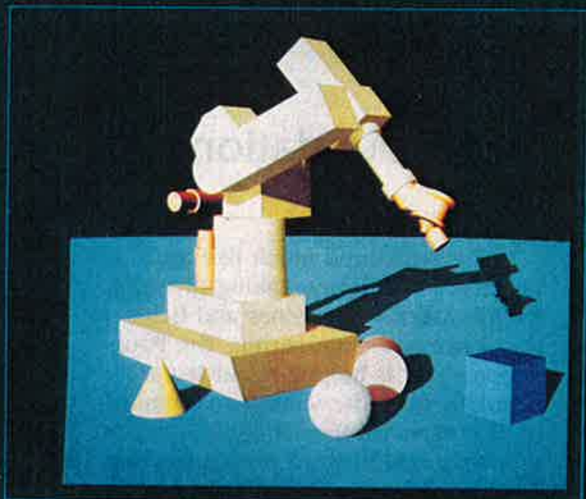
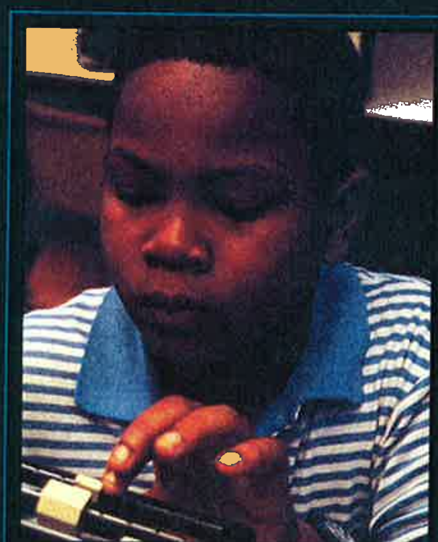
National Science Foundation

Annual Report 1986





About the National Science Foundation

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

NSF funds research in all fields of 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 30,000 proposals each year for research, graduate fellowships and math/science/engineering education; it makes more than 13,000 awards. These 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 aids cooperative research between universities and industry and U.S. participation in international scientific efforts.

NSF is structured much like a university, with grant-making divisions for the various disciplines 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 50,000 scientists and engineers a year. NSF staff members who are experts in a certain field or area make final award decisions; applicants get verbatim unsigned copies of peer reviews and can appeal those decisions.

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 the handicapped to compete fully in its programs.

Letter of Transmittal

Washington, D.C.

DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1986 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

National Science Foundation

Annual Report, 1986

Annual Report for Fiscal Year 1986

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

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DIRECTOR'S STATEMENT

An annual report necessarily reflects on the past. But it is the Director's privilege to treat the past as prologue, and look instead to the future. As I look back on our achievements, I cannot help seeing still greater accomplishments ahead.

Recent news confirms again the spectacular dynamism of science and engineering. At the end of 1986 we had the first of a series of discoveries of new materials capable of superconductivity at temperatures not previously believed possible. Superconductivity, first discovered in 1911, has long promised technological benefits. But the promise has remained unrealized because the necessary temperatures involved have been too expensive to achieve.

Suddenly, however, superconductivity is possible at temperatures that can be maintained with inexpensive liquid nitrogen, and still higher temperatures are likely. This opens technological vistas of great scope, including revolutionary changes in electric power generation and transmission, and in transportation.

The last supernova that occurred close to the earth was the "new star" observed by Tycho Brahe in 1572. The revelation that such a thing was possible forced a reconsideration of the medieval world view, and was a major step on the road to modern science. And now we have a new supernova, the first one nearby since Tycho's, and the first to be observed with modern instruments. A new subdiscipline, "neutrino astronomy," has been proclaimed. Will the 1987 supernova have an effect as great as Tycho's? Fundamental new insights are the only safe prediction.

"I believe that science and engineering are just entering a long period of accelerating progress."

Supercomputers and complex models have enabled scientists and engineers to make rapid progress in many fields, such as the geosciences, where experimentation is difficult or impossible.

Reports of major discoveries in biology and medical sciences are a daily occurrence. Genetics is yielding new insight into mental disorders. A malaria vaccine is ready for testing. Understanding of many diseases grows rapidly.

I believe that science and engineering are just entering a long period of accelerating progress. We have never seen anything like it before, so we are in many ways unprepared to deal with it.

What must we do?

The first answer is "Educate." Science and technology are central to our civilization, and daily become more so. But our schools and colleges remain far from capable of either teaching the substance of elementary science and mathematics to all students, or of preparing students to deal rationally with the social, economic, or philosophical consequences of all this new knowledge.

"The economic consequences of basic science and engineering are great and ever increasing."

The second answer is "Compete." Because technology now flows rapidly from new understanding, the economic consequences of basic science and engineering are great and ever increasing. "Knowledge is power" is an old saying, but never more true.

Especially, knowledge is *economic* power, but it has to be current. In fields such as microelectronics, the knowledge on which the technology of five years ago was built is no longer economically significant. Our national economic health, standard of living, and national defense depend on constantly staying ahead of our competitors in creating new knowledge, in converting it to new products and processes, and in manufacturing and marketing efficiently.

"Knowledge is* economic *power, but it has to be current."

The third answer is "Commit." We must commit to steady investment in basic science and engineering research, and in education at all levels. Nothing else will maintain our economic and military strength.

And we must commit to changing our research and educational institutions to deal with a rapidly changing world. In particular we must be sure that our universities, industries, and government are encouraged to work together cooperatively for the common good.

Educate, Compete, and Commit. These are active concepts. If we use them as guides to the future—soon to be the world of the 21st Century—we will use our new knowledge creatively and for the benefit of all. They are fit concepts to guide the National Science Foundation in the years to come.

Erich Bloch
NSF Director

Watching the Ozone "Hole" over Antarctica

Although ozone, a form of oxygen, is found in small amounts throughout the atmosphere, most of it is located in the stratosphere above 6 miles altitude. This critical compound screens out nearly all of the sun's harmful ultraviolet radiation that would cause skin cancer in humans and harm plants, both on land and in the sea. But measurements taken on the ground at a British antarctic station and from U.S. satellites show that the amount of ozone over Antarctica has been declining by about 50 percent during the austral spring since the mid-1970's.

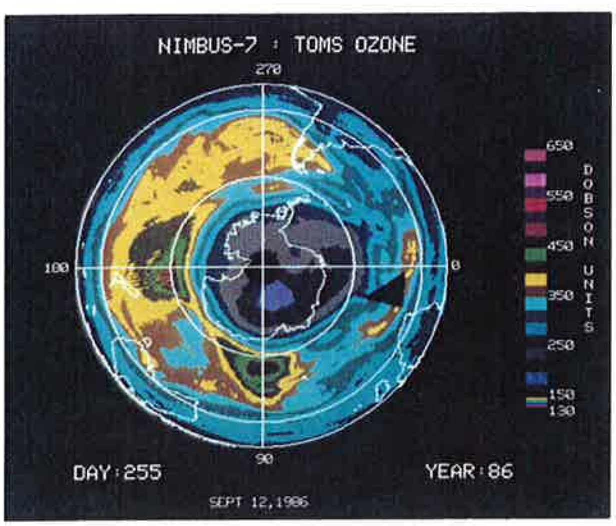
The decline in ozone seems to appear in August and continues through September and early October; recovery of ozone occurs around late October or early November. Scientists working in Antarctica began to record these dramatic changes in the ozone layer in the 1970's. At this writing, the so-called ozone "hole," which extends over most of Antarctica, is about the size of the United States. Scientists have suggested various theories to explain the phenomenon, including disruption of the ozone layer by pollution from synthetic chemical products; changes in solar activity; increased levels of volcanic activity; and seasonal atmospheric processes.

In August 1986 (the austral spring) 12 scientists on four research teams went to McMurdo Station, the U.S. Antarctic Program's research station on Ross Island, to take measurements that would help to explain the alarming annual depletion in the ozone layer. Preliminary data suggest that high solar activity and upward movement of the polar winds do not cause the hole. Dynamic processes in the antarctic atmosphere set the stage for the seasonal appearance of the hole, but at this writing scientists believe that a chemical process is fundamentally responsible.

NOAA

Jim Herpolsheimer

Dr. Susan Soloman, head of the antarctic ozone research team (above). Other team members are shown working with equipment that samples levels of ozone and atmospheric particles.



Antarctic ozone hole. Development of the hole in the 1986 southern hemisphere Spring, as followed with the Nimbus 7 TOMS (Total Ozone Mapping Spectrometer). By October 2, the region of lowest ozone (below 200 Dobson Units, or purple area) had expanded to cover much of the antarctic continent to the right of the Greenwich meridian. On October 10, the center of the low region had decreased so that a region below 175 DU had appeared (see expanding black area in center). The maximum ozone in the circumpolar ring is near 500 DU (areas of yellows, browns, and greens). (NASA photo)

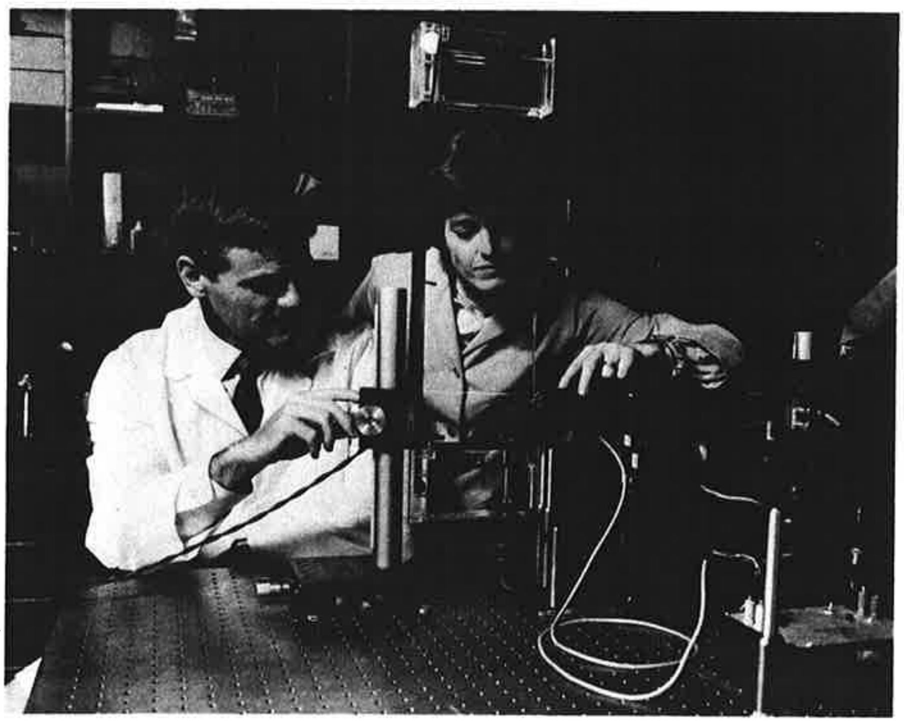
Decoding Genes Quickly

Researchers at the California Institute of Technology have built a machine that analyzes DNA hundreds of times more rapidly than was previously possible. DNA analysis in turn allows researchers to unravel the body's genetic information. Among its other benefits, the Caltech machine will help researchers lay the foundation for studying thousands of inherited diseases.

All genes are combinations of only four chemical compounds, called nucleotides and abbreviated as A,T,G, and C. The genetic code depends on the sequence in which those nucleotides are arranged: AAG, for instance, tells the body to make the amino acid, lysine. Caltech's machine, called a sequenator, labels each nucleotide with a fluorescent dye, uses a laser to detect the sequence of colors, then reads out the sequence of nucleotides. The sequenator, developed under the direction of biologist Leroy Hood, reads out the sequences more quickly and at a much lower cost than before.

The sequence of nucleotides from one individual is then compared to sequences from other individuals to find any differences. Although they usually have no immediate effect, changes in sequence occasionally cause disease. On one gene, for example, substituting an A for a T changes the way the body makes hemoglobin and results in sickle-cell anemia. Identifying that substitution allows researchers to find the adults who carry the gene for sickle-cell anemia (or any other genetic disease) and who could thus pass the gene along to their children.

Genetic engineers also use knowledge of the exact sequence of nucleotides to move a specific gene from one organism to another, an important step in innovative methods for creating new drugs or vaccines. Medical researchers use gene sequencing to understand what changes might turn a normal gene into a cancerous one. And for biologists, a complete map of all human genes would provide valuable insight into the way the human body functions.



Robert Paz, Caltech

Caltech sequenator: Leroy Hood and Jane Sanders were part of the team that developed the sequenator, shown here.

H I G H L I G H T S

GALE Project on East Coast Winter Storms

Winter storms along the East Coast area of the United States can strike with capricious violence: hurricane-force winds, cities buried in snow and ice, motorists stranded. A massive field study was designed to give scientists a better idea of how to predict these surprise storms more precisely.

This type of winter storm results from a combination of effects involving the Appalachian Mountains, the ocean, and the jet stream. Cold air heading south from Canada is trapped along the eastern slopes of the Appalachians. Warm, moist air heated by the ocean, especially by the Gulf Stream, circles in over the East Coast, hits the Canadian cold air, and rises up over it. The contact between warm and cold air creates rain, ice, and snow storms over the coastal plain east of the Appalachians. In some cases this further results in the explosive development of an East Coast cyclone. These storms move north along the jet stream, often tracking the coastline. Once fully developed, they can paralyze travel and commerce all along the coast.

A large consortium of 250 researchers from 17 universities and 7 federal agencies—using 5 satellites, 8 airplanes, 2 ships, 10 weather radars, 60 upper-air sounding stations, and 60 special surface stations and buoys—participated in a $10 million study called GALE, for Genesis of Atlantic Lows Experiment. GALE should give researchers the information they need to explain why storms are generated over the Carolinas' coastal area and why some intensify explosively while others remain innocuous. Ultimately, GALE should allow improved 12- to 24-hour prediction of these storms, their paths, the type and amount of precipitation they produce, and their rate of intensification. GALE was organized at the National Center for Atmospheric Research in Boulder, Colorado, and directed by Richard Dirks of NSF.

Thomas Lee, University of Miami

Charles Semmer, NCAR

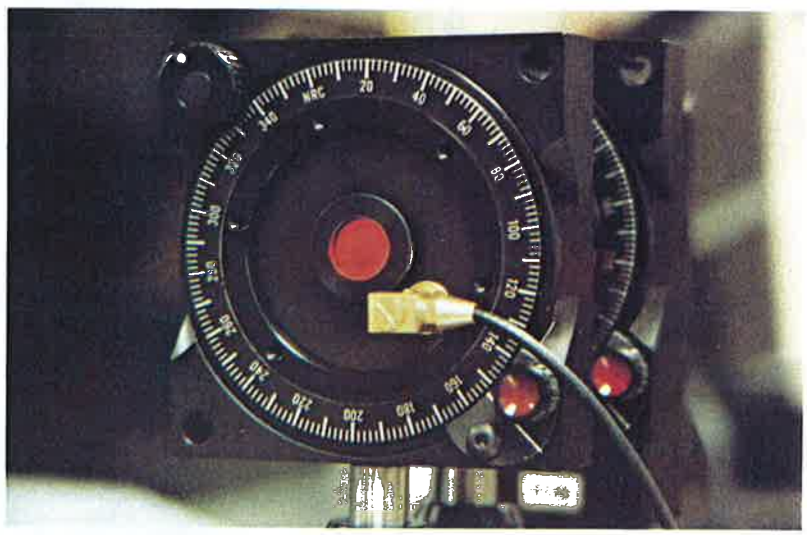
GALE research.* Buoy deployment from the research vessel** Cape Florida ***(center photo); Portable Automated Mesonet Station to gather weather data on land; NCAR **Electra** ***aircraft outfitted with gust probe***

Fast, Cool Switching Devices for Lightwave Technology

A young engineer has been working with a material that may be used in components of a computer that operates not with electric current, but with light—a so-called optical computer. Light can carry and process information in the computer more efficiently, making possible new types of computers that can operate much more quickly and work on several problems at one time. Before optical computers become a reality, however, several difficulties must be solved.

One of these is to synthesize a material that allows information to be both fed into and read out of the computer optically. Such a material needs to switch a light signal off and on quickly and with high contrast, not overheating in the process. One such material is gallium arsenide. Single switches made of gallium arsenide can turn the signal on and off at speeds that range from .000001 to .000000001 seconds. But to make a computer that can solve several problems at once, many switches must be linked together, much the same way tiles are linked to make a mosaic. The more switches in the mosaic, the more power needed to do the computing. The more power, the hotter the whole system gets. Up to 10,000 gallium arsenide switches can be linked together; more than that, and the system melts.

At the University of Colorado at Boulder, engineer Kristina Johnson is using a material synthesized by Noel Clark, a condensed matter scientist, and David Walba, a chemist. This material can switch light off and on in .000001 second, not quite as fast as gallium arsenide. The advantage of their material, a ferroelectric liquid crystal, is that it requires much less power to operate, so that it runs 10,000 times cooler. Such coolness means that almost a million ferroelectric liquid crystal switches can be linked together. The material also has a hundred times better contrast than gallium arsenide.



Lightwave technology implement. This ferroelectric liquid crystal light shutter is used by engineers, chemists, and physicists at the University of Colorado (Boulder). The device switches in microseconds, has very high contrast, and can be easily fabricated in large arrays.

This kind of work brings optical computers a few steps closer and advances a relatively new field called lightwave technology. The technology promises to have a significant effect on such areas as electronics, information processing, computing, robotics, artificial intelligence, aviation, and communications. Johnson is also a Presidential Young Investigator (see description of this NSF program in chapter 2).

HIGHLIGHTS

Finding the Vulnerable Point of a Cold Virus

Researchers have mapped, in atomic detail, the place on a cold virus where an antiviral drug attaches. The researchers at Purdue University were led by Michael Rossmann, who last year mapped a cold virus's overall structure for the first time.

A virus is a simple creature, a strand of RNA or DNA surrounded by a protein coat. Once a virus gets inside a cell, the coat breaks apart and releases the virus's RNA or DNA, which then takes over the DNA of the cell. As a result, the cell eventually manufactures more viruses, which break out and invade other cells.

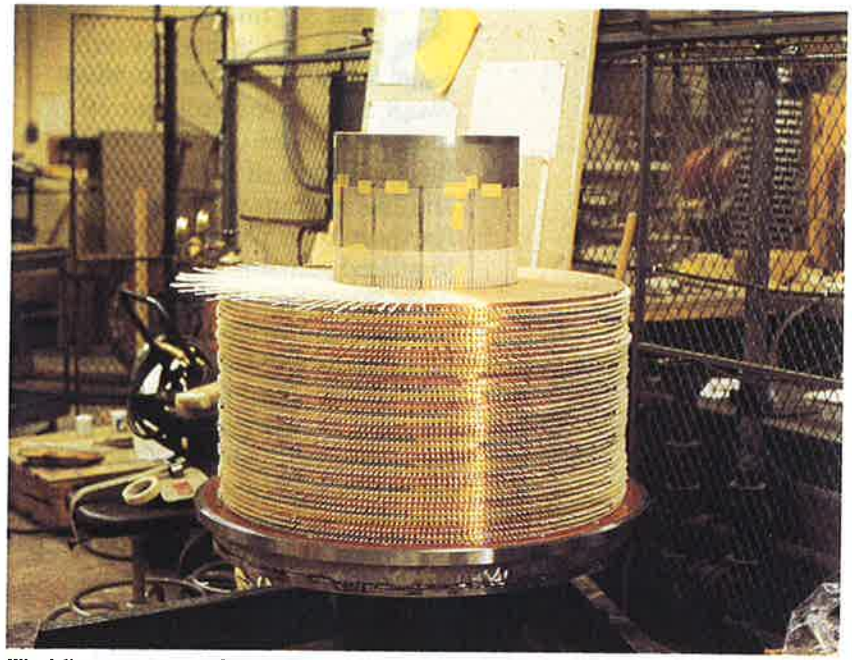
Rossmann's team used a supercomputer to find the exact spot on the virus's coat where an antiviral drug attaches. The drug prevents the coat from breaking apart, and unless the coat is broken, the virus's RNA or DNA cannot get free to cause infection. Researchers still have not found a cure for the common cold. But knowing how and where a drug attacks the virus will help with the development of more effective drugs. It will also provide fundamental and detailed knowledge of how viruses carry on their lethal business.

***Cold virus model.** Michael Rossmann at Purdue University is shown with model first developed by Rossmann and his team in 1985.*

World's Most Powerful Magnetic Field

At the Francis Bitter National Magnet Laboratory, Massachusetts Institute of Technology, a group headed by Lawrence Rubin has generated the world's most powerful magnetic field. Use of high magnetic fields helps materials researchers learn about the behavior of electrons in solids. Applying such a field profoundly affects the way electrons move through a conducting solid material, resulting in dramatic, observable changes in the way the solid conducts electricity. Research of this kind may lead to new materials for electronic, magnetic, and superconducting devices, instruments, and machines.

The record field set by the Laboratory was 33.6 tesla. The previous record, set in Japan, was 30.7 tesla. By comparison, the earth's magnetic field is about .00005 tesla; the small magnets that hold messages on refrigerators produce about 0.1 tesla. The highest magnetic field anyone has measured in the universe is that of a white dwarf, a compact and dense star about the size of the earth. (Our sun will eventually become such a star.) The white dwarf's field—measured by Gary Schmidt, Steven West, and James Liebert at the University of Arizona, Richard Green at Kitt Peak National Observatory, and H.S. Stockman at the Space Telescope Science Institute in Baltimore, Maryland—was 50,000 tesla. Neutron stars, even denser than white dwarfs, are predicted to have even stronger fields—around 100 million tesla.



World's most powerful steady-state magnet. At 33.6 tesla, the magnet consists of a superconducting outer coil, a water-cooled insert and pole pieces made of the element holmium. Most of the superconducting outer coil is shown being built around the channel for the water-cooled insert and the holmium pole pieces.

Dawn Apes of the Fayum

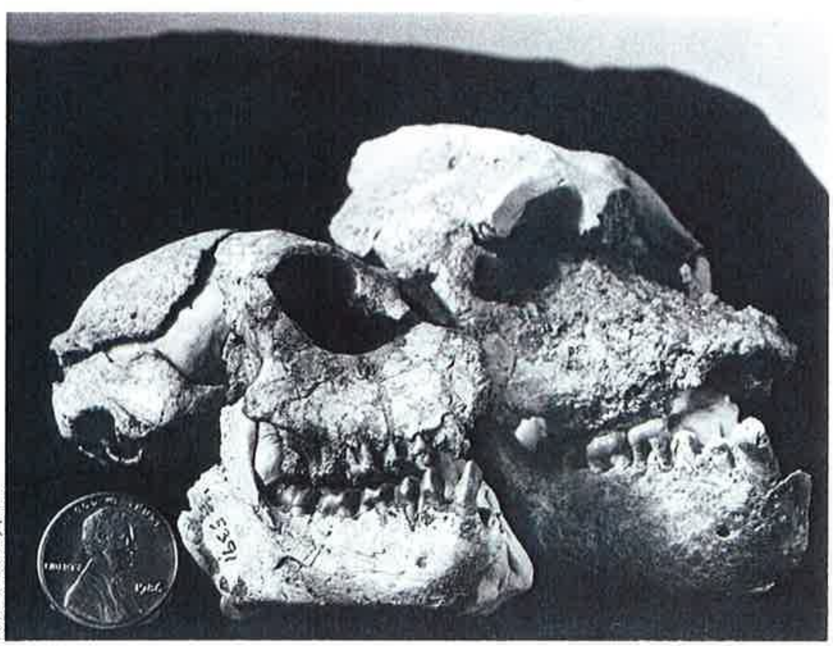
Some 32 million years ago there was a tropical rain forest in the barren wind-swept Sahara Desert about 60 miles southwest of Cairo, Egypt. Elwyn Simons of Duke University and his collaborators have labored for more than a decade to collect fossilized remains of species that once flourished there. Paleontologists and paleoanthropologists have focused considerable attention on the Fayum, a small area, because it contains the only fossil-bearing deposits in the Old World of this Oligocene age, and these deposits provide the first good documentation of warm-blooded animals and birds from Africa.

In October 1985 the Duke team recovered a small skull that was badly crushed and encased in a block of rock-hard matrix. A year later a second skull was recovered; only after laborious cleaning and reconstruction has it become evident that these remains—dubbed Adam and Eve—are in fact the two oldest adult skulls ever found that appear to belong to the direct ancestry of humans. One is the skull of a mature male, the other that of a mature female. (Fragments of a third skull had been discovered in 1966.)

This new pair of skulls belongs to a primate genus *Aegyptopithecus* and the species *A. zeuxis;* it is widely believed to be a common ancestor of humans, the apes, and possibly Old World monkeys as well. The name "zeuxis" means yoke or link, and this animal is a connection between ancient prosimians or submonkeys and modern primates.

Aegyptopithecus was a tree-dwelling animal approximately the size of a fox or a large house cat. What the two new skulls provide is clear evidence of sexual dimorphism: the male is larger than the female. Modern primate species that exhibit this degree of dimorphism usually live in large multi-male and multi-female social groups. This advanced type of social structure, Simons postulates, can now be traced back as far as 32 million years ago.

Although the skulls are small, the size of the brain is relatively large. Casts made from the skulls' interiors reveal a brain at the general level of complexity of those found in modern owl and titi monkeys of South America. The teeth indicate ties with ape forms that inhabited East Africa during the Miocene age, about 12 million years later, and these in turn are broadly ancestral to both modern apes and humans.

