilities and equipment.

Other Organizational News

- In March 1989, NSF's Directorate for Engineering consolidated its seven divisions into six. They are:
  - Chemical and Thermal Systems
  - Electrical and Communications Systems
  - Mechanical and Structural Systems
  - Design and Manufacturing Systems
  - Biological and Critical Systems
  - Engineering Centers

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[1] Original federal agencies: National Science Foundation, National Institutes of Health, Office of Naval Research, Agriculture Department, Energy Department. Additional federal participants: U.S. Army Medical Research and Development Command; Environmental Protection Agency; Alcohol, Drug Abuse, and Mental Health Administration; Air Force Office of Scientific Research.

[2] *Modernizing Academic Research Facilities: A Comprehensive Plan* (NSF 89-61)

• In the Directorate for Science and Engineering Education, the *Office* of Undergraduate Science, Engineering, and Mathematics Education (USEME) became a division with the same name.

Board News

• The National Science Board has set up three new task committees to consider issues and make recommendations on (1) Europe in 1992: Implications for U.S. Science and Technology, (2) Industrial Support for Research and Development, and (3) the Global Environment. One objective for these committees will be to involve other federal agencies in the NSB committee process and in implementing future recommendations.

• The Board also issued two major reports during the fiscal year:

— *The Role of the National Science Foundation in Economic Competitiveness* (statement of October 14, 1988, plus committee report)

— *Report of the NSB Committee on Openness of Scientific Communication* (NSB 88-215, December 1988), which includes recommendations for NSF, the federal government in general, the universities, and professional societies.

Chapter 5

CONCLUSION

I know much, but seek to know more.

***—Wolfgang von Goethe,* Doktor Faustus**

Finding a possible galaxy in its birth throes, creating a new state of matter, imaging organic molecules in one ten-billionth of a second—these are among the endeavors that NSF supported in 1989. Since its founding in 1950, NSF has encouraged thousands of such quests into the unknown and helped spark interest in research areas ranging from atmospheric science to building safety, from anthropology to robotics. Many of these projects have required intensive collaborations and the sharing of resources, and the Foundation has taken the lead in promoting and initiating such cooperation.

NSF also achieved an education milestone in 1989: it has supported more than 25,000 fellowships for graduate students in science and engineering. Such fellowships help form the backbone of the U.S. research community, infusing new people and talent into areas of basic and applied science. Nurturing the spirit of natural curiosity by supporting innovative research and promoting the importance of science education are continuing challenges that NSF faces. Indeed, they are integral parts of its mission as the Foundation begins a fourth decade of activity.

Fractal graphics—computer graphics derived from new concepts in the geometry of dynamical systems

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PATENTS AND FINANCIAL REPORT FOR FISCAL YEAR 1989

Patents and Inventions Resulting from Activities Supported by NSF

During fiscal year 1989, the Foundation received 196 invention disclosures. Allocations of rights to 87 of those inventions were made by September 30, 1989. These resulted in dedication to the public through publication in 41 cases, retention of principal patent rights by the grantee or inventor in 46 instances, and transfer to other government agencies in 16 cases. Licenses were received by the Foundation in 77 patent applications filed by grantees and contractors who retained principal rights in their inventions.

Financial Report for Fiscal Year 1989

(Dollars in Millions)

Research and Related Activities Appropriation

Fund Availability		
Fiscal year 1989 Appropriation	$1,620.50	
Unobligated balance available, start of year	.62	
Adjustments to prior year accounts	.56	
Fiscal year 1989 availability		$1,621.68
Obligations		
Total, all directorates		$1,492.39
Program Development and Management		91.29
Subtotal, obligations		$1,583.68
Unobligated balance available, end of year	$ 37.95	
Unobligated balance lapsing	$ .05	
Total, fiscal year 1989 availability for Research and Related Activities		$1,621.68

U.S. Antarctic Program Activities Appropriation

Fund Availability		
Fiscal year 1989 appropriation	$131.00	
Unobligated balance available, start of year	.15	
Adjustments to prior year accounts	.09	
Fiscal year 1989 availability		$ 131.24