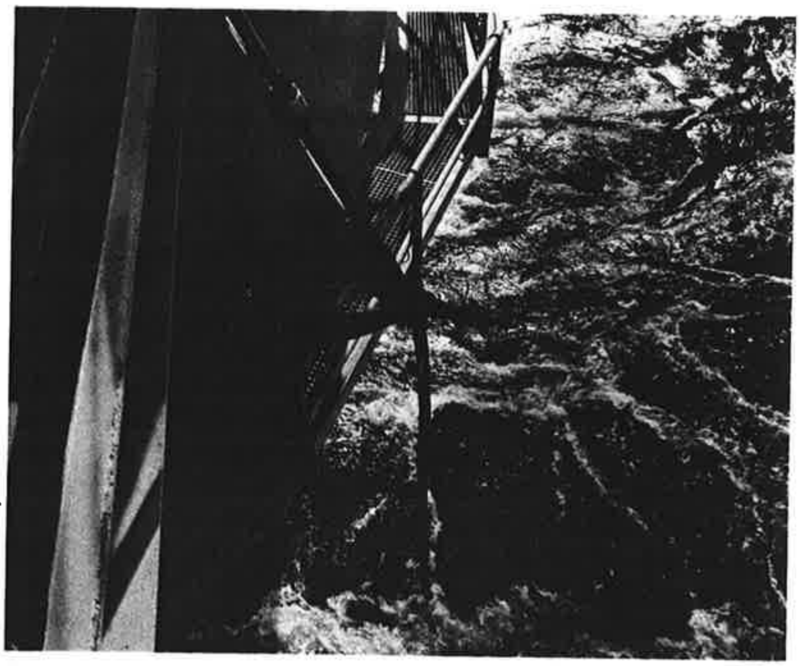


Duke University photo

***Anthropology find.** These are the two oldest adult skulls ever found that appear to belong to the direct ancestry of humans. Skull at right is that of a mature male, the other that of an adult female. Both come from an excavation site in the wind-swept badlands of the Fayum Province southwest of Cairo, Egypt.*

New Devices to Study Newly-Created Crust

Most of the earth's crust is ancient. Some parts of the crust, however, are being created right now; they are, as geologists say, of zero age. Scientists aboard the JOIDES *Resolution*, the research ship of NSF's international ocean drilling program, have finally been able to look closely at zero-age crust in the process of being formed.



Texas A&M University

Ocean science at work

One place where crust is being created is along the Mid-Atlantic Ridge, a jagged chain of underwater mountains strung from Iceland down the middle of the Atlantic Ocean to the antarctic. Along this ridge two of the earth's tectonic plates are tearing apart, carrying Africa and Europe away from North and South America at about an inch a year. Where the plates move apart, molten rock from the interior of the earth moves to the surface, piling up new crust into a ridge. At sites 1200 miles southeast of Bermuda and 2 miles down, the international team of scientists drilled into the ridge.

The drilling process itself was an innovation. The new crust lacks the thick layers of sediment that provide stability for a drill, and young rock is hard and abrasive. The drill is consequently difficult to aim; it skitters all over. So engineers developed what they call a guide base, a 20-ton, room-sized doughnut held in place by 100,000 pounds of cement. They positioned the drill by using a real-time underwater television camera. With the guide base and drill, scientists were able, for the first time, to look closely at rock formed at the Mid-Atlantic Ridge. Using the camera, they could also watch what happens when molten rock and sea water meet.

The new rock is porous and hot; sea water circulates through it, dissolving its minerals and becoming extremely hot. Such circulation probably helps to determine the mineral composition of the oceans. What the camera saw was a landscape of 30-foot-high chimneys, formed when the dissolved mineral condensed back out of the water, that send out clouds of black smoke and metal-rich water. The chimneys, called black smokers, are made of copper, zinc, and iron sulfides, sometimes in massive nuggets. Swimming around the chimneys is a unique community of shrimp and eel-like creatures; thus the scientists called the area the Snakepit.

The JOIDES *Resolution*, operated by Texas A&M University, is funded by Canada, France, Japan, West Germany, the United Kingdom, and the United States through the National Science Foundation. In 1986, these countries were joined in the Ocean Drilling Program by the European Science Foundation, representing 12 European countries.

Tying the Universe Together with String

Physicists are finding that a new theory, which sees particles not as tiny points but as the vibrations of tiny bits of string, may explain the force that governs the universe. For centuries, physicists have studied the gravitational force between all bodies with mass and the electromagnetic force between all particles with charge. During this century, they described two more: the weak force that governs the radioactive decay of particles and the strong force that holds particles together in the nucleus of an atom. For decades now, physicists have been trying to learn whether these four phenomena are, in some profoundly fundamental way, all faces of the same force. In short, physicists look for what they call a Theory of Everything.

One sticking point in their search has been the gravitational force. Until recently, it appeared that Einstein's well-confirmed theory of the gravitational force is incompatible with quantum mechanics. Since quantum mechanics is an extremely successful body of general physical laws believed to describe correctly the physical effects of any force, this incompatibility has been a serious problem. Now Michael Green, at the University of London, and John Schwartz, at the California Institute of Technology, have shown the following: if elementary particles are actually the vibrations of tiny strings, and if the forces among the particles include electromagnetism, the weak force, the strong force, and possibly some other forces not yet observed in the laboratory, then the theory of the gravitational force becomes compatible with quantum mechanics.

The work done by Green and Schwartz, along with that of physicists at Princeton University (see later chapter on "Awards"), has led to what is called superstring theory, which perhaps may be the Theory of Everything. In it, tiny bits of string wiggle in 10 dimensions: 3 dimensions of space, 1 of time, and 6 others that have shrunk (physicists say "compactified") to imperceptibility. Strings can be open, like shoelaces, or closed, like rubber bands; they can connect to other strings, or split from them. They vibrate, and the frequency of their vibration determines what particles they seem to be. An extremely high frequency vibration of a string may appear to be, say, a quark; a lower frequency of the same string may be an electron.

Superstring theory sounds bizarre, and though it has more internal consistency than previous Theories of Everything, it awaits confirmation. At this writing, the theory has made no predictions by which it can be tested. And experiments that find strings directly are still out of reach of the most powerful particle colliders, either in existence or imaginable.

Superstrings—the universe's building blocks (reprinted by permission of Nature*)*

Models for the Way Gears Fail

Any mechanical system with moving parts is likely to depend on gears. The stress of gears running against each other is so great that, sooner or later, all gears wear out and fail. Herbert Cheng and Leon Keer, at the Technological Institute at Northwestern University, have created a computer model for predicting just when a gear will fail.

One metal gear turning against another puts stress on both in such a way that their surfaces flow plastically, much the way mud flows, but much more slowly. Metal cannot flow far without making microscopically tiny cracks. These microcracks on gears are semicircular, running from one point on the surface to another. With continued operation, the microcracks grow until the metal above them flakes off, forming little pits on the gear's surface. Lubricating oils can only retard pitting, they cannot prohibit it. Once enough pits form, a gear is useless. In effect, all gears have a certain lifetime.

Engineers cannot stop a gear from failing, but they would like to be able to predict its failure. This will allow them to select gear materials and operating conditions such that the failure will not occur during the expected life of the mechanical system. Cheng and Keer have a computer model that does just that. They study closely the growth of a pit on a real gear, then use that information to simulate on a computer how many times the gear had to turn before a microcrack started, what the pattern of cracks was, and how they grew into damaging pits. Microcracks, they found, start early in the life of a gear but grow slowly.

The computer model allows Cheng and Keer to predict both the shape of the crack and the way it grows, and ultimately—given how long a gear has been used—to predict how likely it is to fail. Eventually, the model should allow engineers to design gears that will avoid the patterns of cracks that lead to failure, thus greatly extending the life of a gear.

Mussels That Live on Methane

Oceanographers working in the Gulf of Mexico have discovered a mussel that lives on methane. The mussel, a new species, was found near what oceanographers call hydrocarbon seeps, areas where methane—commonly called natural gas—leaks from beneath seafloor sediments up into the ocean. The mussel is the only known example of a higher animal that utilizes methane for sustenance.

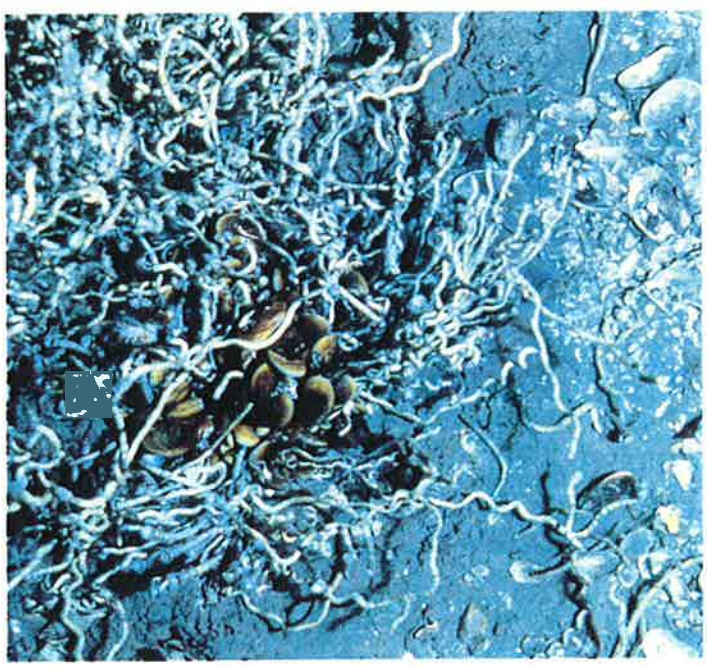
James Childress and Charles Fisher (University of California at Santa Barbara) and James Brooks (Texas A&M University) found the mussels, ranging from one to six inches in length, about 150 miles off the coast of Louisiana and 1800 feet below the surface.

Until recently, animals were thought to depend, ultimately, on photosynthesis for their nourishment. Lacking sunlight, the deep sea is without photosynthesis, and only meager food substances come down from the surface waters. A process involving methane seems to ameliorate the low food level.

The mussel does not use methane directly. Instead, it is host to tiny, free-living bacteria in its gills that take methane and turn it into organic compounds. Mussels then use the organic matter as food.

The mussel is not the only deep-sea creature that does not depend on photosynthesis. In 1977, oceanographers discovered giant clams, other species of mussels, and four-foot-long worms living, cut off from sunlight, near hydrothermal vents where hot water pours from beneath the earth's crust. These creatures live on the sulfur dissolved in the hot water—or rather, like the methane-eating mussels, they live in symbiosis with bacteria that consume the sulfur and provide food substances.

Since hydrocarbon seeps occur throughout the Gulf of Mexico and off the coast of California, oceanographers speculate that other types of bacterial symbioses might be more common than they had thought.



***Methane mussels.** Tubeworms surround these mussels (center of photo), which lie on the ocean bottom near methane seeps. Each clam is about four inches long.*

Flashing Genes

Biologists and chemists looking for a way to find out which genes are activated in which organs have come upon an ingenious method. They have engineered genes that make the roots, stem, and leaves of a tobacco plant glow.

In most parts of organisms, each cell carries a full set of genes. But the genes that control the color of your eyes, for instance, are activated in your eyes only and in no other organ. In fact, which genes are activated determines the way each organ functions. In order to track the genes activated in the roots, stem, and leaves of a tobacco plant, a team of biologists and chemists at the University of California at San Diego inserted a gene from a firefly into the genetic structure of the plant.

One part of the San Diego team isolated the gene that the firefly uses to produce an enzyme, called luciferase, which makes the firefly glow. The other part of the team took the gene for luciferase and attached it to a gene from a plant virus—specifically, to the gene that controls the virus's growth. Then the luciferase and virus genes were both attached to yet another gene—this one from a bacterium that injects its own genes into a plant's. The plant took up some of the bacterium's genes and, along with them, the viral genes and the genes for luciferase.

Keith V. Wood

No ordinary tobacco plant. Scientists at UC-San Diego have altered the genetic

e

glow—just like a firefly.

When the viral genes were activated in all the plant's organs, so were the luciferase genes, and

In fact,

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succeeding generations of plants also glowed.

The researchers noted that the luciferase gene reports whether or not a gene is activated with particular sensitivity, and that detection of the gene's activity is both non-invasive and non-destructive. The luciferase gene should help both genetic engineers trying to breed resistance to diseases into plants and biologists studying which genes affect which organs.

Redrawing the Birds' Family Tree

Ever since the Swedish botanist Linnaeus (1707-78), biologists have classified animals by comparing anatomy: legs that run versus the legs on birds that fly, for example, or beaks that crack seeds versus beaks that drill holes. A new technique makes it possible to classify animals more accurately by comparing their genetic makeup, their DNA. Using this technique, Charles Sibley and Jon Ahlquist at Yale University found that the family tree of all birds needs to be redrawn.

For years, standard classification based on external anatomy assumed that all groups of birds had a single common ancestor. But anatomy can be misleading. Swifts and swallows are unrelated but look alike because both adapted to feed on flying insects. In fact, animals' anatomies generally are shaped less by whom they are related to than by what they do. So classifying by comparing genetic makeup is more reliable.

Over the last 10 years, Sibley and Ahlquist compared the DNA of 1600 species of birds. The more similar the DNA of any two species, the more closely they are related. For instance, vultures of the Old World resemble turkey vultures of the New, since all vultures find and feed on carrion. But Sibley and Ahlquist found that the DNA of the former resembles that of hawks and eagles, while the DNA of the latter resembles that of storks.

More interestingly, they found that a variety of birds in New Guinea and Australia—warbler and thrush-like species—were actually more closely related to one another and to crows than to their European look-alikes, warblers and thrushes. Sibley and Ahlquist group these birds as Corvida, crow-like forms, which they maintain evolved in isolation from other birds on the New Guinea-Australian landmass about 60 million years ago. This evolution within the Corvida calls to mind the variety of marsupial mammals, from koala bears to kangaroos, that has evolved under the same circumstances.

Mathematical Theory of Knots Unties DNA Molecules

To a mathematician a knot is like a knot in a shoelace: a closed, one-dimensional string that curves through three-dimensional space. One knot can be twisted, pulled, pushed into another knot, and as long as the string is neither cut nor untied, the two knots are, to the mathematician, the same. The method for proving the similarity of any two knots is called knot theory. Normally studied for its own sake, knot theory can surprisingly enough be applied to the workings of a molecule of DNA.

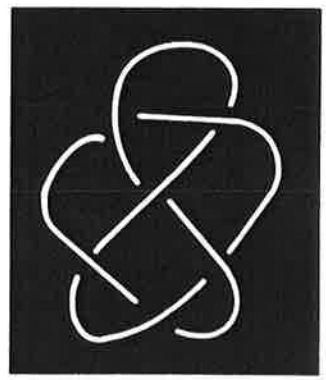
A DNA molecule consists of two strands of chemicals twisted together into a helix. The helix in turn twists into a coil, which winds around, curving back on itself, forming knots. In order for the DNA molecule to reproduce itself, enzymes must straighten out those knots and coils, preparatory to pulling the strands themselves apart. These enzymes, however, can begin work only on those portions of the knot of DNA that are exposed to view. So to understand what portions of the knot the enzymes would "see," biologists had to understand by what rules the knot had formed.

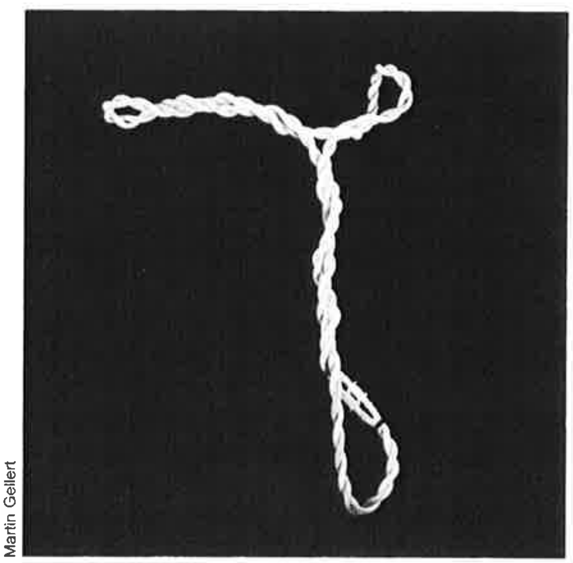
Enter the mathematician Vaughan Jones. While at the University of Pennsylvania, under a grant from the Modern Analysis Program in NSF's Mathematical Division, Jones developed algebraic methods for solving some long-standing problems in an area of mathematical analysis known as von Neumann algebras. This component of Modern Analysis arose nearly a half-century ago from the mathematical formulation of quantum mechanics, and both scientifically and philosophically it is far removed from knots and DNA.

However, Jones—looking beyond the boundaries of his previous research—observed that this same methodology which was successful in the theory of von Neumann algebras applies equally well to the classification of knots. In fact, his construct, now called "the Jones polynomial," reduced the study of complicated knots to simpler mathematical expressions.

Molecular biologists Steven Wasserman and Nicholas Cozzarelli, at the University of California, Berkeley, used Jones' method to predict the sequence in which DNA could form increasingly complicated knots—those that crossed once, twice, and so on. When they looked at the actual DNA under an electron microscope, they found the knot that ended that sequence, one that crossed itself six times. According to a National Research Council report on trends in mathematics, "these developments emphasize again the eternity of a good mathematical result, . . . the unpredictable relationships between fields, and the many bridges across the humanly created gap between core mathematics and the basic sciences."

Knot samples. The highly supercoiled DNA molecule modeled below contrasts sharply with the simple knot shown in drawing.





Martin Gellert

Unique Techniques from Small Businesses

Small businesses involved in scientific and technological innovations are often unable to support the high-risk basic research needed for the next generation of innovations. NSF's Small Business Innovation Research Program (SBIR) funds high-quality, high-risk research at such companies. The return on NSF's investment includes not only research results but economic and social benefits to the nation.

Instruments and techniques developed by small, high-technology businesses under the SBIR program are often unique. Among them is the Redox Chemilluminescence Detector, invented at Sievers Research in Boulder, Colorado. The instrument measures, with high sensitivity and accuracy, trace amounts of organic compounds in a gas. The detector has been delivered to several companies, and it is estimated to have a large market nationally and internationally.

Another such instrument, developed by Charles Evans and Associates near San Mateo, California, is a laser that helps to identify the materials in thin films. Thin films of varying materials, stacked layer by layer, are used in the semiconductor industry. The laser probes the entire stack, making it a useful tool for constructing depth profiles of the layers in the semiconductor material.

Small business innovation. The Redox Chemilluminescence Detector was invented at Sievers Research in Colorado, with NSF support.

President Recognizes Outstanding Science and Mathematics Teachers

In 1983, a new program was established to recognize outstanding high school and middle school teachers: the Presidential Awards for Excellence in Science and Mathematics Teaching. The quality of teachers in these fields is important in determining whether this country will, in the future, have the scientists and engineers we need. NSF, in cooperation with the White House and several scientific and educational professional associations, established the awards to encourage high-quality teachers to enter and remain in the field.

Each year two teachers from every state, the District of Columbia, Puerto Rico, and the U.S. territories receive the award. In 1986, 108 teachers from those jurisdictions and from the U.S. Department of Defense Dependents' Schools were honored. Each awardee's school was given an NSF grant of $5000, to be used under the awardee's direction to improve science and mathematics courses.

In general, the winners spend their school's awards on professional development activities, new equipment, materials for student research, and other books, media materials, and software. Many awardees have supplemented the presidential award grant with matching funds from their school districts, local businesses, and other sources.

Specifically, some of the winners in previous years have used their award money as follows:

- Doris DeBoe, mathematics teacher at Banneker High School in Washington, D.C., operated a summer math program, purchased teaching aids, and supported a mathematics tutoring effort.
- Arthur Farmer, physics teacher at Gunn High School in Palo Alto, California, set up a unique model for teaching physics at his school. He has disseminated the model widely to colleagues at both the high school and college levels.
- Juliana Texley, biology teacher at Richmond High School in Richmond, Michigan, used her award to establish an advanced-placement biology course, purchase equipment for student projects, and update the facilities of her school's science department.

B. Wimmer, Image Associates

Presidential awardee. Blanche Brownley teaches mathematics at the Friendship Education Center in Washington, DC. She is a 1986 winner of the Presidential Award for Excellence in Science and Mathematics Teaching.

CHAPTER 1

Much depends on science and engineering: our international economic competitiveness, our technological innovativeness and productivity, and our ability to defend this nation and provide for its people's health and well-being. Among all federal agencies, only the National Science Foundation has the broad mission of ensuring the overall health of science and engineering and the education of future scientists and engineers.

To meet its responsibility, NSF focuses on several areas of concern, including these:

- the number and quality of scientists, mathematicians, and engineers;
- the state of precollege science and engineering education and the importance of education to our future research capabilities;
- the U.S. position in the international science and engineering community; and
- public attitudes toward science and engineering.

Several major reports have assessed these topics, and NSF has responded to many of the issues raised (see below). Among those reports are the following:

The Health of U.S. Colleges and Universities

A special panel of the White House Science Council examined the overall status of U.S. research and higher education in science and engineering, focusing on ways that the federal government, universities, and industry could act in partnership. To maintain the strong science base essential to our national future, the Council's report recommended: (1)

- significantly increasing federal support for basic research in universities and colleges;
- establishing science and technology "centers" that would work cooperatively with state government and industry in research areas of national importance;

- supporting scholarships, fellowships, and other programs to attract more of our brightest students to science and engineering careers; and
- improving academic research facilities, equipment, and instrumentation.

1. See *A Renewed Partnership,* White House Science Council, Panel on the Health of U.S. Colleges and Universities, Feb. 1986 (also known as the Packard-Bromley Report, named for panel chairman David Packard of the Hewlett-Packard Company and vice chairman D. Allan Bromley of Yale University).

State of Undergraduate Science and Engineering Education

In March 1986 NSF's governing body, the National Science Board, issued *Undergraduate Science, Mathematics, and Engineering Education.* This report found that the quantity of U.S. educational opportunities is high, but the quality of that education needs attention. For example, the Board noted that laboratory work is increasingly absent in introductory courses. Laboratory instruction is too often "uninspired, tedious, and dull," and many facilities are "obsolete and inadequate." Faculty members cannot always stay current with their fields, and both courses and curricula are often out of date, unimaginative, and poorly organized. State funding of undergraduate institutions has dropped, and corporate and federal funding is aimed elsewhere, at graduate education and basic research.

The report recommended that NSF establish and expand its undergraduate education programs; encourage similar state, local, and private funding efforts; and work harder to attract minorities and women into math, science, and engineering.

ISSUES AND INITIATIVES

Research Facility Needs

An NSF survey done in the spring of 1986 produced these findings: (1)

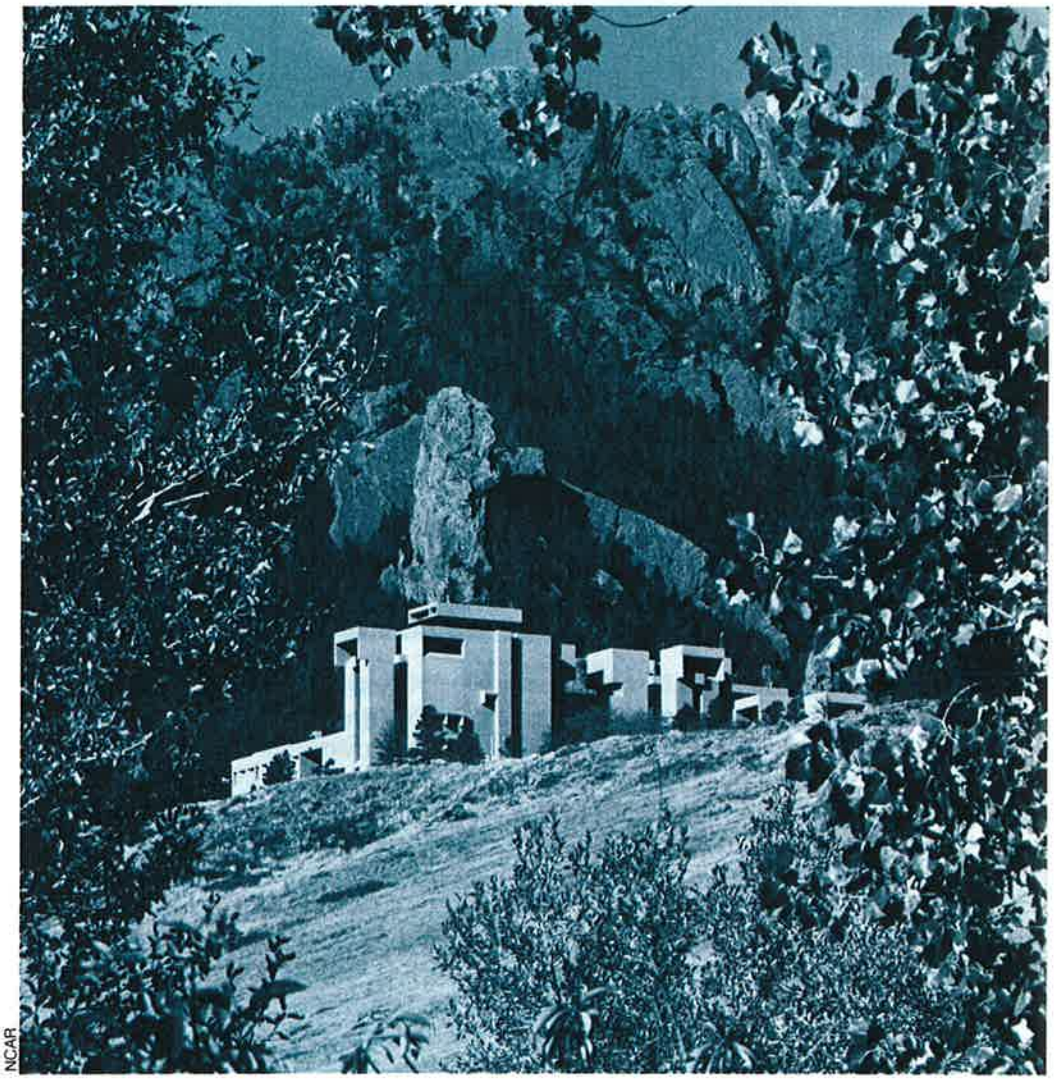
- A majority of the research administrators and deans at top-50 schools (those with the highest expenditures in research and development) reported that the condition of their *existing* research facilities was good or excellent. A majority of those officials responding for schools ranked below the top 50 rated the condition of their existing facilities as fair or poor.