Science and Engineering Education Activities Appropriation

Fund Availability		
Fiscal year 1989 appropriation	$ 171.00	
Unobligated balance available, start of year	$ .04	
Adjustments to prior year accounts	.19	
Fiscal year 1989 availability		$ 171.23

SOURCE: Fiscal Year 1991 Budget to Congress - Justification of Estimate of Appropriations

Table 1.
Biological, Behavioral, and Social Sciences, Fiscal Year 1989
(Dollars in Millions)

	Number of Awards	Amount
Molecular Biosciences	599	$ 46.70
Cellular Biosciences	868	55.53
Biotic Systems and Resources	779	62.82
Behavioral and Neural Sciences	799	44.83
Social and Economic Science	510	30.87
Instrumentation and Resources	414	36.57
Science and Technology Centers	2	4.15
Total	3,971	$281.47

Table 2.
Computer and Information Science and Engineering, Fiscal Year 1989
(Dollars in Millions)

	Number of Awards	Amount
Computer and Computation Research	332	$ 21.17
Information, Robotics and Intelligent Systems	288	19.14
Microelectronic Information Processing Systems	182	14.98
Advanced Scientific Computing	45	55.59
Networking and Communications Research and Infrastructure	115	17.61
Cross-Disciplinary Activities	90	17.43
Science and Technology	2	5.92
Total	1,054	$151.84

Table 3.
Engineering, Fiscal Year 1989
(Dollars in Millions)

	Number of Awards	Amount
Chemical & Thermal Systems	506	$ 30.98
Mechanical & Structural Systems	410	23.04
Electrical & Communications Systems	472	29.87
Design & Manufacturing Systems	270	18.05
Biological & Critical Systems	471	34.07
Engineering Infrastructure Development	153	10.62
Engineering Centers	105	40.43
Total	2,387	$187.06

Table 4.
Geosciences, Fiscal Year 1989
(Dollars in Millions)

	Number of Awards	Amount
Atmospheric Sciences	600	$ 98.58
Earth Sciences	815	54.22
Ocean Sciences	858	145.88
Arctic Research	128	10.29
Science and Technology Centers	1	.94
Total	2,402	$309.91

Table 5.
Mathematical and Physical Sciences, Fiscal Year 1989
(Dollars in Millions)

	Number of Awards	Amount
Mathematical Sciences	1,345	$ 66.02
Astronomical Sciences	330	89.22
Physics	630	122.28
Chemistry	1,151	96.75
Materials Research	872	115.08
Major Research Equipment	1	.50
Science and Technology Centers	5	13.95
Total	4,334	$503.80

Table 6.
Science and Engineering Education, Fiscal Year 1989
(Dollars in Millions)

	Number of Awards	Amount
Research Career Development	283	$ 30.98
Materials Development, Research, and Informal Science Education	157	43.99
Teacher Preparation and Enhancement	477	63.66
Studies and Program Assessment	24	4.50
Undergraduate Science, Engineering, and Mathematics Education	562	28.00
Total	1,503	$171.13

Table 7.
Scientific, Technological, and International Affairs, Fiscal Year 1989
(Dollars in Millions)

	Number of Awards	Amount
Industrial S & T Innovation	233	$ 19.05
Internat'l. Coop. Sci. Activities	517	11.22
Policy Research and Analysis	14	.85
Sciences Resources Studies	47	4.26
Research Initiation and Improvement	136	22.93
Total	947	$ 58.31

Table 8.
U.S. Antarctic Program, Fiscal Year 1989
(Dollars in Millions)

	Number of Awards	Amount
U.S. Antarctic Research Program	175	$ 15.57
Operations Antarctic Program	16	88.50
Major Construction and Procurement	4	27.00
Total	195	$131.07

Source: Fiscal Year 1991 Budget to Congress-Justification of Estimates of Appropriations (Quantitative Program Data Tables).

Other NSF Publications of General Interest

About the National Science Foundation (brochure)

NSF Bulletin (published monthly except in July and August)

Publications of the National Science Foundation

Grants for Research and Education in Science and Engineering

Guide to Programs

NSF Films (booklet)

Mosaic Magazine

NSF Directions (bimonthly newsletter)

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

FY 1989 Annual Report
Principal writer: Ron Cowen
Design: Hausmann Graphic Design, Inc.

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