- Virtually all campuses need *more research space*, according to their research administrators and deans. Both groups said that facility needs limited the number and type of projects that could be done on their campuses, and that it has been necessary to divert funds from other research areas to maintain and/or repair facilities.

- Research administrators most often cited engineering; biological, biomedical, and physical sciences; animal care facilities; and biotechnology as areas with significant facility needs.

- Universities have earmarked $7.5 billion for research facilities through 1991. Of the four major funding sources for construction, the federal government ranked last, accounting for 10 percent of ongoing construction. State governments accounted for more than two-fifths of the total, with tax-exempt bonds and private donations or endowments providing the remainder of construction support. Public institutions rely most heavily upon state support, whereas private institutions receive most of their money for research facilities from private donations or endowments.

1. *Science and Engineering Research Facilities at Doctorate-Granting Institutions,* September 1986, Division of Science Resources Studies.



NCAR

Facilities like this, along with personnel (photo on next page), are vital elements of the science and technology enterprise.

Valentina Semilka, U. of IL at Chicago

Public Attitudes Toward Science and Technology

Studies cited in the latest *Science Indicators* (1) found that the public is highly interested in science and technology but knows little about them. Nearly half of those questioned in one 1983 survey said that they were very interested in new discoveries, and a similar number had high confidence in the research community. College students also showed high interest levels. However, only 14 percent of the American public and 10 to 12 percent of college students thought of themselves as very well-informed about scientific and technological discoveries.

1. *Science Indicators, The 1985 Report,* National Science Board, 1986

Continuing Need for Math Support

According to a 1986 report commissioned by NSF from the National Research Council (*Mathematical Sciences: A Unifying and Dynamic Resource*), the United States leads the world in mathematics research—a field that continues to find more and newer applications. But, said the report, mathematics is also in a "precarious situation, and we believe that it may be worsening."

An earlier study by the National Research Council in 1984 found that in spite of a decade of "dazzling achievements," federal support for mathematics had declined. The current report notes that, because math has become increasingly sophisticated, a would-be mathematician must get an increasing amount of education beyond the doctorate; unfortunately, declining federal support and those increasing educational requirements have caused fewer and fewer people to seek doctoral degrees in mathematics. The most recent study also says that the decrease in Ph.D. production "will continue if the potential talent does not feel that continuing, as well as entry level, research support will be available."

Evaluating Merit Review

In recent years, an increasing number of academic research facilities have by-passed the merit review system to seek funding directly from Congress. In response, an NSF advisory committee has studied the merit review system (formerly called peer review) for its timeliness, strengths, and shortcomings, and found no fundamental problems. (1) However, the committee did recommend some procedural changes, and NSF has responded accordingly (see section that follows).

RESPONSES AND RESULTS

Some of NSF's major activities in fiscal year 1986 were direct responses to the areas of concern discussed above. During the year NSF also launched major research initiatives, along with efforts to improve the way it does business. Some examples:

1. *Final Report, NSF Advisory Committee on Merit Review,* 1986

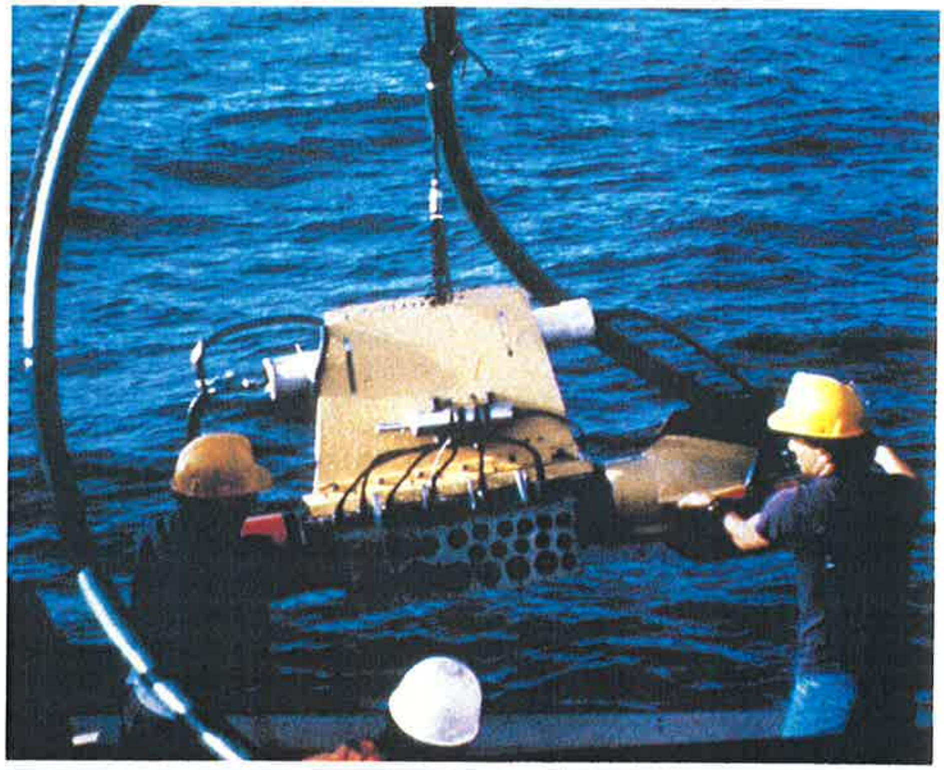
Boosting the Overall Supply of Scientists and Engineers

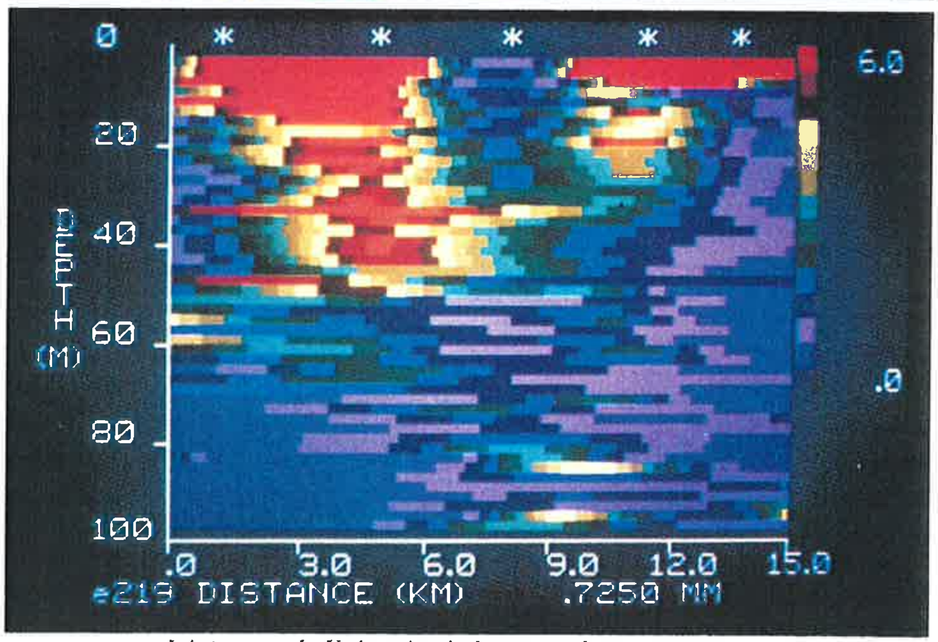
In response to the scientific and technical personnel shortages cited above, NSF has put increased emphasis on programs to support precollege education in math, science, and engineering; to attract underrepresented groups, such as minorities and women, to careers in those fields; and to aid young researchers just beginning their careers. Chapter 2 includes a full discussion of those efforts.

Cooperation Between Industry, Government, and the Universities

NSF endorses the idea that top-quality research be the joint responsibility of industry, academia, and government. Many of NSF's programs—including the centers for engineering research, materials research, and supercomputers—incorporate such cooperation.

A good example of cooperative effort is a joint study by the California firm Tracor Incorporated, the Office of Naval Research, and NSF grantee Richard Pieper at the University of Southern California. Using a suite of sonar instruments, they can monitor the ocean's zooplankton, the insect-like swimmers that feed on plants and are themselves food for fish. The sonar gives readings, in real time, of the size and distribution of the zooplankton. Keeping track of zooplankton can tell the researchers where fish graze and how much they will have to eat.





Tracor, Inc. and USC

Joint research. University, industry, and government researchers work on a zooplankton study. Here they use 21-frequency sonar with chlorophyll/depth/temperature/conductivity sensors and a water pump. The computer color-enhanced profiles of zooplankton were obtained with a multi-frequency sampler.

The productivity of design engineers and the quality of the designs they produce are critical to the competitive success of U.S. industries. In another example of collaboration between university and industry researchers, the long-term goal is to achieve a better understanding of the links between design and manufacturing and—with this understanding—to create computer-based tools that will allow designers to work more effectively and efficiently.

The members of this interdisciplinary research team are John R. Dixon from the Department of Mechanical Engineering at the University of Massachusetts, Paul R. Cohen at the same university's Department of Computer Science, and Melvin K. Simmons at General Electric Research. For example, the team has been exploring the use of expert, or knowledge-based, systems for design and manufacturing. Such systems have evolved out of the field of artificial intelligence.

NSF also supports a series of Industry/University Cooperative Research Centers, or IUCRs. The Foundation awards grants for collaborations between university researchers and groups of industrial firms to plan programs that are broad-based and meet industry needs. Grants to operate the programs usually follow. Both kinds of awards are supported by NSF and the industrial firms, with the idea that a center will, within five years, become self-sufficient.

At this writing, 39 IUCRs are distributed across the country, studying topics ranging from hazardous waste management at the New Jersey Institute of Technology, to optical circuitry at the University of Arizona, to non-destructive evaluation of materials at Iowa State University.

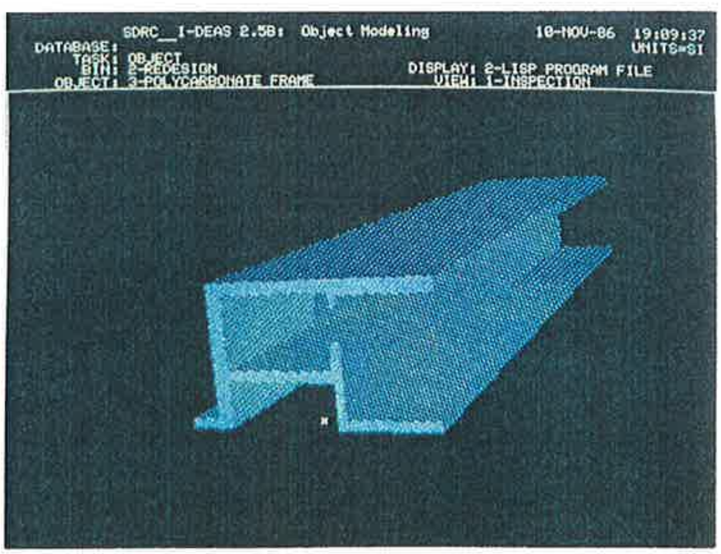
IUCR CENTERS
(AS OF OCTOBER 1, 1986)

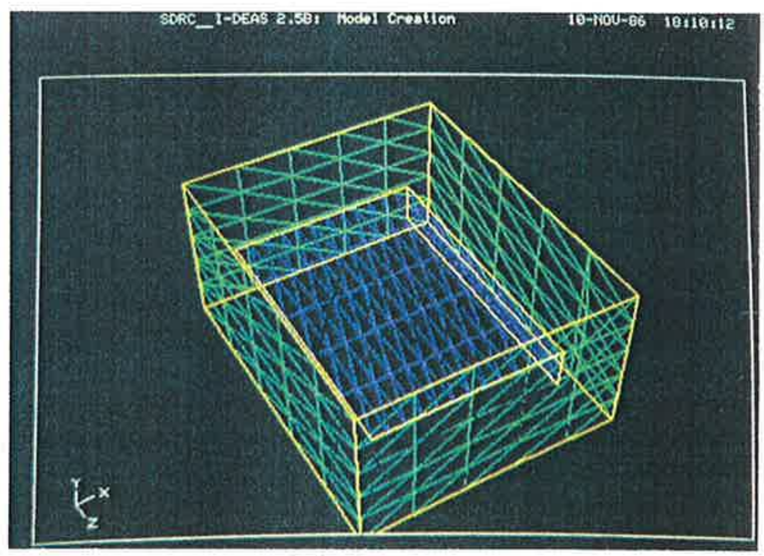
LOCATION	RESEARCH AREA	YEAR INITIATED
NORTH CAROLINA STATE UNIV.	TELECOMMUNICATIONS	1982
RUTGERS UNIVERSITY	CERAMICS	1982
GEORGIA INST. OF TECHNOLOGY	MATERIALS HANDLING	1983
TEXAS A&M UNIVERSITY	HYDROGEN TECHNOLOGY	1983
PENNSYLVANIA STATE UNIV.	DIELECTRICS	1983
COLORADO SCHOOL OF MINES	STEEL PROCESSING	1983
UNIVERSITY OF WASHINGTON	PROCESS ANALYTICAL CHEM.	1984
NEW JERSEY INST. OF TECH.	HAZARDOUS WASTE MGMT.	1984
UNIVERSITY OF ARIZONA	OPTICAL CIRCUITRY	1984
WEST VIRGINIA UNIVERSITY	FLUIDIZED BED RESEARCH	1984
NORTHWESTERN UNIVERSITY	TRIBOLOGY	1984
U. OF NORTH CAROLINA/DUKE U.	MONOCLONAL LYMPHOCYTE TECH.	1984
UNIVERSITY OF ARIZONA	MICROCONTAMINATION CONTROL	1984
U.TX HLTH.SCI.CTR., SAN ANTONIO	CELL REGULATION	1985
DARTMOUTH COLLEGE	ICE RESEARCH	1985
WASHINGTON UNIV., ST. LOUIS	COMPUTERIZED CHEMICAL ENG.	1985
CARNEGIE-MELLON UNIVERSITY	STEELMAKING	1985
NORTHEASTERN UNIVERSITY	ELECTROMAGNETICS	1985
LEHIGH UNIVERSITY	INNOVATION & RES. MGMT.	1985
IOWA STATE UNIVERSITY	NON DESTRUCTIVE EVALUATION	1985
OKLAHOMA STATE UNIVERSITY	WEB HANDLING	1985
LEHIGH UNIVERSITY	CHEM. MODELLING & CONTROL	1985
UNIVERSITY OF MINNESOTA	BIOCATALYTIC PROCESSING	1986
ALFRED UNIVERSITY	GLASS RESEARCH	1986
UNIVERSITY TX. ARLINGTON	ADVANCED ELECTRON DEVICES	1986
UNIVERSITY OF TENNESSEE	MEASUREMENT & CONTROL ENG.	1986
RUTGERS UNIVERSITY	PLASTICS RECYCLING	1986
UNIVERSITY OF WYOMING	MATHEMATICAL MODELING	1986
NM INST. ON MINING & TECH.	ENERGETIC MATERIALS	1986
UNIV. OF FLORIDA/PURDUE UNIV.	SOFTWARE ENGINEERING	1986
UNIV. OF CALIFORNIA, BERKELY	INTEGRATED SENSORS	1986
ILLINOIS INSTITUTE OF TECH.	INTEGRATED INFO. & TELE SYS.	1986

IUCR CENTERS SELF-SUFFICIENT
(AS OF OCTOBER 1, 1986)

LOCATION	RESEARCH AREA	YEAR INITIATED
MASSACHUSETTS INST. OF TECH.	POLYMER PROCESSING	1973
RENSSELAER POLYTECHNIC INST.	COMPUTER GRAPHICS	1979
UNIVERSITY OF MASSACHUSETTS	POLYMERS (PROPERTIES)	1980
OHIO STATE UNIVERSITY	WELDING	1980
CASE WESTERN RESERVE UNIV.	POLYMERS (APPLIED)	1981
UNIVERSITY OF RHODE ISLAND	ROBOTICS	1982
WORCESTER POLYTECHNIC INST.	AUTOMATION TECHNOLOGY	1983

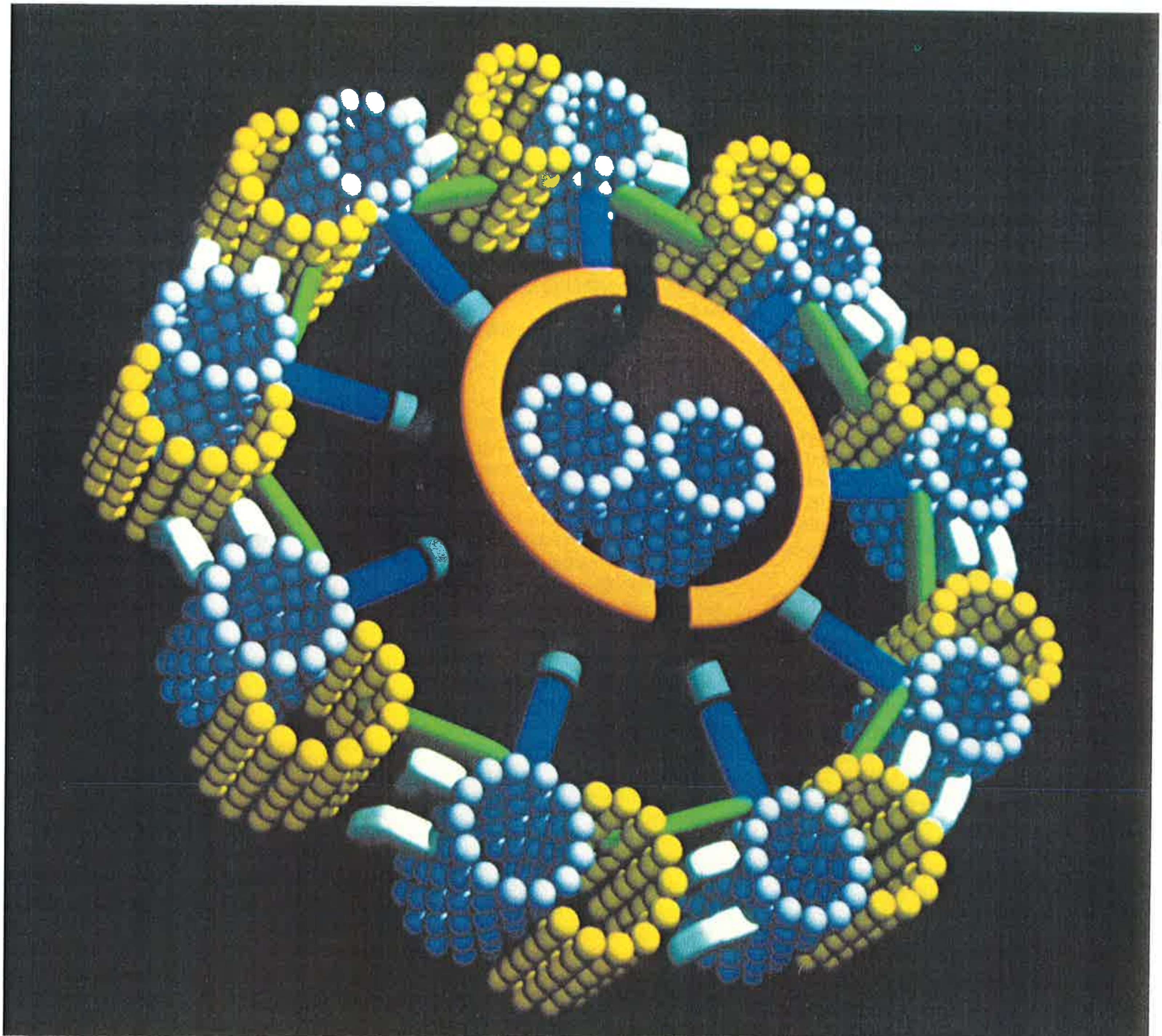
The IUCR at the Georgia Institute of Technology developed software that has already been used by a major soft drink firm. Usable on small computers, the software automatically determines the most efficient delivery routes, the best time schedules, and the most effective loading sequences.





University of Massachusetts

***Design-manufacturing links.** An industry-university team produced a computer-aided design (left) for a polycarbonate resin extrusion. This representation aids automated redesign, structural analysis, and evaluation of manufacturing potential. Second photo shows model for designing a bracket mold.*



IUCR product. The Center for Interactive Computer Graphics at the Renssalaer Polytechnic Institute produced this representation of an organic compound structure. The image was produced with a technique known as ray-tracing. Image-generation techniques are used in a wide variety of applications, from computer-aided design and manufacturing to advertising and entertainment.

NSF also backs a program to encourage innovations in small businesses. (See "Highlights" section for an example of such work.) The Small Business Innovation Research Program, or SBIR, funds small companies to explore advanced high-risk ideas which may be the basis for new inventions. SBIR effectively moves basic research into the marketplace, and for every dollar put into the program by NSF, the private sector has added eight dollars.

Cooperation Between NSF and the States

The Experimental Program to Stimulate Competitive Research, or EPSCoR, is designed to enhance the competitive ability of university researchers in states that receive relatively fewer NSF awards than other states do. During FY 1986, 11 states and Puerto Rico, with NSF assistance, analyzed their science and technology bases to determine current barriers to excellence. They then developed comprehensive five-year plans for making substantial improvements in their universities.

Based on these plans, seven states (Alabama, Kentucky, North Dakota, Nevada, Oklahoma, Wyoming, Vermont) and Puerto Rico were awarded EPSCoR grants of $2.5 to $3.0 million each over five years. The NSF commitment for that period totals $23.5 million, and participating states have committed more than $70 million to the effort.

The EPSCoR plans in each state represent a cooperative effort among the academic, state and local government, and business communities. On a national basis, the program contributes to a broader geographic distribution of scientific and engineering quality.

By several measures, EPSCoR has been a success. Since 1980, when the program began with awards to five states (Arkansas, Maine, Montana, South Carolina, and West Virginia), the number of publications in professional journals and the amount and size of competitive grants awarded to participating scientists and engineers have all risen. Moreover, several researchers have received national honors for work begun with these monies.

In a separate state effort during 1986, NSF launched a project with the Conference Board, Inc., the nation's largest business research organization, and the National Governors' Association, which represents the governors of all 50 states, to determine how government, business, and academia can join forces to make the United States more economically competitive through basic research and education. The project includes a national survey of business, state, and university leaders to determine which issues they perceive have highest priority. This effort will also encourage the states to share information on programs that focus on research and education as a part of their economic development initiatives.

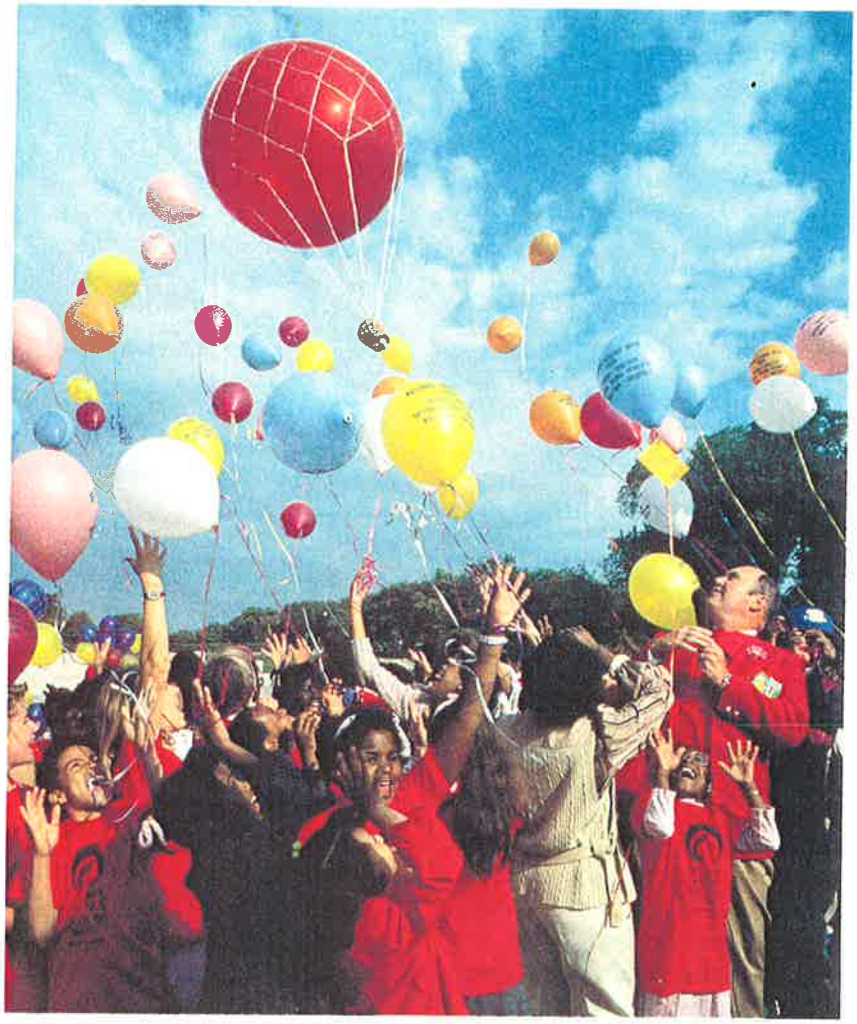
A related program, the NSF-States Initiative, is studying the way states with different resources and infrastructures are supporting education and research to further their economic development. The four states involved in a pilot project are New Jersey, Michigan, Arkansas, and Utah. This pilot effort was begun to enhance communication between NSF and state policy makers and to encourage cooperation among government, business, and academia. The pilot study will be evaluated in 1987 to determine the direction of future efforts with the states.

National Science Week

Thousands of schools, community groups, businesses, professional organizations, government agencies, and individuals all over the country celebrated May 11-17, 1986 as the second annual National Science Week. A highlight of the Week, featured on NBC's *Today* show, was the launch of thousands of balloons—carrying weather information cards—by Washington, D.C. teachers, hundreds of school children, and *Today* weather reporter Willard Scott.

NSF supports National Science Week in an effort to increase public awareness of science and engineering—and to encourage young people to get involved in those fields. Other 1986 activities included education packets for elementary teachers, hands-on science fairs, films, lectures, displays, programs and exhibits at museums and libraries, and "open house" days at research facilities, colleges, and universities.

Corporate sponsors for the 1986 Week included the AMOCO Foundation, Atlantic Richfield Foundation, Dow Chemical Company Foundation, Dupont Company, Eastman Kodak Company, General Electric Foundation, and IBM. For 1987, National Science Week has been expanded to National Science and Technology Week (April 5-11).



National Science Week 1986—making the public aware of science. One highlight of the Week was the National Balloon Launch (above). NBC's Today *weather reporter Willard Scott is at far right of photo. Also shown here is the official poster for NSW 1986.*

> **Perhaps more than at any time in the past, our nation now realizes the indispensable role that science, engineering, and technology play in assuring this country's economic competitiveness, national security, and prosperity. Because of the pervasiveness of science and technology and the rise of foreign competition in technology-based industries, we understand the need to increase our investment in basic research and to identify, attract, and nurture the new talent that will maintain America's future leadership in these fields.**
>
> Statement by President Reagan during National Science Week 1986

Global Geosciences

Since science is by nature international, NSF activities have always included support of international research collaborations, exchanges, and programs. International cooperation is also essential in studying those phenomena, such as climate, volcanoes and earthquakes, or acid rain, that affect our whole planet or significant parts of it.

The oceans, atmosphere, land, and plants all form a complex feedback mechanism. Global scientists seek to understand the earth as it was and is, to monitor how it might be changing, and to predict the effect of variations—both natural and human-made—on the global environment. Only in the last few years has the study of our earth as a global system become technologically feasible. Satellites measure the motion of tectonic plates along fault lines; instruments on earth allow measurements in

Global geoscience concerns

the deepest oceans or the upper atmosphere; computers are used to store and analyze the masses of data. NSF cooperates with other federal agencies in a program that in its scope may be the biggest of all big science. For more on global geosciences, see chapter 2, "Focus on International Science and Engineering."

Biotechnology Guidelines

Biotechnology, the engineering of genes to make new products, is used to help crops resist insects or frost and to make vaccines, drugs, and diagnostic tests for diseases. Biotechnology and its products will surely become a major force in the nation's economy.

Several government agencies—including the Occupational Safety and Health Administration, the Environmental Protection Agency, the Department of Agriculture, the Food and Drug Administration, the National Institutes of Health, and the National Science Foundation—have issued a set of guidelines to ensure the safety of biotechnology research and products. These guidelines spell out agency responsibilities, the processes by which a genetically engineered product can be manufactured and sold, and the conditions under which it can be released into the environment. David Kingsbury, NSF's Assistant Director for Biological, Behavioral, and Social Sciences, coordinated this interagency effort, done under the auspices of the White House Office of Science and Technology Policy.

Double helix of DNA molecule

Improving the Proposal Process

Responding to the Merit Review Report described earlier, NSF has developed procedures to use multi-stage review panels to evaluate large-scale projects. Among other responses, NSF is:

1. Formulating ways to process and review unsolicited interdisciplinary research proposals that do not fall into established program areas; and

2. Assuring that its program officers adhere to established guidelines to include more female and minority scientists or engineers and persons from predominantly undergraduate institutions in the many stages of reviewing proposals. Program officers also are encouraged to support high-risk proposals.

Other 1986 initiatives seek to improve the process by which a researcher proposes a project for NSF to fund. One effort would speed up the proposal process. Every year, NSF receives multiple copies of more than 30,000 research proposals. The proposals can be 50 pages each and contain text, images, graphics, and photographs. More than half of these are mailed to some six or eight reviewers apiece; the reviewers' responses come back to NSF, which then notifies the researchers of acceptance or declination. Now, through a project called Experimental Research in Electronic Submission (EXPRES), the Foundation seeks to have this process done by computer—in short, to transmit documents and images electronically and to standardize transmission technologies. Ultimately, NSF hopes for a proposal-handling system that is virtually paperless.

Still another initiative would simplify the proposal process. NSF has been working with five other federal agencies (the National Institutes of Health, the Office of Naval Research, and the Departments of Health and Human Services, of Energy, and of Agriculture) to standardize and simpify the way all of them approve and administer research grants.

Researchers often receive funding for different pieces of their work from two or more federal agencies. The agencies want to help those investigators avoid duplication of effort. They also want to reduce federal controls, agree on the same rules, and in general simplify the whole process. A program at the University of Miami and the Florida State University System, called the Florida Demonstration Project, is concentrating on ways to achieve those goals. The project involves, for example, coordination of start and stop dates for grants, plus an effort to turn over to the local university the authority to approve such items as foreign travel and equipment purchases.

A recent pilot project at NSF will expedite funding for innovative or exploratory engineering research. Much of the increase in our country's productivity in the last 50 years has been due to technological innovations, which NSF wishes to stimulate. Thus the Directorate for Engineering has set aside 5 percent of its budget for an experimental program to fund novel ideas and do so quickly. Proposed research can include work on the initial elements of a subject in an emerging area of science and engineering, the exploration of new ideas for cross-disciplinary approaches to research, or investigation of new ways to conduct basic research on science and engineering problems.

Yet another initiative aims at strengthening ties between NSF and university grant administrators, upon whom academic scientists and engineers often depend to help them prepare proposals and administer their grants. Thus the Foundation, the National Council of University Research Administrators, and the Society of Research Administrators are jointly sponsoring the Research Administrator's Development Program. It provides for those university staff to spend four months at NSF, learning the details of the awards system. In addition to their own professional development, the administrators learn the proposal review process and the system by which award budgets are negotiated and administered. The program, although only in its first year in 1986, has been well-received, with two university representatives working at the Foundation during the fiscal year (1). Both NSF and university research administrators have come to understand the grants process and its problems from each other's vantage point.

A New Directorate

NSF's investment in computer and information science and engineering has been growing rapidly, as has the investment by the whole science and engineering community. Thus NSF consolidated its programs relating to computers into a new directorate called Computer and Information Science and Engineering (CISE). For more on this move, see chapter 5.

1. Joan E. Snook, University of Hawaii, and Ruth Kemp, Stanford University

CHAPTER

2

CENTERS AND INSTRUMENTATION

Truth is divined through experience and experimentation.

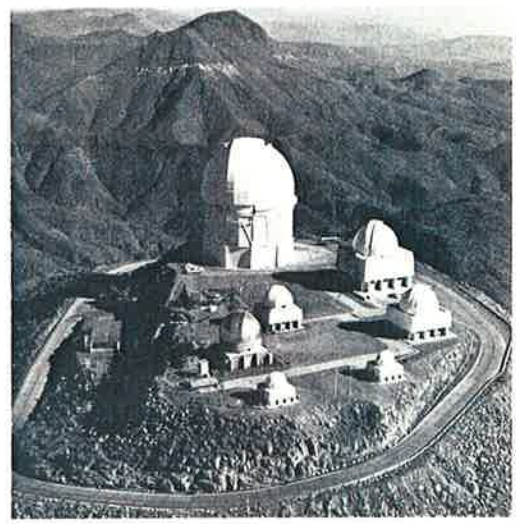
Albert Einstein

Research in science often has unexpected applications in technology: scientists curious about the ways atomic nuclei interact with matter uncovered the principles behind nuclear magnetic resonance, a technique that has revolutionary applications in such fields as biology, chemistry, geology, and physics. Similarly, new technologies often drive basic science: bigger and faster computers have turned computer simulations into a unique approach to science, halfway between theory and experiment. Science and technology form a loop in which progress and creativity flow both ways.

In the last few years, several trends have coincided to alter the science-technology loop. First, federal support for non-defense research and development has decreased, although industry support has increased. Second, the instruments and facilities necessary for research in the universities have been found wanting in many cases. (See "Research Facility Needs" in chapter 1.) To remedy the situation, universities, industry, and the federal government have increasingly pooled their scientific and engineering talents; in some instances industry and the federal government have jointly funded university-based programs that range from small collaborations of several researchers to huge facilities with scores of investigators.

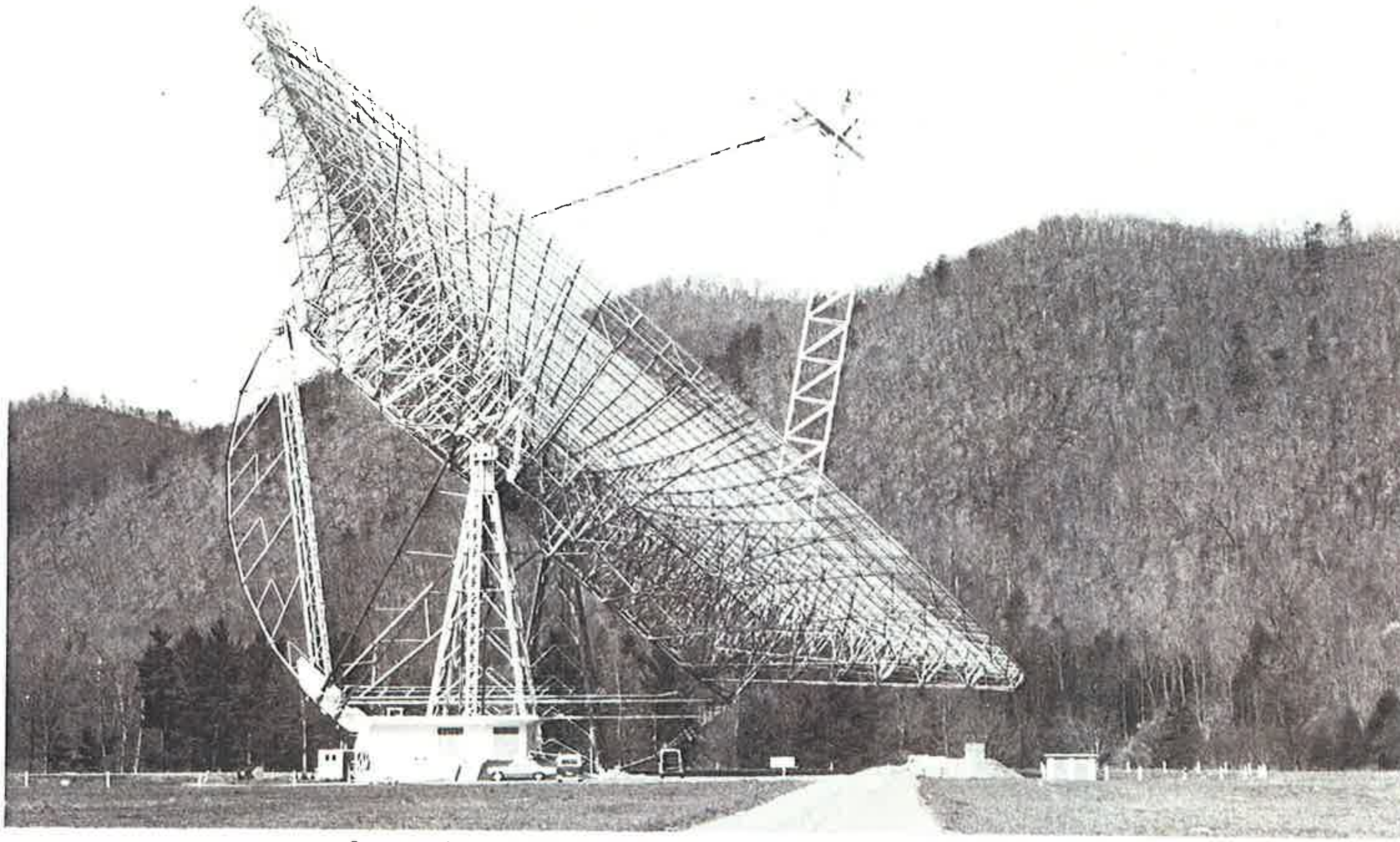
Some of the large centers that NSF helps to support offer instruments that no one university could afford:

- The National Optical Astronomy Observatories (NOAO), headquartered in Tucson, Arizona, include three facilities. Two of them—the Kitt Peak National Observatory in Arizona and the Cerro Tololo Inter-American Observatory in Chile—provide access to optical telescopes in both the Northern and Southern Hemispheres. The third site, the National Solar Observatory, has observing facilities in New Mexico and Arizona for solar research.
- The National Radio Astronomy Observatory, with headquarters in Charlottesville, Virginia, has facilities for astronomical observations at radio frequencies in West Virginia, New Mexico, and Arizona.



Sky coverage North and South. Kitt Peak National Observatory in Arizona (below) and Cerro Tololo Inter-American Observatory in Chile

FOCUS ON . . .

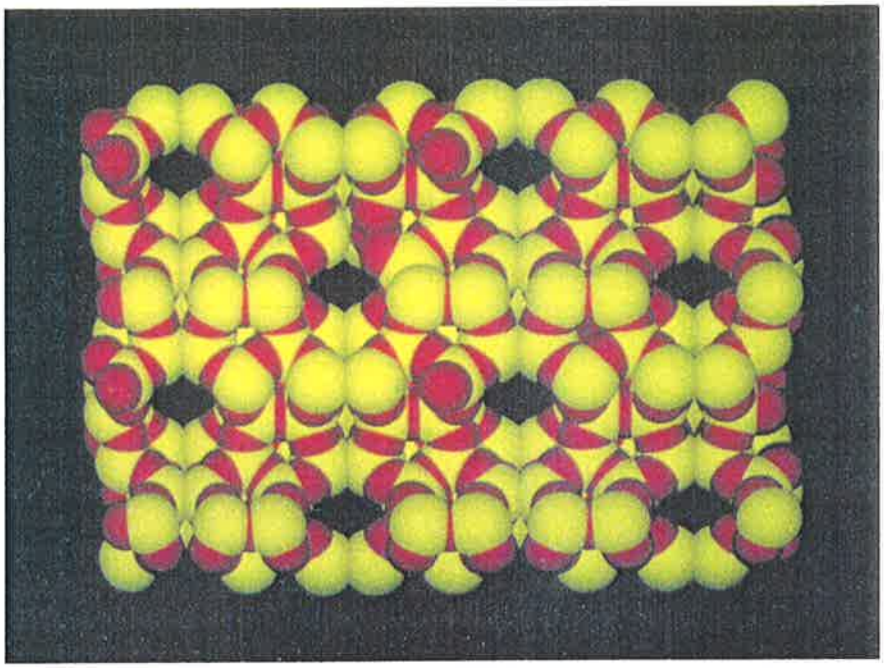


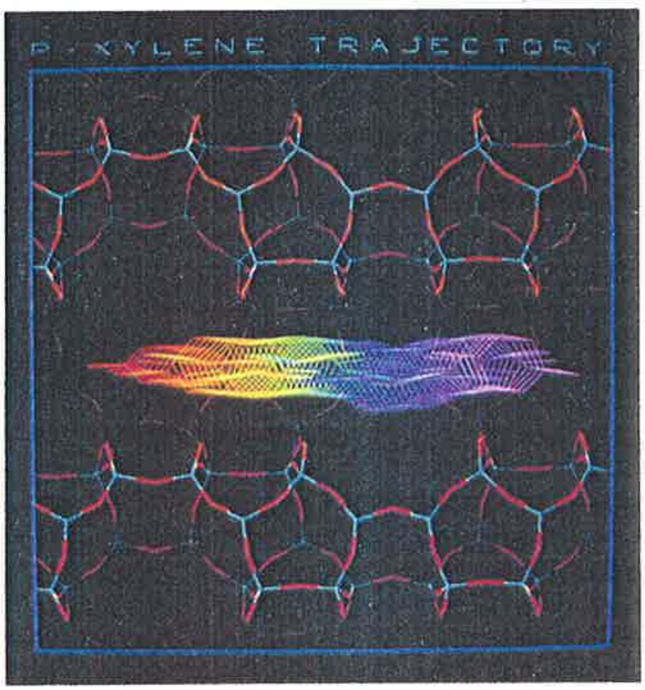
***Survey telescope.** The 91-meter transit radio telescope at the National Radio Astronomy Observatory in Green Bank, West Virginia*

- The National Astronomy and Ionosphere Center operates the world's largest single radio telescope near Arecibo, Puerto Rico.
- At the National Center for Atmospheric Research in Boulder, Colorado, scientists from various fields study current weather patterns, long-range global climate trends, and related topics.

Newer large-scale programs aided by NSF include Materials Research Groups, Engineering Research Centers, and Supercomputer Centers. All include research that crosses several scientific and engineering disciplines, and all depend heavily on collaborations between universities, industry, and the federal government.

Six new *Materials Research Groups* have been established this fiscal year, bringing the total to eleven. This program was started in FY 1985 to bridge the gap between two types of NSF funding modes: the large, multi-disciplinary Materials Research Laboratories and individual project support. Materials Research Groups focus on complex materials problems that require a team approach combining the complementary expertise of several investigators from one or more disciplines, working with major, sophisticated instrumentation. Such projects have the dual goal of acquiring fundamental knowledge and assisting technological growth.





Materials Research Group. A group at Caltech is carrying out computer graphics simulations of a number of materials, including zeolites (top). Other photo shows motion dynamics for the molecule para-xylene.

New Materials Research Groups are at the Carnegie Mellon University, Case Western Reserve University, University of Michigan, Michigan State University, Purdue University, and the University of Texas. Their research areas involve several disciplines, including physics, chemistry, materials science and engineering, and other branches of engineering. The research areas are, respectively:

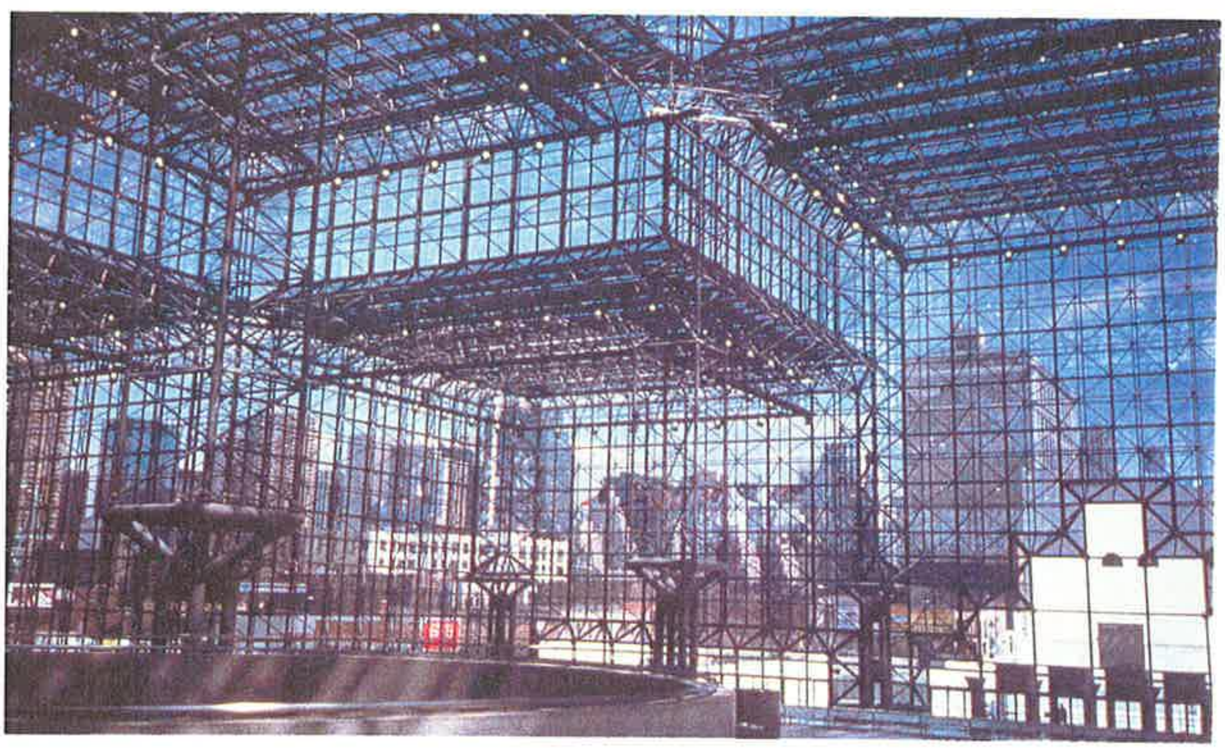
- new magnetic materials, including (1) thin films for potential use in magnetic recording and information storage, and (2) permanent magnet materials;
- ferroelectric liquid crystal polymers for potential optoelectronic applications;
- new multi-layered metal and semiconducting structures with novel electronic behavior;
- the potential catalytic properties of silicate clays;
- the relationship between the electronic structure and magnetic properties of a novel class of semiconductors for potential use in infrared detectors;
- the design and construction of a synchrotron radiation facility at the National Synchrotron Light Source, Brookhaven National Laboratory, for studying the electronic properties of magnetic materials.

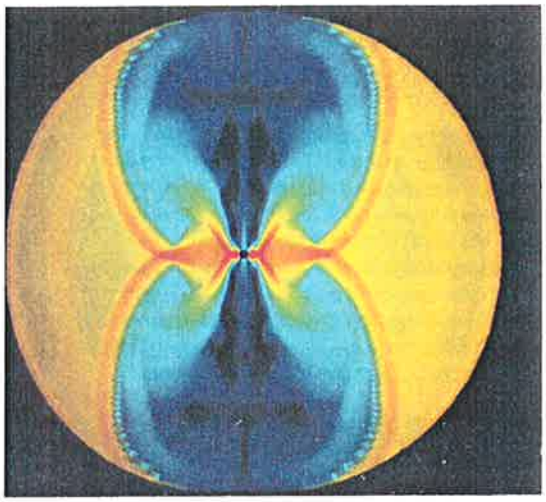
Five new *Engineering Research Centers* joined the six launched in FY 1985, bringing their total number to eleven. These Centers work closely with industry on the research agenda; industry also provides interactions with its technical personnel, and cooperates in academic seminars and classes.

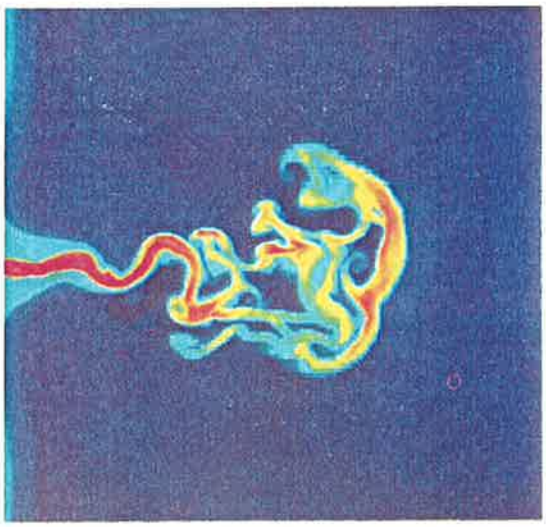
The new Centers are at Brigham Young University/University of Utah, Carnegie Mellon University, the University of Illinois at Urbana, Lehigh University, and Ohio State University. There researchers are studying, respectively, the process of combustion; the theory of engineering design; compound semiconductor microelectronics for optical interconnects in digital integrated circuits; large-scale structural systems; and the manufacture of formed parts to near-final shape with as few steps as possible.

By providing capabilities for massive calculations and simulations, supercomputers are becoming increasingly important in many fields of science and engineering. Not only do they make previously impossible computations practical, but they add another dimension to theory and experimentation in the study of complex natural phenomena. To deliver the needed computer time to the academic research community, a fifth NSF-supported *Supercomputer Center*—run jointly by Carnegie Mellon University and the University of Pittsburgh—was brought online in 1986. (Four were launched in 1985.) In addition, NSF sponsors institutes to help train potential users in this powerful new tool. Cooperating with other federal agencies, the Foundation has also arranged access for medical researchers funded by the National Institutes of Health.

Engineering Research Centers. Ohio State University work involves the computer-aided design and machining of polystyrene models for making dies. Completed model is shown in photo immediately below. At Lehigh University, the Center for Advanced Technology for Large Structural Systems is examining such structures as New York City's Javits Convention Center, shown in second photo.







Supercomputers at work. Shown here are two examples of work done at the National Center for Supercomputing Applications, Champaign, IL. The round image represents a calculation of the axisymmetric accretion of rotating gas onto a "black hole" in space. Second image is a computation of a planar symmetric supersonic jet of gas flowing into a two-phase atmosphere.

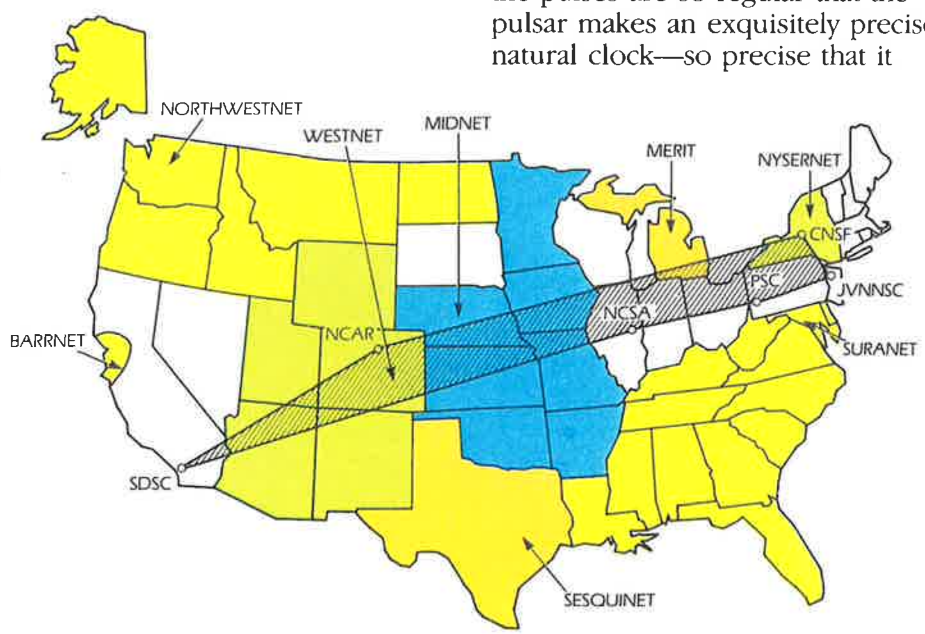
Although the Supercomputer Centers are young, they are heavily used. With rapidly changing and new technologies in mind, research is in progress on ways to make bigger, faster, and more widely distributed machines. Included here are so-called superminicomputers that potentially give users a quarter of the speed of a supercomputer at a tenth of the price.

In a parallel effort, as part of a plan to improve scientific communication and make advanced computing capabilities more accessible, the Foundation is supporting the creation of NSFnet, a network of computer networks. Eventually it will include academic networks; those run by the U.S. Departments of Energy and Defense; and regional networks in the San Francisco Bay, Houston, New York State, Midwest, and Southeast areas—with others still to come.

Along with these centers, NSF also supports the instrumentation that is so critical to research. Some examples:

In astronomy, telescopes

Via the radio telescope at Arecibo, Puerto Rico, a group under the direction of Joseph Taylor at Princeton University discovered the fastest binary pulsar. This pulsar is a neutron star (the remnant of a supernova explosion) that orbits another star. Although many single pulsars are known, astronomers have identified only seven that exist as members of binary systems. Pulsars are extraordinarily dense and roughly 10 miles in diameter. They also spin, sending out pulses of radio noise with every turn. The pulses of the newest pulsar come every 5.362 milliseconds, meaning that the star spins around every five-thousandths of a second. Indeed, the pulses are so regular that the pulsar makes an exquisitely precise natural clock—so precise that it



Supercomputer network. Regional networks in the future will be linked to the six supercomputer centers, and to one another, via the "backbone" connection shown here (grid area).

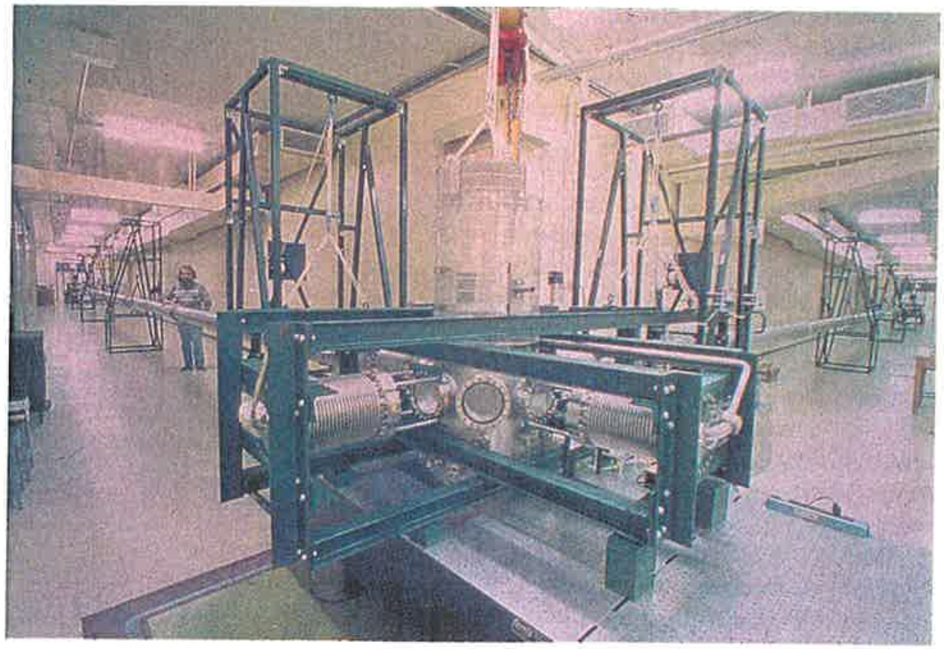
Abbreviations: BARRNET = Bay Area Regional Research Network; CNSF = Cornell National Supercomputer Facility; JVNNSC = John von Neumann National Supercomputer Center; MERIT = Michigan Education & Research Interuniversity Telecommunications; NCAR = National Center for Atmospheric Research; NCSA = National Center for Supercomputer Applications; NYSERNET = New York State Education & Research Network; PSC = Pittsburgh Supercomputer Center; SDSC = San Diego Supercomputer Center; SESQUINET = Sesquicentennial (of Texas) Network; SURANET = Southeastern Universities Research Association Network could provide a better time standard than the best atomic clocks.

In related work at Kitt Peak, UC-Berkeley's Shrinivas Kulkarni has been able to detect for the first time at optical wavelengths the other member of a pair of these binary pulsar systems. Astronomers had not previously known what type of star the neutron star orbited. Two have been found to orbit white dwarf stars, the end-points in the life cycles of stars like our sun.

Other teams analyzed the return of Halley's Comet, using optical telescopes at Kitt Peak and at Cerro Tololo in Chile, along with the National Radio Astronomy Observatory's Very Large Array in New Mexico.

Finally, the high accuracy of Very Long Baseline Interferometry has been used to determine a new value of the distance to the center of our galaxy. In this technique, images of moving water vapor maser spots close to the galactic center were observed over a year's time. From measured positions and velocities, it was possible to provide a statistical estimate of the distance to these objects. An international team, led by Mark J. Reid at the Harvard-Smithsonian Center for Astrophysics, used radio telescopes at the National Radio Astronomy Observatory and elsewhere to obtain a value of 7.1 ± 1.2 kiloparsecs. This measurement indicates that the size of the Milky Way galaxy is significantly smaller than the older 8.5-kiloparsecs size determined from data on pulsating variable stars. (A parsec is equal to 3.3 light years or 31 trillion kilometers.)

This measurement technique, in addition to its importance in determining the distance scale of our galaxy, could perhaps be used in gauging distances to other galaxies. Star-forming regions existing in nearby galaxies can be used to determine extragalactic distance scales. The technique changes our entire concept of our galaxy's size and of distance scales in general.



Gravity wave detector. This prototype instrument is at Caltech. Detection of gravity waves, which are very weak, can tell us much about stars, quasars, black holes, and the nature of our galaxy.

In physics, the gravity wave detector

If Einstein's ideas about gravity are correct, physicists should be able to detect gravitational waves. In Einstein's theory of general relativity, gravitational waves are moving wrinkles in space-time, generated by moving masses, just as electromagnetic waves are generated by moving charged particles.

Gravity waves are extremely weak: those given off by Jupiter as it orbits the sun correspond to a few watts. In order to detect the waves, physicists suspend highly-reflecting mirrors at the ends of two large perpendicular evacuated chambers and then bounce laser beams between them many times. A passing gravity wave should cause the separation between the mirrors in the two chambers to change microscopically.

The resulting changes in length are so small that physicists would have to be able to spot a change the size of a proton over the distance from the earth to the moon. So far, the prototype gravity wave detectors, built at the Massachusetts Institute of Technology and the California Institute of Technology, fall somewhat short of that kind of sensitivity. But they are improving rapidly.

The only events large enough to give off detectable gravity waves are astronomical catastrophes, such as a supernova explosion or the collision of two black holes. In addition to substantiating Einstein's theory of gravity, detection of gravity waves will open a new window into violent processes in the interiors of stars, quasars, and black holes, as well as in the nucleus of our galaxy.

In chemistry, nuclear magnetic resonance

NMR techniques are valuable to many disciplines. The technique depends on the fact that the nucleus of an atom is a tiny magnet, spinning much the way a top spins. And just as a top begins to wobble under the influence of gravity, a nucleus will wobble depending on how strongly its environment affects it. Nuclear magnetic resonance measures the strength of magnetism of the nucleus and, consequently, the strength and nature of the nucleus's environment.

NMR was first developed by physicists to measure the magnetism in the atomic nucleus, then applied by chemists and life scientists to determine the way atoms are linked together to form molecules, then used in medical imaging as a safe replacement for x-rays. The technique now provides a way for geologists to identify slightly differing minerals without destroying them.

Chemists have found ways to make NMR even more sensitive. They use it to map the atoms in a molecule, which in turn reveals the structure of molecules. The more chemists know about a molecule's structure, the more they can understand how it behaves. For instance, Aksel Bothner-By at Carnegie Mellon University has used NMR with unusually strong superconducting magnets to find the detailed structure and shape of important molecules such as DNA and hemoglobin.

Nuclear magnetic resonance work: two investigators. Aksel Bothner-By (at right in first photo) is at Carnegie Mellon University; John S. Waugh is at MIT.

In related work, using a different approach, John Waugh at the Massachusetts Institute of Technology has cooled laboratory samples to within a hundredth of a degree of absolute zero. He has been able, for example, to increase the sensitivity of NMR by a factor of 10,000 by using helium-3, which changes the rate at which the nucleus will respond to an applied high-frequency electric field in the magnet. This allows measurements that were previously impossible because of a lack of sensitivity. It also allows Waugh to observe smaller molecules adsorbed on the surface of a catalyst, or even a single large molecule such as an enzyme. This provides an important advance in unravelling the details of catalyst activity, which is crucial in the development of new and more effective chemical systems.

Instruments to improve undergraduate instruction

A recent report on undergraduate education (1) stated that "Laboratory instruction . . . too frequently is conducted in facilities and with instruments that are obsolete and inadequate." NSF's College Science Instrumentation Program is one response to this need. It provides grants that are to be matched with equal or greater contributions by the grantee institutions. Awards are based primarily on the quality and significance of the teaching improvement made possible by the equipment requested. Projects that not only effect local improvements but also may serve as models for other schools are given priority.

1. *Undergraduate Science, Mathematics, and Engineering Education,* National Science Board, March 1986

Many of the projects supported since the program's inception in FY 1985 use technologies new to undergraduate instruction, such as robotics, biotechnology, laser spectroscopy, and electron microscopy. Computerized instrumentation, for rapid data collection and analysis, is frequently included. In addition to projects focusing on the separate disciplines, a number are interdisciplinary in nature.

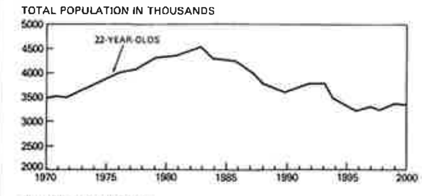
SCIENCE AND ENGINEERING PERSONNEL: MEETING FUTURE NEEDS

> **If I have seen further, it is by standing upon the shoulders of giants.**
>
> Sir Isaac Newton

As part of its mandate, NSF collects information on the numbers and characteristics of science and engineering personnel, monitoring changes in this population over time. The scientific and technological enterprise depends on maintaining a balance between the supply of, and demand for, such personnel. At present, several trends suggest that in the next decade the flow of science and engineering personnel into academia and industry could be reduced.

In the first place, the supply may well decrease. The population of 22-year-olds, of which college graduates are a part, is decreasing (see art), and the percentage of those who graduate in the natural sciences and engineering has been relatively constant. Moreover, undergraduates are expressing less interest in majoring in science and engineering.

ESTIMATES OF 22-YEAR-OLDS IN THE U.S. POPULATION



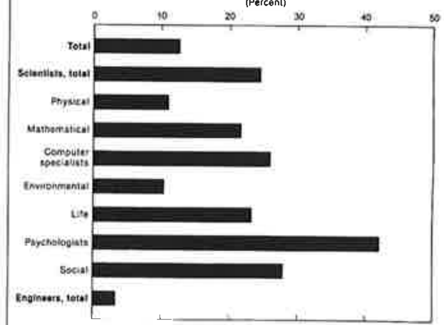
SOURCE: BUREAU OF THE CENSUS

In the second place, while demand for scientists and engineers is always difficult to predict, it has been increasing of late, and indications are that academia and industry—especially those industries depending on engineers and computer specialists—may experience shortages. These trends, added up, could forecast a troubled future for a country whose health depends greatly on its scientists and engineers.

Three other trends, however, also affect supply. One is the increasing numbers of foreign nationals in science and engineering: the number of foreign nationals enrolled in undergraduate and graduate schools, as well as the number hired by U.S. industry and academia as scientists and engineers, is going up. Questions have been raised among science and technology policy officials as to whether the possible return of foreign specialists to their native countries could pose a threat to the long-term competitiveness of U.S. industries.

A second trend is the number of women in science and engineering. Their enrollment increases over the last decade have levelled off. Among college graduates with degrees in science and engineering, 38 percent are women; yet only 13 percent of persons employed as scientists and engineers are females—despite the rapid employment growth of women in the overall workforce.

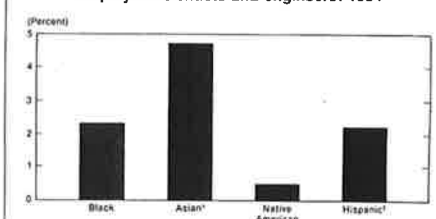
Women as a percent of total science and engineering employment: 1984



Source *Women and Minorities in Science* (NSF 86 301, Jan 1986)

A third trend is the number of minorities, especially blacks. As was the case with women, the numbers of minorities in science and engineering have risen over the last decade. However, despite numerical increases, blacks are now 12 percent of the population but they graduate with 6 percent of the degrees in science and engineering and represent only 2 percent of all scientists and engineers.

Racial/ethnic minorities as a percent of employed scientists and engineers: 1984



[1] In 1984, almost 30 percent of all Asian scientists and engineers were not U.S. citizens.
[2] Includes members of all racial groups.
Source *Women and Minorities in Science* (NSF 86-301, Jan 1986)

Minorities and women are underrepresented in science, math, and engineering; they are a valuable, largely untapped, resource for the future. With the general population of young people dropping, it is even more important to attract these two groups to careers in science and technology. The issues here are both pragmatic—science and engineering cannot afford to overlook any potential talent—and ethical—our country is committed to offering all citizens equal access to professions.

NSF recognizes all these issues and offers a number of programs to attract and assist minorities, women, disabled researchers, and young scholars in general. Some examples follow (see also the section on precollege education, below):

Fellowships and Related Programs

Through Graduate Fellowships and Minority Graduate Fellowships, outstanding students are awarded annual stipends to pursue graduate study in science and engineering. During fiscal year 1986, NSF made 560 such awards under these two programs.

The Foundation also administers NATO Postdoctoral Fellowships in Science (see later focus on international activities), and awards travel grants that enable young scientists to attend certain NATO Advanced Study Institutes abroad.

In FY 1986, NSF began a program to provide supplemental funding for engineering researchers to hire female, minority, and disabled students (both high school and college) to work as research assistants on grant projects.

Many NSF grants for research by principal investigators in all disciplines include support for the graduate students assisting those investigators. The Foundation also works to improve the ratio of graduate students to principal investigators, or PIs; its long-range goal is one or two students per PI.

The Minority Research Initiation (MRI) program helps minority faculty members get their first research grants by funding equipment and release time from teaching, providing assistance in preparing proposals, and linking the researchers with NSF programs in their disciplines. Since 1981, when this program began, the number of grants under it has risen and an increasing number of MRI grantees goes on to apply to (and receive awards from) other NSF programs and other funding agencies. Some of these grantees have later received the Presidential Young Investigator awards (described below).

Among those receiving awards in FY 1986:

- Henry L. Neal of Atlanta University is using several chemisorption models to investigate the photoemission spectra of several transition metals.
- Maria Garcia of the University of Massachusetts (Amherst) received a planning grant to find ways to get explicit mathematical solutions for systems of nonlinear equations and to develop a full-scale NSF research proposal addressing this topic.

NSF also funds grants to boost the research capabilities of minority colleges and universities. Under the **Research Improvement in Minority Institutions Program,** these institutions receive support for such activities as organizing and managing research programs, buying equipment and facilities, and collecting and publishing data. In FY86, NSF made grants totalling more than $4.5 million to 16 of these institutions. For example:

- Civil engineers at the University of Texas-El Paso are developing a testing facility for investigating the dynamic properties and holding capacities of plates and anchors in soil and in cemented sand. Results from these experiments will have important implications for decreasing earthquake damage to various structures.
- Physicists at Fisk University in Nashville, Tennessee are using an upgraded and updated molecular spectroscopy laboratory to study the vibrational determination of crystal structures and to develop crystals that will conduct light.
- A project at Southern University in Baton Rouge, Louisiana uses new technological methods to synthesize and purify certain virus inhibitors found in embryos of the cowpea. The study will provide important information on ways to control plant and animal viral infections.

The Research Opportunities for Women (ROW) program, begun in fiscal year 1985, provides opportunities for female scientists and engineers to undertake independent work. ROW supports (1) research planning and research initiation grants for women who have not previously been principal investigators or are reentering research careers, and (2) career advancement awards for any female investigators eligible to receive standard NSF research grants. The program thus responds to NSF's concern for the quality, distribution, and effectiveness of the human resource base in science and engineering.

The Visiting Professorships for Women give both promising and established female researchers the chance to engage in research and teaching as visiting faculty members at host institutions. The program has several aims: to provide role models for women who wish to go into science and engineering; to increase the visibility of women as faculty members; to enhance the awardees' own work; and to enable them to return to their home institutions with new ideas.

Among those receiving awards in 1986 were:

- **Ann M. Boesgaard,** professor of astronomy at the University of Hawaii, went to the California Institute of Technology to study the way all the chemical elements created in stars are distributed throughout interstellar space.

Ann M. Boesgaard

- **Jean M. Bennett,** from the Naval Weapons Center in China Lake, California, went to the University of Alabama at Huntsville to work on ways of improving the quality and reflectiveness of optical surfaces and coatings.

Facilitation Awards for Handicapped Scientists and Engineers provide additional support to make available special equipment or assistance under NSF grants to reduce or remove barriers to participation in research and training by disabled individuals. These awards respond to NSF's long-standing policy of encouraging disabled researchers to participate fully in NSF programs.

Jean M. Bennett

UCSB Learning Resources

NSF Facilitation Awardee. Reginald G. Golledge is Professor of Geography at the University of California at Santa Barbara. In 1983 he was stricken with a progressive eye disease that left him legally blind. In 1985, NSF made an award that enabled Golledge to purchase a stereo copying machine. Interpreting graphic and cartographic images is a critical part of his research; this machine uses a capsule paper that expands instantly upon absorbing heat or light from a map or a graph, producing a raised image of the original. The stereo copier (not shown in photo) has been of great value in helping Golledge to continue his research and teaching.

Presidential Young Investigators

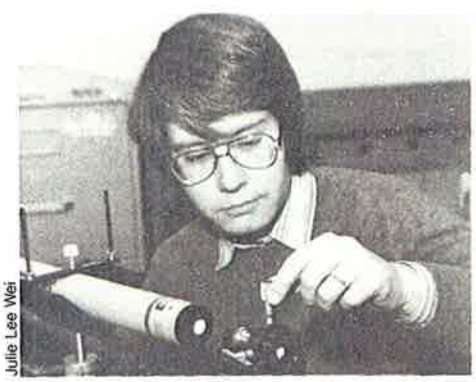
NSF also seeks to develop science and engineering personnel by selecting highly talented young faculty for the Presidential Young Investigator (PYI) Awards. Cosponsored by industry, these awards can involve up to $100,000 a year for as long as five years. The PYI awards are intended to help universities attract and retain faculty who might otherwise pursue nonteaching careers. Of the 100 awards made in fiscal 1986, three-quarters went to researchers in the physical sciences and engineering. Among the recipients:

• **Wendell Hill,** an assistant professor at the University of Maryland, did his undergraduate training at the University of California at Irvine and his graduate work at Stanford University. Hill's research is in chemical physics—in particular, how molecules in the atmosphere form and how they fall apart. He shines a laser (tuned to a certain energy) at an oxygen molecule until it disassociates, or falls apart, then studies the way the energy is distributed among the fragments.

One possibility is that the molecule simply falls apart into two atoms, each with a specific level of energy. Another scenario is that the molecule does not fragment at all, but sends off a single electron so that the entire molecule carries a charge and fluoresces. A third possibility is that the molecule falls apart into fragments that consist of one neutral oxygen atom, one charged oxygen atom that is missing an electron, and the electron. Hill wants to know which possibilities are most likely to occur.

Wendell Hill (at left)

"I'm doing this first of all because it's interesting," says Hill, "and second, because new instruments have only just recently made it possible, and third, because it's related to what goes on in the atmosphere." In the upper atmosphere, sunlight hits molecules of oxygen and, as in Hill's experiments, disassociates them. One outcome is the formation of ozone, which, along with oxygen, absorbs the ultraviolet part of sunlight. Chemicals manufactured on earth can destroy the ozone, and thus allow more ultraviolet through the atmosphere. The effects of increased levels of ultraviolet light include increased levels of skin cancers. Hill's research on what happens to individual oxygen molecules should help scientists understand—and perhaps may suggest controls over—the whole process. (See also "Highlights" for discussion of Antarctic ozone hole.)



Julie Lee Wei

Doreen Weinberger

• **Doreen Weinberger,** an assistant professor in the Department of Electrical Engineering and Computer Sciences at the University of Michigan, did her undergraduate work at Mt. Holyoke College and her graduate work at the University of Arizona at Tucson. Weinberger is an experimentalist whose research combines optics and semiconductors. Communications systems, robotics, and computers all depend on how quickly signals can travel through various materials and how quickly those signals can be switched off and on. Ordinarily, these systems use electric current as signals; Weinberger is most interested in using light, the fastest signal possible. In one line of her research, she looks at the way light affects semiconductors. An intense laser can induce changes in the properties of the semiconductor that allow a second, less intense laser—also shone at the semiconductor—to be effectively switched on and off.

Another Presidential Young Investigator. Mark O. Robbins is a Presidential Young Investigator at Johns Hopkins University whose research covers a broad range of condensed matter physics. One of his projects is to understand the ways in which a system's orderliness affects its behavior. His theories apply to the way fluids, such as oil, move through rock, or the way a wave of electrons moves through a crystal as though it were one electron. Some of Robbins' work involves simulating these systems on a supercomputer; he has been allotted time to pursue his theories at the University of Illinois Supercomputer Center.

In another line of research, Weinberger looks for novel devices that combine semiconductors, which control a light signal, and optical fibers, which carry the signal from one point to another. Weinberger has built one such device, an optical fiber with a hole in its side, laid down on a chip. Light comes through the hole and triggers a semiconductor detector grown on the same chip. Weinberger's next step is to grow, on the same chip, a many-layered semiconductor device that will switch the light from the hole on and off. The rest of the light continues travelling down the length of the fiber. Such a device would be the basis for the extremely fast and capable new generation of computers called optical parallel processors.

PRECOLLEGE EDUCATION AND THE PERSONNEL ISSUE

All who have meditated on the art of governing mankind have been convinced that the fate of empires depends on the education of youth.

Aristotle

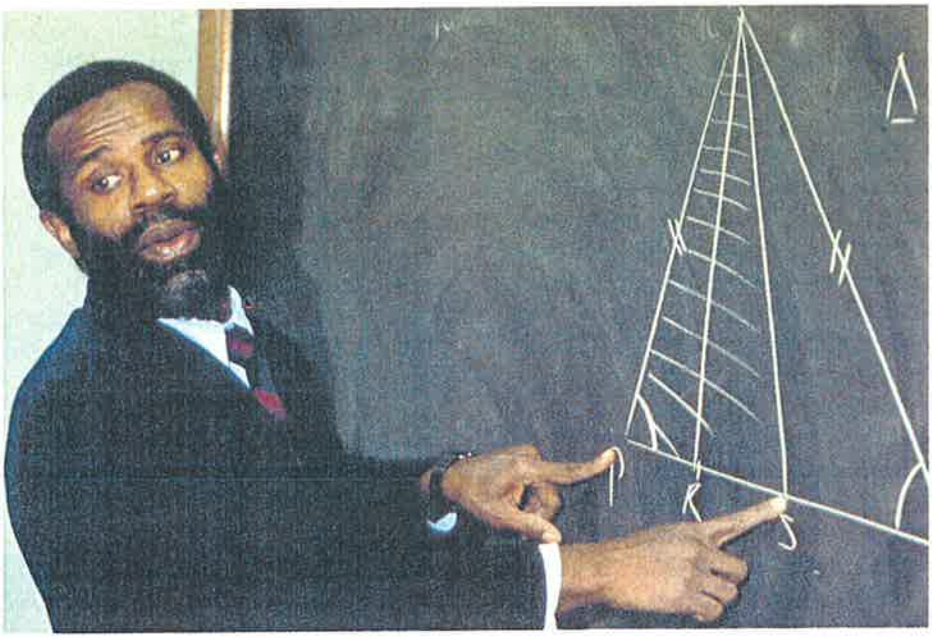
The quality of science and engineering education, particularly at the precollege level, is a matter of critical national concern. For example, the Carnegie Corporation's Forum on Education and the Economy reported in 1986 that the system of precollege education, not only in science but generally, was so badly in need of repair that it should be rebuilt from the ground up.

In general, too few of this country's elementary school teachers have even a minimal science background; too few of the science and mathematics teachers at the high school level have been well-trained in their subjects. Too many classrooms have poor or out-of-date equipment, and adequate support systems are rarely available. By the time they reach high school, most girls and most minority-group students are not pursuing the "difficult" courses that are needed for science literacy, as well as to prepare for a science or engineering education in college. By the time students reach college status, fewer and fewer are either prepared for, or interested in pursuing, a science or engineering career. Moreover, a survey by the National Science Teachers Association, with support from NSF, found that a third of the country's high schools offered no physics courses, nearly a fifth offered no chemistry, a tenth no biology, and almost three-fourths no earth or space science.

NSF's Directorate for Science and Engineering Education is directly concerned with these issues and with raising the quality of precollege education at *all* levels, using a variety of approaches.

One approach is to focus on the teachers. NSF cooperates with other agencies and organizations to offer the Presidential Awards for Excellence in Science and Mathematics Teaching, to encourage high-quality teachers to enter and remain in the field (see "Highlights"). In addition, NSF funds public schools, colleges, museums, and professional educational organizations that offer teacher enhancement projects, including workshops, institutes, and other forms of inservice training. The teacher enhancement projects, with additional support from business and industry, aim at keeping teachers updated, encouraging them to share materials and curricula among themselves, and bringing well-trained master teachers together with instructors who feel they need more training. NSF also works with university education departments to develop new programs that prepare candidates to become science and mathematics teachers.

Project RISE. This is an example of an NSF-funded effort to enhance the teaching profession. Here two high school chemistry teachers in California demonstrate the properties of melting silver by using extra oxygen.



Education for tomorrow's scientists. Math teacher Timothy Howell, from St. Paul's School in Concord, NH, won a Presidential Teaching Award for Excellence in 1984.

Another approach is to improve curricula. NSF funds efforts by universities, public school systems, and professional organizations to design, develop, and field test science and engineering curricula. The American Chemical Society, for instance, used NSF support to design and develop a new kind of high school chemistry course. Instead of the usual "junior version" of college chemistry, this course, called CHEMCOM, is a broad introduction to the role that chemistry plays in our water supply and biological processes, and to the products that result from chemical processes. At this writing, CHEMCOM has begun a field test involving 3000 students and 63 teachers in 13 states.

One new precollege initiative funds coalitions between university education departments, large public school systems, and publishing companies to design, develop, and market curricula in all science and engineering fields. With NSF support, for example, the Technical Education Research Centers group in Cambridge, MA—cooperating with a number of major public school systems and the National Geographic Society—is creating and marketing an innovative science curriculum. It extends from kindergarten through sixth grade and emphasizes experiments and computers.

Another approach to improving the general state of education is through a series of creative informal programs. Many school children and much of the general public learn what they know about science and engineering outside of school—from books, newspapers and magazines, television and radio programs, and museums. NSF concentrates particularly on the last two.

NSF funds museum collaborations to create science exhibits that travel between the museums. Subjects of these well-attended exhibits include robots, genetic engineering, the tropical rain forest, ancient technologies, the biochemistry and biophysics of cells, and the engineering design of bridges and buildings.

A museum in Columbus, Ohio has held a weekend "science camp-in" for Girl Scouts. Other examples of museum activities funded by NSF in FY 1986 and/or earlier years:

- the Academy of Natural Sciences in Philadelphia and its popular dinosaur exhibit;
- the Smithsonian Institution's "Discovery Room," with its hands-on, "please touch" approach to learning;
- the Boston Children's Museum and the San Francisco Exploratorium.

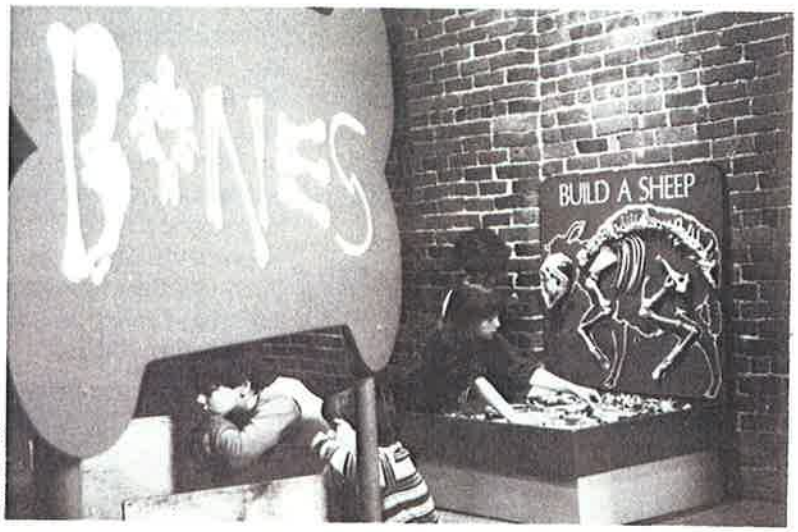
"Sun Painting" (by artist Bob Miller) at the San Francisco Exploratorium

INFORMAL EDUCATION THROUGH MUSEUMS

Exploratorium's "Color Table"

"Distorted Room" at Exploratorium

Richard Howard



Michael Dick

Three exhibits at Boston Children's Museum

The success of the Girl Scout "Camp-In" program at the Columbus, OH science museum has fostered similar programs in 19 science-technology centers across the country.

NSF also provides key support for television science series such as "How About," with Don Herbert (Mr. Wizard), and specials such as the award-winning series, "The Brain." Other programs are aimed at young people. "Reading Rainbow," a summer show hosted by actor LeVar Burton, dramatizes children's books, including general-interest science works; the program has contributed to a dramatic jump in children's book sales. The shows "3-2-1 Contact" and the new "Square One" are extremely popular, award-winning science and mathematics programs produced by the Children's Television Workshop in New York City.

Children's TV Workshop

Media education. Television programs such as "3-2-1 Contact" are a valuable way to increase public understanding of science. "Contact" co-host Judy Leak is seen here learning about the properties of light.

Finally, in an example of local cooperation, several federal agencies have outreach efforts with Washington, D.C. area schools. (This is part of the National Partnership in Education Program launched by President Reagan in 1983.) NSF's "Partner in Education" is Benjamin Banneker High School in the District of Columbia. This high-achiever school—the city's first public academic high school—is named for Benjamin Banneker (1732-1807), the Maryland farmer descended from slaves who became a self-taught astronomer, mathematician, almanac writer, inventor, and surveyor.

Banneker and NSF have participated in a variety of activities—from classroom lectures and career-day mentoring to "hands-on" experience for Banneker students at NSF-funded research facilities. For example, two students won a math/science contest and went to the Woods Hole Oceanographic Institution in Massachusetts for two days in September 1986. There they explored the facility and examined *Alvin,* the three-passenger submersible that helped bring back pictures of the *Titanic.*

Patrick Olmert

'Tis education forms the common mind; Just as the twig is bent, the tree's inclined.
Alexander Pope

INTERNATIONAL SCIENCE AND ENGINEERING

Cooperation and Competitiveness

Science is by nature international: inquiry into the origin of galaxies or the structure of molecules has no national boundaries. Some science, such as high-energy physics, requires machines that are very expensive for a single country to afford. Other scientific efforts, such as antarctic research or the global geosciences, are intrinsically international—either by treaty or because they study worldwide systems.

The Foundation encourages and supports U.S. participation in international science and engineering activities that promise significant benefit to the U.S. research effort. It is Foundation policy to foster the exchange of information among scientists in the United States and foreign countries, and to initiate and support scientific activities in matters relating to international cooperation. In meeting these goals, NSF provides support to U.S. scientists and engineers for access to unique sites, facilities, or expertise abroad.

Educational partners. Washington, DC students George Kelley and Tamara Cleveland visit the Woods Hole Oceanographic Institution. They are students at Benjamin Banneker High School, NSF's high-achiever "partnership school."

Accordingly, NSF has bilateral agreements with 30-odd countries, both well-industrialized and less so. Activities include cooperative research, scientific visits, and seminars or workshops. The Foundation also has a program to support scientific collaborations aimed at improving the scientific infrastructure of developing countries.

One bilateral cooperative project is with ICOT, the Japanese Institute for New Generation Computer Technology. This agreement enables U.S. computer scientists funded by NSF to travel to Japan and work at ICOT on the development of fifth-generation computers, in collaboration with Japanese researchers.

Another project is the Indo-United States Science and Technology Initiative. This cooperative effort to advance understanding in the areas of health, agriculture, weather, and materials has involved NSF and several other U.S. government agencies.

While most formal international cooperative activities are in NSF's Division of International Programs, many other collaborations are supported throughout the Foundation. Examples include a program on international ecology and a social sciences database shared by researchers taking cross-cultural social surveys; both of these efforts are in the Directorate for Biological, Behavioral, and Social Sciences. In addition, NSF operates the international ocean drilling program (see "Highlights"), is the lead agency for arctic research, and also funds and manages the U.S. Antarctic Research Program.

Science also serves our nation's need to maintain its economic competitiveness in the world. Thus NSF's international programs reflect that concern, too.

One program that watches out for our competitive edge is JTECH, for Japanese Technology Evaluation Program. Sponsored by NSF jointly with the U.S. Department of Commerce, U.S. Department of Defense (Defense Advanced Research Projects Agency), and other agencies, JTECH was set up to assess progress in Japanese research, compare it to U.S. research, and come to conclusions about our competitiveness in the future. Experts in science and technology review both U.S. and Japanese programs, publishing reports on the relative status of various technologies: robotics, biotechnology, computer science, alternatives to silicon for microelectronics, polymers, telecommunications and lightwave technology, and computer hardware for artificial intelligence. At this writing the conclusions of the reports for all fields have been similar: although the United States still has the lead in some areas, that lead is decreasing; in other areas, this nation is a distinct second.

Global Geosciences

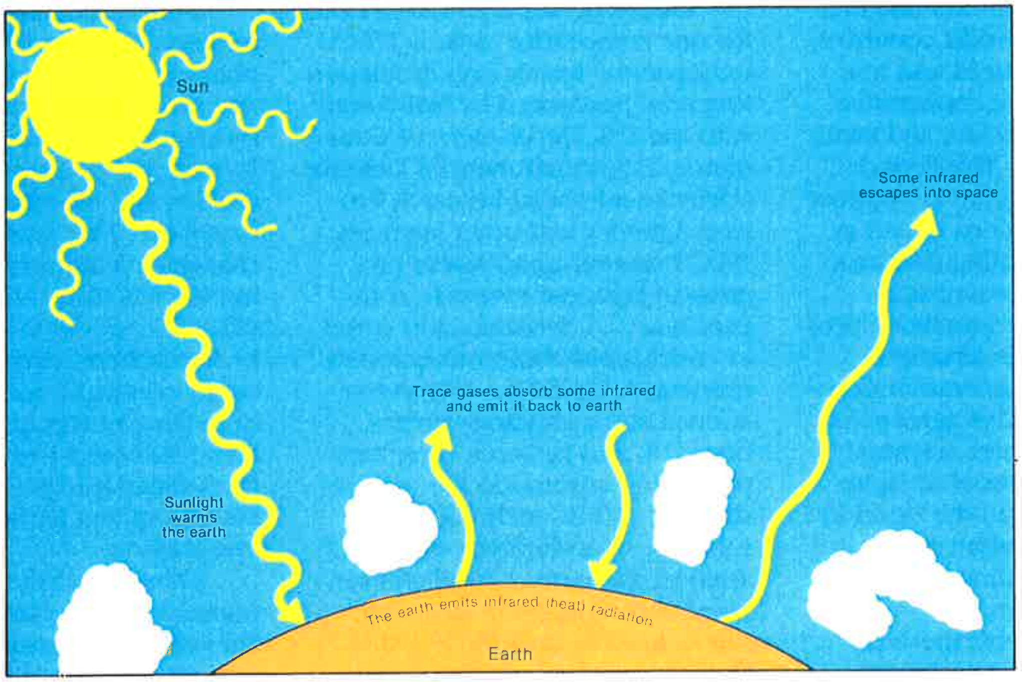
Of particular note is this recent initiative, which is especially international in nature. In order to understand both natural changes and the ways in which human beings influence their world, researchers need to study that world as a single system. They need to examine what it was like in the past, how it may differ in the present, and what the future might be. To do this, they must study simultaneously the atmosphere, the oceans, the continents, life forms, and the ways in which all these are linked so that a change in one triggers a change in one or more of the others.

In one sequence of events, for instance, changes in the atmosphere could lead to a worldwide rise in sea level. Both human-made products and natural processes increase the amounts of carbon dioxide and methane in the atmosphere. This increase in turn changes the atmosphere, producing what is called the greenhouse effect. The result is a slow increase in atmospheric temperature that could eventually, for example, lead to melting of the antarctic ice. Some 90 percent of the world's fresh-water ice is in Antarctica, and melting of that ice would cause sea levels to rise.

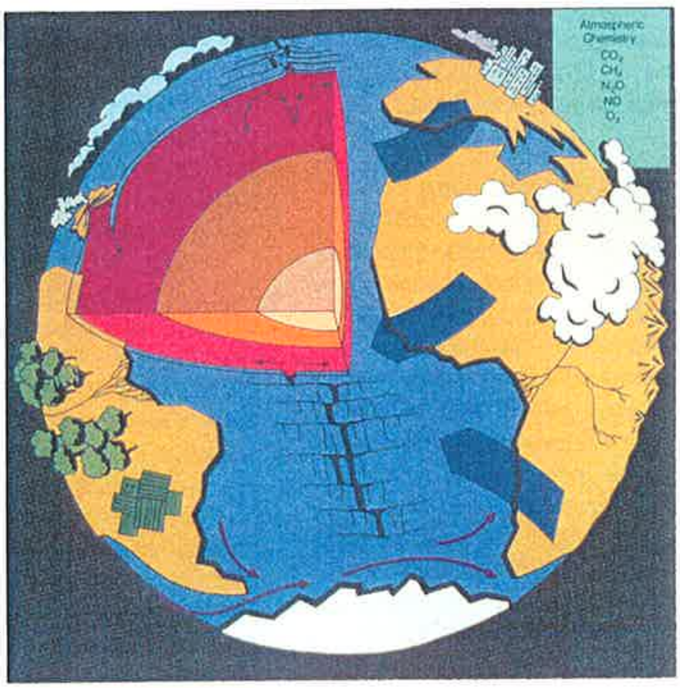
Other examples of phenomena with global implications are volcanic eruptions, earthquakes, acid rain, deforestation, and large-scale climatic events such as El Niño (an oceanic phenomenon that occurs periodically and causes widespread and destructive weather changes worldwide).

In short, human beings continue to make global changes, and scientists do not yet fully understand the global cycles that are natural—let alone those caused by our own actions.

In the global geosciences effort several federal agencies, working together, are supporting researchers and instruments based on the ground, under the ocean, and in the sky. Global geosciences is divided into six different projects: study of the paths and effects of different chemicals entering the atmosphere; study of the ways in which the oceans affect climate; identification of the processes that control ocean circulation; study of the ways in which plants and animals affect the earth; examination of the mid-ocean ridges where the seafloor is spreading apart and growing; and charting the motions of both the earth's interior and its crust.



The greenhouse effect—a warming of the lower atmosphere and the earth's surface



Courtesy of InterNetwork, Inc.

Global geosciences: research that affects all of our world. This schematic view of earth systems shows winds (large arrows); evaporation and precipitation; seafloor spreading at bottom, reshaping the earth's surface and recycling elements through its interior (section); and photosynthesis by terrestrial vegetation.

NATO Postdoctoral Fellowships

Since 1959, NSF has administered this program, funded by the North Atlantic Treaty Organization (NATO). It grants fellowships to young postdoctoral researchers whose work gives them reasons to study abroad. Such reasons might include the study of environmental systems that our country lacks, or work with international experts in a particular field, or research using techniques or facilities unique to the foreign country.

One fellowship grantee is Ines Cifuentes, a geologist at the Carnegie Institution in Washington, DC. Cifuentes is using the NATO fellowship to complete a postdoctoral program at the Institut de Physique du Globe in Paris. She studies the continental plates and the ways in which they accommodate the forces to which they are subjected.

Ines Cifuentes, NATO postdoctoral fellowship awardee

In particular, Cifuentes studies the Caribbean plate, a small area bounded by the Cocos (or Pacific) plate, the North American plate, and the South American plate. At its northern end, the Caribbean plate is sliding under the North American; at its western edge in Central America, it is sliding past the Cocos. The movements together create volcanoes, earthquakes, and some minor rifting. Cifuentes maps earthquakes and faults, watches how the crust moves, what happens at plate boundaries, and how the plates change with time. The answers to her questions may help to solve a related problem: the Caribbean plate appears to be composed of fragments from other, older plates. Part of Cifuentes' work could be working backward to the what and where of those older plates.

POLAR PROGRAMS

The arctic and the antarctic have apparent similarities. Both are hosts to multinational communities, are dominated by rigorous cold, and undergo extended periods of daylight alternating with equal periods of darkness. Despite these similarities, however, the two regions are very different. The arctic is essentially an ice-covered ocean surrounded by North America, Europe, and Asia. The antarctic, which is also a desert, is a perennially ice-covered continent surrounded by a great southern ocean and isolated from the other continents.

Temperatures in the arctic can range from above freezing in some areas during the short arctic summer to below −50 degrees Fahrenheit over the Arctic Ocean during the winter. In the antarctic interior the average winter temperature is approximately −90 degrees Fahrenheit, but on the coast the winters may be as warm as −4 to −27 degrees Fahrenheit. The lowest temperature recorded in Antarctica is −128.6 degrees Fahrenheit.

In the arctic tundra there is a great variety of plants and animals, and people have lived in this region for thousands of years. Antarctica has never been inhabited, and only a few hardy insects, mosses, lichens, and one type of grass exist on land year-round; however, the oceans surrounding the continent support abundant marine life with a harvest potential estimated to be equal to the current world total catch.

The Arctic

This area is contiguous with, and an integral part of, modern commerce. Its skies are crucial to airline traffic, communications, and national defense. Its gas, oil, minerals, and coal represent a significant fraction of the world's total. Its fisheries account for around 10 percent of the world's catch, and weather in the arctic influences weather all over the world. Thus it is an area of considerable importance.

- **Setting Policy for Use of the Arctic.** For these and other reasons, the Arctic Research and Policy Act of 1984 set up two groups to oversee U.S. policies for research in the arctic. One, the Interagency Arctic Research Policy Committee, is a federal group that sets policy and formulates a comprehensive five-year plan for research in the arctic region. Such a plan must balance national

National Geographic Society

Arctic research

needs—defense, communications, and development of natural resources—with the need to disturb the environment as little as possible. The Committee also works with state government officials, and with private sector and public interest groups. The other body, the U.S. Arctic Research Commission, is an independent group; its task is to recommend policy, consult with the Committee on developing the five-year plan, and promote research in the arctic in general.

The Committee and the Commission have agreed that certain research areas are critical. One area with especially high priority is resolution of the health problems and of the social and cultural issues faced by the people who are native to this increasingly industrialized and urbanized region. Another concern is to understand the relationships between atmosphere and ocean, and between atmosphere and land, in order to predict weather and large-scale climatic changes and to ascertain the impact of resource development. Still another issue is research on the upper atmosphere and the earth's magnetosphere in order to predict disturbances to defense and communications systems from sunspots and solar storms.

- **Research on the Seas Around the Bering Strait.** A research project called ISHTAR (Inner Shelf Transfer and Recycling) studies the biology and oceanography of the seas on either side of the Bering Strait: the Bering Sea on the south, the Chukchi on the north. The shallow strait overlies a large underwater shelf. Wind blows mainly from the north over these shallow seas and circulates Pacific Ocean water that carries nutrients. The combination of Pacific nutrients and sunlit waters makes the seas around the Bering Strait extremely productive. This richness feeds the whole food chain, from plants to fish to birds and mammals. Through ISHTAR, collaborating scientists at the Universities of Alaska, South Florida, and Washington study this rich and fragile system—the flow of nutrients, the entire food web, the chemical balance of the seas—so that scientists can design better schemes to protect it.

new logo for U.S. Antarctic Program, managed and funded by NSF

The Antarctic

U.S. policy here is different from that which applies to the arctic. The United States is a consultative party to the Antarctic Treaty, which was signed by 12 countries in 1959 and entered into force in 1961. At this writing, 18 countries are full members of the treaty organization; 16 others recognize the treaty, which prohibits territorial claims in Antarctica, bans military activities (except for those that support research programs), and prohibits nuclear testing and nuclear waste disposal.

The United States Antarctic Program, managed by the National Science Foundation, includes scientific research as the nation's principal expression of interest in the continent. Each year, NSF supports as many as 100 research projects in Antarctica and its surrounding seas. There is a growing recognition of the region's significant role in global processes in the oceans, the atmosphere, and in near-earth space. For example, most of the deep-bottom water throughout the world's oceans is believed to be formed in the southern oceans, and it is clear that the huge ice dome (averaging 2 miles thick over 5 1/2 million square miles) covering Antarctica is the major heat sink for the global atmosphere.

- **Life at the Edge of the Ice.** Scientists from government laboratories, universities, private institutes, and industries are collaborating in an ambitious project called Antarctic Marine Ecosystem Research at the Ice Edge Zone, or AMERIEZ, which focuses on the exceptionally high productivity at the edge of the sea ice.

Each winter, the sea around Antarctica freezes from the land out for about 1000 miles, growing

NSF's McMurdo base on Ross Island in Antarctica

until it more than triples the size of the continent. In late spring, the ice begins to melt, retreats at a rate of 20 to 30 miles a day, and is gone by the end of summer. As the ice melts, the ocean in this area literally blooms with plant life. More plants and animals live in the ice-edge zone than in the open ocean.

As the AMERIEZ scientists have discovered, the water from the melting ice is less dense than the sea water and floats above it. The melting ice contains algae and other micro-organisms. This rich organic soup supports krill and other small animals and ultimately marine mammals and birds.

Project AMERIEZ in progress: A Weddell Sea scuba dive

• **Life Frozen in Antarctic Ice.** During the 1985-86 austral summer, several geologists and glaciologists studied the region near the Beardmore Glacier, in the Transantarctic Mountains near the center of the continent. This glacier flows from the east antarctic ice sheet, one of two such sheets covering Antarctica and held in place by ice shelves that float on the ocean.

New data acquired during the investigations near the Beardmore Glacier suggest that as recently as two to three million years ago the east antarctic ice sheet may have withdrawn and a waterway may have existed across Antarctica. (Past data suggested that the ice sheets have covered Antarctica for the last 15 million years.) The research teams found ancient marine plants, fossilized wood, and fossil remains of terrestrial land animals and plants that require a temperate environment. The theory now proposed is that periodic warming and cooling trends cause the ice sheets to fluctuate. By studying the ice sheets of Antarctica, scientists hope to learn more about global climate cycles.

NATURAL DISASTERS

Volcanoes

Covered by glacial snow and ice, Nevado del Ruiz is the northernmost volcano in the high Andes in Colombia. On November 13, 1985, the volcano erupted with an explosion heard 18 miles away, sending a column of ash nearly 7 miles into the sky. Soon after the eruption, two groups of NSF-supported volcanologists—one headed by Haraldur Sigurdsson at the University of Rhode Island, the other by Stanley Williams at Louisiana State University—went to the site. The teams reported back on the exact sequence of events leading up to and during the eruption, and on the geochemistry of the volcano's lava, ash, and mud.

Since the previous November, Nevado del Ruiz had been sending out danger signals: small explosions of steam and gas, earthquakes centered below the volcano, and a minor mudslide. In November 1985, however, the top of the mountain blew off, sending ash 250 miles away. Hot lava from the volcano triggered three mudflows that moved at around 20 miles an hour down the mountain and into nearby valleys. One mudflow hit the town of Armero, 30 miles from the volcano, killing most of Armero's 25,000 people.

Nevado del Ruiz had not exploded like this since 1595. It and all other volcanoes sit over underground reservoirs of melted rock, called magma, which rises to the surface through fissures in the rock. Magma can rise slowly for years, until the upward pressure builds to more than the rocks above can withstand. Moreover, the magma under Nevado del Ruiz, like that under Mount St. Helens in Washington State, is full of dissolved gases, so the upward pressure builds more precipitously and the volcano erupts more violently.

After the November 13 catastrophe, Nevado de Ruiz remained active, venting 5000 tons of sulfur dioxide daily, sending out ash and dust, and rumbling with constant earthquakes. Such activity is evidence that the volcano could explode again, and since 90 percent of the glacier remains, the potential for more mudflows remains as well. Scientists have been monitoring it and nearby volcanoes closely.

Mount Augustine on Lower Cook Inlet in Alaska is the same sort of explosive volcano as Nevado del Ruiz and Mount St. Helens (1), only with shorter periods between eruptions. Scientists at the University of Alaska have monitored it so as to warn the Cook Inlet communities in time for them to evacuate. Since Mount Augustine, unlike Nevado del Ruiz, is on an island, its eruption could trigger a tsunami. Tsunamis are fast-moving waves, caused by earthquakes, that are imperceptible in the open ocean. Once they hit the shallower waters along a coast, however, they build. Tsunamis have reached speeds of 375 miles an hour, and heights of 100 feet.

1. At Mount St. Helens, a mild eruption in October 1986 added new material to the dome top, which has been rebuilding since the major eruption in 1980. Hawaii's Kilauea volcano erupted after this publication was prepared and will be discussed in a later report.

Earthquakes

On March 3, 1985, an earthquake shook an 800-mile stretch of Chile, toppling buildings, killing 180 people, and leaving hundreds of thousands homeless. On July 8, 1985, an earthquake along the San Andreas fault hit southern California, blocking roads and causing power failures, which in turn disrupted the water supply. On September 19 and 20, 1985, two earthquakes nearly destroyed parts of Mexico City, collapsing or damaging 300 buildings and breaking the lifeline system of water supply, sewage disposal, communications, electricity, and all transportation. The two quakes killed 20,000 people and left 30,000 homeless.

Nevada del Ruiz in Colombia (above) and Mt. Augustine in Alaska (below) are two volcanoes that have erupted since late 1985.

Some 39 of our 50 states feel moderate-to-major earthquakes every year. If the 1906 San Francisco earthquakes happened today, property damage would exceed $24 billion, 700,000 people would be injured, and 5,000 would die, just from the ground shaking alone. Thus NSF has programs that study earthquakes to find what causes them and how their devastation can be mitigated.

- The Incorporated Research Institutions for Seismology (IRIS) is a 50-university consortium created by the seismology community. It will put in place some much-needed national facilities to support research during the next quarter-century on earthquakes and the earth's interior.

One indicator of a pending earthquake is a seismic gap, a segment of a major active fault that has a longtime absence of major earthquakes. (The Mexico City earthquake occurred at a well-known seismic gap.) A possible precursor to a major shock is the Mogi doughnut, a ring of minor earthquakes that occur around a seismic gap.

To monitor such phenomena as seismic gaps and Mogi doughnuts, IRIS plans, in cooperation with the U.S. Geological Survey, to establish 100 seismic stations with new, high-quality digital equipment around the world. It will also build an array of up to 1000 portable seismographs that can be moved to the site of an earthquake. These networks will use seismic tomography, a technique analogous to x-ray images of the human body, to make three-dimensional pictures of the earth's interior. Via satellite data transmission, the networks will help determine the size and precise location of an earthquake anywhere in the world within minutes of the event.

● Immediately after the earthquake in Mexico City, NSF dispatched a team, assembled by a Berkeley, California research institute and the National Academy of Engineering, to the quake site to collect valuable and perishable field data. NSF also made grants to 28 U.S. research institutions, to cooperate with Mexican researchers in studying the Mexico City earthquake. The site had been well-monitored, and many of the buildings that collapsed were designed using state-of-the-art principles, techniques, and standards. The extent of the damage was unexpected, and researchers needed to collect all the information they could.

The Mexico City earthquake occurred along a subduction zone, where one plate dives under another. (Subduction zones also occur along the Washington State and Oregon coasts, and along southern Alaska and the Aleutian Islands.) Although the earthquake was centered 230 miles away, Mexico City was badly damaged because it sits on an ancient lake bed whose silts and sands amplified the shaking of the ground; in addition, the earthquake lasted an unusually long time. Concrete and mid-sized buildings were the most seriously damaged, steel and larger structures less so. Rescuing people trapped under collapsed buildings was a serious problem, and the main aqueducts bringing water to the city failed. The subway system, however, was relatively unharmed.

Remnants of Mexico City earthquake

Researchers studied both what went wrong and what did not. They investigated the causes of the earthquake, how quakes affect different kinds of ground and different structures, what kinds of hazards such features as glass and elevators cause. Ultimately, what researchers learn from the Mexican earthquake could help lessen the impact of similar shock waves.

● NSF is giving this sort of research special emphasis in a new Earthquake Engineering Research Center. This Center, at the State University of New York at Buffalo, is conducting research to improve basic knowledge about earthquakes, engineering practice, and the implementation of seismic hazard mitigation procedures to minimize the loss of lives and property.

Major areas of study initially are being directed toward buildings and other structures built before the need to mitigate the effects of earthquakes was realized. Emphasis is given to a systems approach in which earthquake requirements are integrated with consideration of other hazards, such as high winds.

Although the award went to Buffalo, which will serve as a focal point for the Center's activities, the new facility also involves the coordinated efforts of the City College of New York, Columbia and Cornell Universities, Lamont-Doherty Geological Observatory, Lehigh and Princeton Universities, and the Rensselaer Polytechnic Institute.

NSF funds are being matched for the first year by the Urban Development Corporation of the State of New York, a partnership to promote improved cooperation among universities, government, and industry.

Microbursts

Microbursts are those small, lethal downdrafts of wind that can cause airplane crashes and result in scores of injuries and deaths. During a microburst the air suddenly rushes downward, then spreads outward along the ground. A plane encountering such a burst (on landing, for example) is potentially in danger: it will initially run into a headwind, add lift and rise. It will then be followed by a tailwind that reduces aircraft lift; these effects can cause the plane to crash short of the runway.

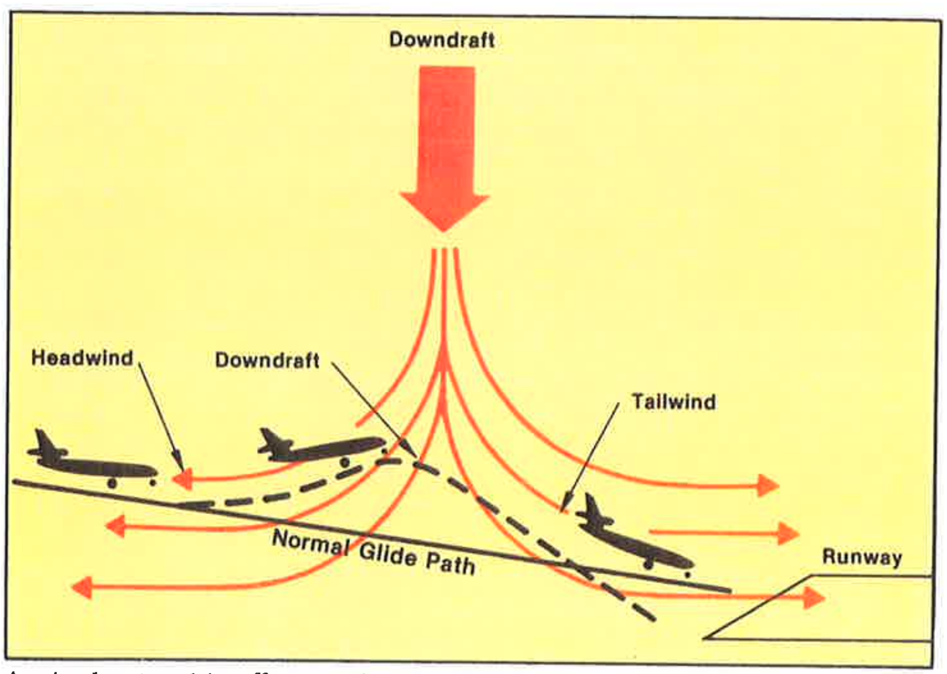
The microburst is some 2 miles across and lasts only about 10 minutes. Downward winds can be more than 40 miles an hour.

NSF, in cooperation with other government agencies, funds projects to study microbursts and help airplanes to avoid them. One project, called Microburst and Severe Thunderstorm, or MIST, has been gathering and analyzing data on surface temperature, atmospheric pressure, moisture content of the air, and the motion of winds in the clouds.

A second project, called Joint Airport Weather Studies, or JAWS, (1) is aimed at improving aviation's safety systems and weather radar networks. JAWS also has helped to document conditions that lead to microbursts: rain evaporating in mid-air, causing the air to cool, then falling. Microbursts can happen both in humid and dry climates, and with torrential rains or much smaller storms. Microbursts also may occur in seemingly calm weather conditions.

1. JAWS is now part of the Research Applications Program at the National Center for Atmospheric Research in Boulder, CO.

Using information from these studies, Doppler radar can now identify some of the precursors of microbursts. Meteorologist Theodore Fujita, at the University of Chicago, has examined recent microburst-related crashes and found radar images of downrushing wind and rain fading just before the burst hits the ground. Surrounding airports with monitors that look for these and other precursors should be able to give 5 to 10 minutes warning of a developing microburst, which is enough time to warn an aircraft.

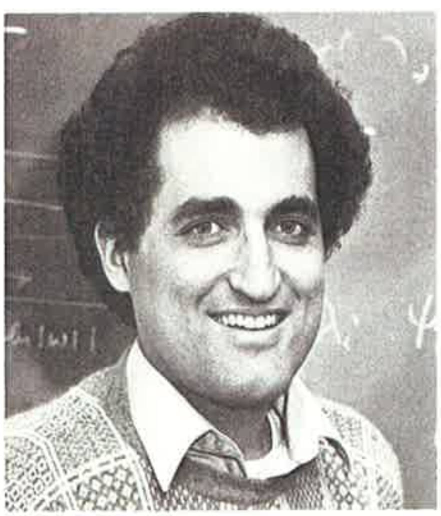


A microburst and its effect on a landing aircraft

CHAPTER

3

● *The Alan T. Waterman Award.* This award, named for NSF's first director, is presented each year by the Foundation to a researcher who is 35 years of age or younger or has had a doctoral degree for not more than five years, and whose research shows excellence, innovation, and the potential for new discoveries. In 1986, the Alan T. Waterman Award went to Edward Witten, professor of physics at Princeton University. Witten is considered one of the most outstanding theoretical physicists of his generation. He is also one of the world's leaders in new developments in superstring theory that may unify gravity with the other forces of nature. (See "Highlights" section.)


Robert Matthews

Edward Witten

The basic theories of 20th-century physics are quantum mechanics (the theory of atomic phenomena) and general relativity (Einstein's theory of gravity). The superstring theory holds that the objects responsible for creation of the fundamental forces of nature—such as photons and gravitons—are not points but extremely small one-dimensional loops of strings of energy.

Dr. Witten also has provided fresh insights into other problems of theoretical physics, including the long-debated question of whether energy in Einstein's theory of general relativity is necessarily positive.

Dr. Witten's research has been supported for several years by NSF's Theoretical Physics Program. He was selected from 165 highly regarded nominees to receive the prestigious award, which includes a medal and NSF support for up to $100,000 a year for three years of research and advanced studies.

● *The Vannevar Bush Award.* The National Science Board, NSF's governing body, grants the prestigious Vannevar Bush Award, named for the engineer and World War II science administrator who prepared the presidential report recommending establishment of the National Science Foundation. The award recognizes individuals who have made outstanding contributions to the nation in science and technology.

In 1986, the Vannevar Bush Award was given to Isidor Isaac Rabi, winner of the 1944 Nobel Prize for physics and Professor Emeritus at Columbia University. Rabi has long been a dominating presence in high-energy physics.

Among the many contributions for which Dr. Rabi was recognized were his efforts in organizing the first International Conference on the Peaceful Uses of Atomic Energy (held in 1955 and sponsored by the United Nations), and in establishing the International Atomic Energy Agency, an outgrowth of the U.N. Conference. Dr. Rabi also made the proposal that led to establishment of the Centre Europeene de Recherches Nucleaires (CERN) in Geneva, Switzerland, one of the major internationally managed scientific facilities.


B. Silverman, *New York Times*

Isidor Isaac Rabi

Rabi's 1944 Nobel Prize was awarded for fundamental contributions that allowed measurement of the magnetic properties of atomic nuclei to a very high precision. This work not only led to a deeper understanding of the properties of matter but also continues to find applications in numerous fields—ranging from space science and technology to the highly sophisticated medical diagnostic tool of nuclear magnetic resonance.

Dr. Rabi was born on July 29, 1898, in Rymanow, then part of the Austro-Hungarian Empire. He was brought to this country as an infant and grew up on the Lower East Side of Manhattan and in Brooklyn. He received his bachelor's degree in chemistry in 1919 from Cornell University and his Ph.D. in physics from Columbia, in 1927. His academic progeny include many of the nation's top scientists.

- *Distinguished Public Service Awards.* NSF awarded two Distinguished Public Service Awards in 1986. This award, for distinguished service to science and engineering, is one of the highest honors conferred by the Foundation. It includes a gold medal and a citation. One award was to William Carey, executive officer of the American Association for the Advancement of Science, publisher of *Science* magazine, and past publisher of *Science 86.* The other honor went to Don Fuqua, longtime and now retired chairman of the House Committee on Science and Technology in the U.S. House of Representatives.

- *New Internal Award Established.* To reflect the Foundation's emphasis on affirmative action and equal opportunity in employment and all program areas, an Equal Opportunity Achievement Award from the NSF Director was established in 1986. The Director's Award for up to $2500 recognizes outstanding achievement in promoting equal opportunity within the Foundation, or in increasing the representation of minorities, women, and disabled individuals in the scientific and engineering communities. Directorate-level awards for up to $500 are also available to reward NSF staff for special achievements in equal opportunity.

The first of the Director's Equal Opportunity Achievement Awards went to these individuals in 1986:

Elvira Doman

Elvira Doman — for her exemplary record of activities and accomplishments in promoting equal opportunities for minorities and women, including scientific outreach through numerous site visits, efforts to recruit minorities and women for NSF, and service as Executive Secretary to the Committee on Equal Opportunities in Science and Engineering.

Judith S. Sunley — for her outstanding efforts to promote equal opportunities for minorities and women in the field of mathematical sciences through her own recruitment efforts at the Foundation, through active support of the Foundation's Visiting Professorships for Women and Minority Research Initiation programs, and as a leading member of the Women in Math organization.

Judith Sunley

- *Nobel Prizes for NSF Grantees.* The most prestigious and well-known of all awards honoring scientists and their contributions to science and the welfare of humanity is the Alfred B. Nobel Prize. In the last decade U.S. scientists have received 60 percent of the total number of prizes awarded in physics, chemistry, and physiology or medicine—an indication of the nation's relative strength in science and technological capability. The Nobel Prize represents the very highest level of achievement in fundamental research.

The National Science Foundation has made a significant contribution in the prior support of Nobel Prize winners. (There can be a delay of 10 to 20 years or more from the time prize-winning work is done until it is recognized by the Nobel committees.) For example, of the nine 1986 Nobel Prize recipients, four are previous NSF grant awardees—some receiving awards for scientific research going back to the mid 1950s. They are:

- Dudley Herschbach, Chemistry (7 previous NSF grants)
- Rita Levi-Montalcini, Physiology/Medicine (9 previous NSF grants)
- James Buchanan, Economics (6 previous NSF grants)
- Yuan T. Lee, Chemistry (7 previous NSF grants)

Among the Nobel Laureates from 1980-86, 17 had received more than 200 NSF awards at some time during their research careers.

CHAPTER 4

ELVIRA DOMAN

Associate Program Director for Regulatory Biology

Division of Cellular Biosciences

Directorate for Biological, Behavioral, and Social Sciences

Tenure at NSF: 1978 to present

Special achievements:

Dr. Doman has a distinguished record of accomplishments extending far beyond her regular programmatic responsibilities in physiology and endocrinology. She has, for example, been very active in a number of activities to promote increased participation in science and engineering by underrepresented groups.

In 1981, Elvira Doman organized and headed a successful event for Women in Science and Engineering (WISE), an interagency group. Entitled "Science in Your Life," the program was held at the H.B. Owens Science Center in Lanham, Maryland. Dr. Doman is still involved in the WISE Student Challenge Program, which encourages 9th- and 10th-grade girls to pursue careers in science and engineering.

Elvira Doman has served on the NSF Black History Committee since 1983 and played a major role in bringing outstanding scholars to the Foundation for Black History Month, as well as for National Hispanic Week. In 1985, she was cited by NSF Director Erich Bloch as the "outstanding outreach presenter within the Biological, Behavioral, and Social Sciences Directorate since the inception of the NSF Outreach Service." (1) In 1986, Dr. Doman's record was again recognized when she received the Director's Equal Opportunity Achievement Award (see chapter 3).

Other activities during her years at NSF include service as an Equal Employment Opportunity (EEO) Counselor and the representative for Native American Indians on NSF's EEO Council. To encourage young people to pursue careers in science and engineering, she has served as role model, panelist, keynote speaker, and science fair judge for public schools in the Washington, D.C. area.

In recent years, Dr. Doman was the coorganizer of an NSF workshop on "Research Funding at Four-Year Institutions," and she was instrumental in two scientific workshops: "Regulatory Mechanisms in Insects: Future Directions," and "Strategies for the Study of Invertebrate Peptides."

Prior experience/education/ other interests:

Elvira Doman holds degrees in chemistry, molecular biology, physiology, and biochemistry. Her postdoctoral studies were completed at Rockefeller University. She was a part-time lecturer at Douglass College, the women's division of Rutgers University, while bringing up her family. She accepted an Assistant Professorship of Biology at Seton Hall University, where she also served as Chief Pre-Medical Professions Advisor. In 1977, she moved to Washington, D.C., where she served one year as a volunteer for the D.C. public school system.

To promote women in science, Dr. Doman is active in the local chapters of Minority Women in Science (MWIS) and the Association for Women in Science (AWIS). She also sings in two church choirs, plays tennis, and has been Administrative Vice-President and Educational Vice-President in a local club of the International Toastmasters. She is a wife and mother of two children. Her daughter, Paula, holds a degree in electrical engineering from Cornell University; her son, Rodney, is a high school senior who plays varsity basketball and is business manager of his school newspaper.

1. Through the Outreach Service, administered by NSF's Office of Legislative and Public Affairs in conjunction with the research directorates, Foundation staff travelling on official business give orientations about NSF funding opportunities at all institutions, especially those that are not among the leading recipients of NSF funds. These include predominantly minority or women's colleges/universities and primarily undergraduate institutions.

Except where indicated, all photos in this chapter are by Morton Broffman.

NSF PEOPLE

JOHN WOOLEY

Program Director for Biological Instrumentation
Division of Molecular Biosciences
Directorate for Biological, Behavioral, and Social Sciences

Tenure at NSF: 1984 to present

Special achievements:

Under Dr. Wooley's leadership, his program has emerged as one of the Foundation's leading activities. The area of instrumentation development has grown several-fold since John Wooley became Program Director. In addition, more multiuser proposals have been jointly reviewed with other NSF instrumentation programs, resulting in a substantial increase in jointly supported awards. This works to the benefit of the entire science and technology community, as requests for multiuser equipment may now include subprojects from chemists, materials scientists, or engineers, as well as biologists. Dr. Wooley has proven especially effective in helping to assure the coordination needed in reviewing these proposals.

John Wooley was also highly effective as liaison to NSF's Office of Advanced Scientific Computing, located in the new computer sciences directorate. He has helped to provide a better understanding of supercomputer opportunities throughout the BBS directorate. Moreover, the National Institutes of Health, another federal agency, has based key instrumentation efforts largely upon the role model provided by the NSF, as shaped by Dr. Wooley.

With a substantial increase in both proposal load and the quality of projects received, Dr. Wooley has worked closely with the scientific community to "stretch" NSF dollars as far as possible through cost-sharing by institutions and through discounts, where available.

Dr. Wooley is also an unusually capable supervisor and has provided notable leadership for both support and program staff. Even with an especially productive administrative year, he found time to pursue personal research at the Brookhaven National Laboratory, and he copublished two papers in professional journals.

Prior experience/education/ other interests:

John Wooley received his B.S. in biochemistry from Michigan State University (1967) and his Ph.D. in biophysics from the University of Chicago (1975). He carried out postdoctoral studies at Harvard University in biochemistry and molecular biology, and has held faculty appointments at the Searle Molecular Biology Institute in High Wycombe, England; the Marine Biological Laboratory at Woods Hole, MA; and Princeton University. His research interests have been in protein-nucleic acid interactions and chromatin structure. The role of nuclear ribonucleoprotein complexes in RNA processing and gene expression is the current focus of Dr. Wooley's research. Along with the "microphotography" associated with these research studies, employing the scanning transmission electron microscope, he also is interested in mountaineering and the macrophotography of alpine and arctic flowers.

KENT K. CURTIS

Director, Division of Computer and Computation Research

Directorate for Computer and Information Science and Engineering

Tenure at NSF: 1967 to present

Special achievements:

From the time he joined NSF, Kent Curtis has been intimately involved in improving support for the field of computer research. NSF's commitment to this field has grown in the past decade from a small office to a directorate, paralleling the growth of the field, and Kent Curtis has had a major role at each step along the way.

With Mr. Curtis serving first as a section head for the computer research part of NSF's Division of Mathematics and Computer Science, then as Division Director for Computer Research, the Foundation has become a key actor in developing the nation's research infrastructure in computer science, as well as a significant source of project support. Early on, Kent Curtis recognized that the health of the field depends upon a complex interplay between theoretical research, personnel development and production, and application and use of computers.

Under the direction of Mr. Curtis, the Division of Computer Research (formerly in NSF's Directorate for Mathematical and Physical Sciences) introduced a variety of innovative programs within NSF and helped to develop important new interagency programs. For example, an electronic information exchange facility, CSNET, was created to unify the computer research community by connecting academic, industrial, and governmental research groups. The Coordinated Experimental Research (CER) Program, developed under the leadership of Kent Curtis, has successfully expanded the number of excellent university departments by improving the infrastructure of the institutions involved. The program has done this by helping to increase the number of much-needed Ph.D. computer science graduates, and by improving the overall environment in the computer science research community. Curtis also chaired the task force that led to the creation of NSF's advanced scientific computing initiative; today that initiative provides state-of-the-art supercomputer facilities to research scientists in many disciplines.

Kent Curtis has managed the growing number of professionals and support staff in his division with skill and dedication. Beginning with 3 individuals, the division now includes 11 professional positions and 8 positions in the support center. (See chapter 5 for more information on resource/administrative/program support centers.)

Prior experience/education/other:

B.S., Yale University, 1948

M.S., Dartmouth College, 1950

Head, Mathematics and Computing Services, Lawrence Berkeley Laboratory, 1957-1967

From 1982 through 1983, Kent Curtis was an IEEE (1) Distinguished Lecturer on needs and prospects for computer science personnel. He has served as a consultant to several of the National Laboratories, received the NSF Sustained Superior Accomplishment Award in 1980, and is listed in *American Men and Women in Science.*

1. Institute for Electrical and Electronics Engineers

IRENE LOMBARDO

Administrative Officer
Division of Advanced Scientific Computing
Directorate for Computer and Information Science and Engineering

Tenure at NSF: 1979 to present

Special achievements:

Each month, hundreds of scientists and engineers telephone NSF's Division of Advanced Scientific Computing (DASC) seeking access to the powerful supercomputers administered by this part of the Foundation. More often than not, their first contact is with Irene Lombardo, whose good humor and unlimited patience ease the way for them.

Serving as the Administrative Officer for this division since its inception in 1983, Irene Lombardo has participated in the growth of supercomputer users from a handful of hardy pioneers to several thousand researchers. She has been responsible for coordinating all their accounts, working with program directors from all over NSF.

Her duties have become so extensive that they are now shared. However, if there is some bottleneck to unplug, or a knotty problem to untangle in order to help a research project get going a little sooner, Ms. Lombardo gives it her special attention. All the researchers are known to her by name, and all are treated as persons instead of grant numbers. She also keeps all of the financial records for the division, and has organized a smooth-running administrative support center.

In addition to her regular duties, Ms. Lombardo is an editorial correspondent for *Discovery,* an inhouse newsletter at NSF.

Prior experience/other interests:

Before joining DASC, Irene Lombardo was a program assistant in the Division of Molecular Biology and a section secretary in the Division of Materials Research. Since she arrived at NSF in 1979, Ms. Lombardo has been promoted through six government grade levels.

In her few off-hours, Ms. Lombardo exercises her talent in arts and crafts. Weekends often find her at country fairs where she sells a wide variety of artifacts crafted in collaboration with her daughter and mother.

HOPE W. DUCKETT

Administrative Officer/
Center Manager

Division of Mechanics, Structures, and Materials Engineering

Directorate for Engineering

Tenure at NSF: 1969 to present

Special achievements:

Starting as a Clerk-Typist at NSF, Hope Duckett eagerly took courses at George Washington University to advance her career. She progressed through the ranks to Program Secretary, Section Head Secretary, Division Secretary, and Administrative Officer. She now holds the dual position of Administrative Officer/Center Manager with her division.

Since joining the Foundation, Ms. Duckett has received numerous achievement awards, served on several NSF program committees, assisted with the recruitment of high school students as NSF support staff, and participated in many other activities. These include the NSF softball team, the Social Committee of the Federal Employees Association, programs for NSF Secretaries' Week, NSF Christmas activities, and the Savings Bonds and Combined Federal Campaign drives.

Prior experience/other interests:

Ms. Duckett came to NSF from the Civil Service Commission (now the Office of Personnel and Management), where she worked as a clerk from 1966 to 1969. She is a member of such organizations as the National Organization for Women, the National Association for the Advancement of Colored People, Blacks in Government, and the American Federation of Government Employees. Her union involvement brought her to one of her current posts as an Equal Employment Opportunity Counselor at NSF.

Hope Duckett is known for her sensitivity, open-mindedness, and fairness in dealing with coworkers. Her counseling skills were honed by involvement in the counseling program of a local high school where her daughter was a student.

J. ELEONORA SABADELL

Program Director for Natural and Man-Made Hazard Mitigation

Division of Emerging and Critical Engineering Systems

Directorate for Engineering

Tenure at NSF: 1985 to present

Special achievements:

Dr. Sabadell has successfully increased interest in the new NSF program, Natural and Man-Made Hazard Mitigation, by the research community—including those in disciplines other than civil and mechanical engineering. She has actively sought every opportunity to visit universities, attend meetings, inform other agencies and researchers, and respond promptly to domestic and international inquiries about the program.

At NSF Dr. Sabadell has been able to persuade other program officers to share in funding proposals that bridge several research areas. Eleven grants have been split-funded, five with other programs in the Engineering directorate, four with the International Programs Division (STIA directorate), and two with the Social and Economic Science Division (BBS directorate).

Eleonora Sabadell's professional expertise has been recognized by both national and international organizations and governments. She has been invited to visit research centers, serve on advisory bodies, chair meetings, and set guidelines for possible cooperation in research activities in India, China, Japan, Pakistan, Portugal, Spain, and Austria.

Dr. Sabadell also has actively participated in NSF activities to increase the number of female engineers, advance their careers, and add to the number of successful proposals by these investigators. To that end, her program has funded a Visiting Professorship for Women award, a female undergraduate student, and two female principal investigators.

Prior experience/education/ other interests:

Dr. Sabadell was born in Buenos Aires, Argentina, and received both her bachelor's and advanced degrees from the National University of Buenos Aires. She has been in the United States for 23 years. She has three children; one daughter is an architect, another daughter is a graduate student in mechanical engineering at Princeton University, and her son is a graduate student in civil engineering at Colorado State University. Her husband is a chemical engineer.

Before coming to NSF, Dr. Sabadell was a lecturer at Princeton University, a program director at the U.S. Department of the Interior, and a senior scientist in the graduate program of science and technology policy at George Washington University, Washington, DC.

In addition to her work at NSF to attract and encourage female engineers, Eleonora Sabadell is active in the American Association of University Women and the Society of Women Engineers. She frequently gives lectures, participates in seminars, and organizes meetings aimed at drawing other women into her profession.

During her many international travels, Dr. Sabadell has developed a large and unique collection of boxes that reflect the diversity of cultures she has experienced. She notes that she is "very proud" of these artistic and cultural artifacts, which come in a variety of shapes, sizes, and materials (e.g., wood, glass, marble). Her other current hobbies include knitting "very fancy things," and she has done both painting and ceramics in the past.

U.S. Navy photo by P.J. Porbansky

David Bresnahan

NSF REPRESENTATIVE, ANTARCTICA

Division of Polar Programs
Directorate for Geosciences

Special achievements:
The NSF Representative in Antarctica makes science happen on a continent of 5.4 million square miles. In the antarctic summer, when the sun is up and outdoor work is practical, two "NSF Reps" serve two to three months each to cover the five-month season (October through February). In recent years these representatives have been *David M. Bresnahan* and *Erick Chiang,* both career civil servants.

The NSF Rep works at McMurdo, the largest station in Antarctica and the hub of the U.S. Antarctic Program, which the Foundation funds and manages. Available resources include the Naval Support Force Antarctica (including the Navy's Antarctic Development Squadron Six) and a support contractor. In a typical antarctic summer season about 2,000 personnel operate three year-round research stations, six LC-130 airplanes, six UH-1N helicopters, two icebreakers, a research ship, and a massive sealift and airlift from the United States.

In the 1986-87 summer, leaders of 75 NSF-funded research projects (250 scientists and technicians) in the geosciences, engineering, and biology turned to the Foundation for support that was planned months before in the United States.

People plan antarctic research, but nature is in charge. When the weather is good, events happen rapidly: planes arrive, deliver cargo, resupply inland stations, deploy field research parties. By December the sea ice runway will be rotten, forcing the planes onto an ice shelf skiway where they cannot take large loads. Similarly, the annual resupply ships have a narrow window to get through the pack ice at its summer minimum. Support personnel must reopen a runway after a blizzard, close in new buildings before winter, and refuel the South Pole Station, while scientists work to get necessary data.

Much of the science is observational and must meet nature's schedule—e.g., measure the marine plankton bloom, get an atmospheric reading before the moon sets. Despite meticulous advance planning, changes caused by storms or equipment availability are inevitable. To maintain scientific productivity, the NSF Rep has to weigh alternatives quickly. There is rarely time to seek outside counsel; decisions tend to be quick and final, and at all times they are influenced by the need to operate safely in the extreme environment.

The NSF Rep deals with a wide array of personal and organizational cultures—scientists, pilots, mechanics, chaplains, postal clerks, builders, the military, and representatives of the other Antarctic Treaty consultative nations. The Rep succeeds through good planning, informal communication, personal credibility, and the ability to motivate others.

Information flows heavily: through the local two-way radio network, single-sideband radio, and telegraphic messages from within or outside Antarctica; local (McMurdo has several hundred telephones) and long-distance telephone (via a satellite network); and a constant stream of personal contacts and site visits, memoranda, notes, and letters. The NSF Rep is obliged to discern immediately the value of current information.

U.S. Navy photo by Larry Vaughan

Erick Chiang

Days are long (typically 7:30 a.m. to 9 p.m., six days a week); personal and professional lives are inseparable. At day's end, the NSF Rep does not go home to family or a separate set of friends but is always on duty.

U.S. research in Antarctica was in its 30th consecutive year in 1986, with a safety record second to none. The number of annual research projects gradually has been tripled, while the levels of field-support elements such as aircraft hours and personnel were kept constant or declined. U.S. antarctic research literature from this period led the world and has been among the core documents in numerous subdisciplines. These achievements of safety and research productivity belong to thousands, but the NSF Representative has had a prominent role.

Prior experience/education/ other interests:

David Bresnahan — David Bresnahan joined NSF in 1970, after graduating from Old Dominion University with a B.S. in business administration. Prior to his graduation he had completed two trips to Antarctica, one working as an undergraduate research assistant funded by NSF. Mr. Bresnahan and his family live in rural Virginia, where he is active in local community affairs. He also enjoys gardening.

Erick Chiang — Prior to joining NSF in 1979, Mr. Chiang worked at SUNY-Buffalo; there he was responsible for the arctic and antarctic ice-core facility and participated in several Greenland and antarctic expeditions. He received his B.A. at Rutgers University in 1972 and M.S. at Adelphi University in 1975. His degrees are in geology and earth sciences, respectively. Mr. Chiang is an avid Chesapeake Bay sailor and enjoys both racquetball and tennis.

KATHRYN R. RISON

Administrative Officer
Division of Atmospheric Sciences
Directorate for Geosciences

Tenure at NSF: 1967 to present

Special achievements:
Kathryn Rison has furthered NSF's goals through her long-term, superior contribution to the smooth functioning of all internal operations in her division (ATM). Her constant, concerned attention to all administrative needs concerning ATM staff, the Administrative Support Center, travel, training, equipment, proposal processing, budgets, disbursement of funds, long-range planning, and the ATM Advisory Committee assures her fellow workers that all these duties will be accomplished in a timely and accurate manner.

Kay Rison works in a position, between management and support staff, where she has intimate knowledge about policies and practices that dominate the work place and affect the actions of individual employees. Professional and clerical staff alike, from her office and elsewhere in the Foundation, seek her aid and advice constantly. She is never too busy to provide help, and she either knows the answers or promptly finds them. All of this is done in a quiet, unassuming manner. Because of her attitude, other employees are ready to help her and want her to be pleased with their work.

Mrs. Rison is an outstanding NSF staff member who functions as a key person in Atmospheric Sciences, depended upon by all her coworkers.

Prior experience/education/ other interests:
Kathryn Rison has been ATM's Administrative Officer since the division was established in 1975, after spending several years in one of NSF's biological divisions. She is also a part-time student working toward an undergraduate degree in computers. Other outside interests include gardening, boating, skiing, and school or church activities primarily related to youth development. She serves, for example, on the advisory boards for Lackey High School and General Smallwood Middle School in Charles County, MD.

ELIZABETH G. TUCKER

Staff Assistant
Division of Chemistry
Directorate for Mathematical and Physical Sciences

Tenure at NSF: 1952 to present

Special achievements:
Elizabeth G. Tucker joined the chemistry activity at the Foundation in 1952. She was NSF's first chemistry employee, to be joined one month later by Walter R. Kirner, the first program director to implement chemistry's role in the Foundation. Except for a short interlude in the NSF grants office, Mrs. Tucker has been employed continuously in chemistry. Not only that, she has been at the Foundation *continuously longer than any other NSF employee.* During this time she has watched the program grow to a section and finally to a division as it is today.

Mrs. Tucker has not only processed every grant, declination, and withdrawal that chemistry has handled since the Foundation began but, more importantly, she has set a standard of excellence that is a model for efficiency and accuracy. This standard has become vital as NSF's chemistry activity has expanded to a budget approaching $90 million. This standard of excellence was established in handling 73 advisory committee meetings; providing support for 59 rotating program directors; organizing travel, hotel reservations, and documentation for 158 advisory committee members; and providing staff support for 18 permanent staff members in chemistry.

During Elizabeth Tucker's tenure at the Foundation, she has been responsible for keeping track of all chemistry expenditures, so that each year the outflow of funds is exactly equal to those provided by the Congress. She also has arranged nearly every chemistry advisory committee meeting, become acquainted with each committee member, prepared the Foundation's report for each committee meeting, and participated in the growth and development of chemistry as we know it today.

Mrs. Tucker has compiled the most comprehensive database on NSF chemistry in an exceptional file that has migrated to a local computerized system. If anyone wanted to know about the joys of an NSF grant, the anguish of a declination, and the directions that chemistry has taken in the past three decades, she has captured all the hard statistics on these matters in her files. One can easily pinpoint the trends in chemistry from these data. Every discipline needs a corporate memory, and Mrs. Tucker represents that for the Foundation's chemistry activity more than anyone else.

Other interests:
Mrs. Tucker's interests beyond the Foundation include travel (e.g., to Europe and the Caribbean), knitting, caring for several dogs, and dealing with the pleasures and problems of her semirural home about 40 miles from Washington. She also has two children and five grandchildren and keeps in close contact with all of them.

J. Latham

MARTIN L. JOHNSON

Former Associate Program Director for Teacher Enhancement

Division of Teacher Preparation and Enhancement

Directorate for Science and Engineering Education

Tenure at NSF: 1985-1986 (also served as a consultant and a part-time employee 1984-85)

Special achievements:

As a rotator program officer, Martin Johnson demonstrated outstanding ability in the operation and management of NSF's Teacher Preparation Program. For example, he provided strong leadership and support in developing the special program solicitation for middle-school teacher preparation in science and mathematics. He also demonstrated outstanding effort in assisting those interested in the program by providing timely, clear, and accurate information to prospective proposers, principal investigators, and others. In addition, he consistently provided crucial input into NSF concerns for underrepresented minorities.

Martin Johnson is an active, productive scholar, consultant, and leader in mathematics and math education. He is the author or editor of several books and has written many articles and book chapters. He also has contributed to a wide variety of professional meetings and symposia. He is past president of the Maryland Council of Teachers of Mathematics and is serving a three-year term on the Research Advisory Committee of the National Council of Teachers of Mathematics. He continues to publish papers and textbooks in his field. In 1985, the University of Maryland, where he is now a full professor, selected him as Minority Faculty Member of the Year.

Prior experience/education/ other interests:

B.S. in chemistry, Morris College, 1962

Ed.D. in mathematics education, University of Georgia, 1971

Fulbright Scholar in Nigeria, 1983-84

hobbies: reading, golfing

ETHEL SCHULTZ

Former Program Officer for Teacher Enhancement

Division of Teacher Preparation and Enhancement

Directorate for Science and Engineering Education

Tenure at NSF: 1984 to 1986

Special achievements:

To enrich the Foundation and to help administer its education programs, NSF appointed a secondary school classroom teacher from Massachusetts as a rotating program officer. This teacher, Ethel Schultz, was an enormously effective NSF representative to many interested groups, especially those at the state and local levels. She received much praise from these groups on the clarity of her presentations, and on the programmatic content and strategies that she conveyed. She displayed considerable initiative in making these contacts and in carrying the NSF message to groups that had not previously been involved with the agency. Mrs. Schultz became widely recognized as a competent communicator and leader by many prospective grant proposers.

In addition to this admirable leadership, Mrs. Schultz worked very diligently on projects she recommended. Her recommendations contributed significantly to the consistency and coherence of many programs within the Division of Teacher Preparation and Enhancement.

During her tenure at NSF, Mrs. Schultz maintained her involvement in both teaching and professional organizations. She presented papers, for example, at several professional meetings and was selected by the Chemical Manufacturers Association as the recipient of its 1986 Catalyst Award.

Prior experience/education/ other interests:

B.S. in chemistry, Simmons College, Boston

M.Ed. in science education, Northeastern University

Employed at Marblehead (MA) High School since 1962, first as a chemistry teacher (1962-83), now as a science administrator, K-12

Mrs. Schultz has long been active in professional organizations such as the American Chemical Society (from which she has received two awards), the New England Association of Chemistry Teachers, the National Science Teachers Association, and other educator societies.

A wife and mother of three sons, Ethel Schultz describes music and concert going as two of her biggest outside interests.

P. Olmert

PETER W. HOUSE

Director, Division of Policy Research and Analysis

Directorate for Scientific, Technological, and International Affairs

Tenure at NSF: 1983 to present

Special achievements:

Peter House is one of the many "power users" of personal computers on the NSF staff. He has made extensive contributions in the application of personal computers to NSF policy and management tasks. He recognized early the tremendous potential of personal computers for science policy analysis, NSF program data analysis, and general office administration. His ingenuity, leadership, and encouragement have resulted in many innovative NSF computer applications. Some of these achievements include:

- an early microcomputer local area network (September 1984);
- the preparation of briefing charts using computer graphics and high-speed color pen plotters (December 1984);
- a test of secretarial services performed at an employee's home during her maternity leave—done with a computer linked to the office (summer 1985);
- the use of laptop portable computers to extend keyboard availability economically to the entire staff, with capability for direct interface with the local area network within the office, and telecommunication links to the network after working hours (summer 1985);
- establishment of a large mainframe science policy database that allows quick access to information for NSF policy analyses (spring 1986).

In July 1986 Peter House, along with staff from NSF's Office of Information Systems (OIS), conducted a unique demonstration of live computer-driven briefings, using the Foundation's new television projection system. House also worked closely with OIS in the recent plan for acquisition of a new mainframe computer at NSF. His continuing efforts to use new technologies to enhance the productivity of federal employees deserve special recognition.

Prior experience/education/ other interests:

Ph.D. in public administration, Cornell University

Peter House came to NSF from the U.S. Department of Energy; prior to that he was with the U.S. Environmental Protection Agency. He also has served as a visiting scholar at the University of California, Berkeley, and taught at the University of Texas. He has published a dozen books on such subjects as methods in federal S&T policy analysis, forecasting, modeling, technology transfer, research management, and environmental politics.

Peter House's private interests include gourmet cooking, science fiction, landscaping his new home, and neighborhood politics. A chief objective in recent years has been to assure that the recently abandoned railroad right-of-way in front of his house is sold to the National Park Service, rather than to high-rise office building developers.

CHARLES T. OWENS

Former Head, NSF Regional Office, Tokyo

Division of International Programs

Directorate for Scientific, Technological, and International Affairs

Tenure at NSF: 1971 to present

Special achievements:

Charles T. Owens has greatly helped to improve access by NSF and the U.S. research community to information on Japanese science and technology. In 1982, Mr. Owens was appointed head of NSF's Tokyo Regional Office, and he set about establishing a comprehensive reporting program. In four years the Tokyo office prepared some 160 studies on Japanese science and technology policy, R&D budgets of Japanese government agencies, the work of individual Japanese researchers, along with translation of Japanese government documents and literature searches on Japanese automated data bases. In addition, thousands of news items, articles, and books were sent to NSF program staff for information on current developments.

Mr. Owens also was a key figure in the successful negotiations leading to Japanese participation in the Foundation's Ocean Drilling Program and acceptance of U.S. researchers at the research organization for Japan's Fifth Generation Computer Project.

Through Mr. Owens' efforts, NSF management and decision makers elsewhere in the U.S. government have become much more aware of Japanese S&T capabilities and developments; this has in turn enabled us to design better cooperative programs and activities with the Japanese.

Mr. Owens has since returned to Washington, DC and has been setting up a foreign science information and assessment group in his division.

Prior experience/education/ other interests:

1963-70: Foreign Service Officer, U.S. Department of State (service in Argentina and Washington, DC)

U.S. Coast Guard Academy 1957-59; University of California at Berkeley 1960-63, A.B. International Relations

Interests include sailing, classical music, and the Oriental discipline of Tae Kwon Do.


J. Latham

ROBERT D. NEWTON

Former Head of the Policy Office
Division of Grants and Contracts
Directorate for Administration

Tenure at NSF: 1958 to 1987

Special achievements:

During much of his career, Robert Newton studied, and involved himself in, the relationships between those who support research and those who perform it. His efforts to simplify research grant administration have influenced not only NSF but the larger federal and university research communities as well.

At the Foundation, Dr. Newton was instrumental in defining the grant relationship to emphasize grantee responsibility and minimize NSF involvement in the management and administration of research. He pioneered the NSF "master grant experiment" in the late 1970s and developed the expanded "OPAS" concept (Organizational Prior Approval System). This concept serves as the basis of NSF's grant administration philosophy today.

More recently, Dr. Newton spearheaded a cooperative effort among 5 major federal R&D agencies, the National Academy of Sciences (Government-University-Industry Research Roundtable) and 10 public and private universities in the state of Florida. Through his leadership, these parties engaged in a demonstration project using a new, standardized, and streamlined approach to federal support of university research. This demonstration project was remarkable, considering the varied interests of the parties involved. (See chapter 1 for more on this project.)

Robert Newton's clarity of purpose and his commitment to research funding and administration issues that transcend individual agencies and universities made him a widely known and highly respected federal employee. Largely through and because of his efforts, NSF enjoys its reputation as the federal agency with one of the most reasoned and reasonable approaches to research funding and administration.

Prior experience/education/ other interests:

A.B. in philosophy and general science, University of Rochester, 1950

Ph.D. in philosophy and political theory, Columbia University, 1957

2 years with Department of the Army, working in research contracting

Hobbies: running, travel

MARY THOMAS

Oversight and Administrative Specialist and Administrative Support Center Manager

Division of Audit and Oversight
Office of Budget, Audit, and Control

Tenure at NSF: 1974 to present

Special achievements:

Mary Thomas helped to design and establish—and now heads—the Division of Audit and Oversight's (DAO) Administrative Support Center, set up in January 1986. It is one of two such centers in NSF's Office of Budget, Audit, and Control; they share the distinction of being the Foundation's first officially established and fully operational administrative support centers.

These centers were designed to increase the efficiency and effectiveness of NSF programs and activities by equalizing workloads and alleviating occasional staff shortages. DAO staff members feel that their center also allows for growth and training in the division's various activities. They note that the center operation tends to give a more technical character to positions that had been primarily secretarial. Moreover, routine tasks (timecards, supply orders, travel and training arrangements) are rotated every 60 days, allowing everyone to remain proficient in these activities.

In order to design a center that would best suit the needs of DAO and the 15 professionals it was to serve, Mary Thomas held numerous meetings with staff from NSF's Division of Personnel and Management; she also requested input from DAO staff as she was developing plans for the center. After the model was decided upon, Mrs. Thomas prepared the necessary paperwork, including rewritten position descriptions and employee performance plans for the six support staff persons included in the center.

Mrs. Thomas meets often with both program and support staff to remain aware of the workload, to provide assistance in redistributing the work as necessary, to resolve issues, and to keep her division director apprised of center activities and accomplishments. With the acquisition of personal computers in DAO, some of the work is now automated and new procedures have been introduced; Mrs. Thomas has made arrangements for staff training in the use of various computer programs (Word Perfect, Lotus 1-2-3, dBase III) and in working with databases for Hewlett-Packard (NSF's main computer).

Mary Thomas' widely respected knowledge and ability—and her interest in people as individuals—are key factors in the success of DAO's administrative center. She also designed and set up the division's administrative accounts, using the Lotus 1-2-3 program. Because of the efficiency of her design, the accounts are easily maintained and kept current, and account status reports are readily available for DAO management review.

Prior experience/education/ other interests:

Mrs. Thomas is originally from Connecticut, where she attended schools such as the St. Francis Hospital School of Nursing in Hartford. Her prior experience includes 6 years with private industry and 19 years of federal service. Before coming to the National Science Foundation in 1974, she held a variety of secretarial and administrative positions with the Department of Labor and the Department of the Air Force. At NSF, she has served in secretarial and administrative positions with the former Directorate for Applied Research; she currently occupies the dual roles of Oversight and Administrative Specialist and Administrative Support Center Manager in the Division of Audit and Oversight.

During non-working hours, Mrs. Thomas devotes her attention to home and family, including her children and grandchildren, and to travelling with her husband.

SUKARI S. SMITH

Paralegal Assistant
Office of General Counsel

Tenure at NSF: 1971 to present

Special achievements:
As NSF's paralegal assistant, Sukari Smith has major responsibilities in helping NSF staff to avoid or deal with conflicts of interests. Working with a lawyer designated as NSF's ethics counselor, she draws on her extensive knowledge of federal conflict-of-interest laws and the NSF regulations that implement them. Scientists rely on her for advice; many rotators and others, upon leaving the Foundation, receive from her a required briefing—tailored to their particular situations—about the postemployment rules that will for a time restrict them from representing private interests vis-à-vis the NSF.

As the Foundation's *Federal Register* certifying officer and liaison with a key Office of Management and Budget section (Office of Information and Regulatory Affairs), Ms. Smith is the gatekeeper for NSF's published rules and regulations.

Ms. Smith also helps the Foundation's lawyers with work in a wide variety of legal specialties, from patents to legislation. In addition, she is an editorial correspondent for *Discovery,* an NSF inhouse newsletter. In discharging all her responsibilities, she displays a vigor and style that have made her one of the Foundation's best-known personalities.

Prior experience/education/ other interests:
Sukari S. Smith's NSF career started in the Division of Biology and Medical Sciences in November 1971. She worked as Information Assistant in the Division of Polar Programs and as a secretary in the National Science Board Office for several years before joining the Office of the General Counsel (OGC) in 1980. She has assumed increasingly important roles in OGC, becoming the Foundation's sole Paralegal Assistant in 1984.

Ms. Smith received an Associate degree in Arts and Sciences from George Washington University in 1978. She continues to work toward completing an undergraduate degree in sociology at the same institution. During a hiatus in this effort, she spent a year as a volunteer lab technician (in the evenings) with the Washington Free Clinic in Washington, DC. This work grew out of her original interest and studies in medicine at the Washington Technical Institute.

MARY McDONOUGH KEENEY

Coordinator, National Science & Technology Week

Office of Legislative and Public Affairs

Tenure at NSF: 1984 to present

Special achievements:

Since 1985, the National Science Foundation has coordinated National Science Week, a program to increase public understanding and awareness of science, mathematics, and technology. Another goal of the Week is to encourage young people to pursue careers in these fields. So successful were the 1985 and 1986 efforts (see "Highlights" section earlier in this report) that the program was expanded to become National Science & Technology Week (NSTW), held April 5-11, 1987.

Mary Keeney, the Foundation coordinator for this initiative since it began, is also the originator of many of the ideas and activities associated with the Week. Indeed, its success and widened scope can be attributed largely to Ms. Keeney's creativity and extraordinary drive. Additionally, her talents have resulted in plans to carry out NSTW for a number of years to come.

Ms. Keeney's enthusiasm for the program, and her ability to communicate this feeling to members of the science and technology community, have sparked a response throughout the various groups; this has resulted in the participation of many professional societies and associations as sponsors of NSTW activities and events.

Her ability to produce top-quality materials in a high-pressure situation has been demonstrated throughout the last three years as the program has evolved and grown far beyond its original scope.

Ms. Keeney, in addition, has successfully managed the fundraising portion of the program, assuring corporate financing of various Week activities and involving the major corporate sponsors in planning sessions prior to each of the Weeks.

Her dedication to broadening the base of informal science education to include a wide spectrum of ages, interests, and backgrounds is responsible for the breadth and success of NSTW. Moreover, she has been able to draw on groups of people who demonstrate excellence in their fields to act as advisors in many areas of the NSTW program; these advisors serve without recompense, even paying for their own travel and accommodations to attend meetings.

Finally, Mary Keeney's work throughout the Foundation has encouraged various NSF directorates to participate in the sponsorship of NSTW programs that relate directly to their particular disciplines.

Prior experience/education/ other interests:

Mary Keeney previously worked at the Naval Historical Center, the Smithsonian Institution, and, on Capitol Hill, as an organizer for the "Year of the Ocean." Her M.A. degrees are in American history and museum studies (University of Delaware Hagley Program, 1978). She is interested in graphic arts and design and is also a gourmet cook. Ms. Keeney is certified as a SCUBA diver, an activity she shares with her husband.

CHAPTER 5

OPERATIONS

Establishment of Support or Resource Centers. NSF has set up support staff centers, each under a center manager, to coordinate clerical and related services in an organizational unit. Under the new system, based on industry models, people learn to perform most of the services a unit requires. As a result, they can act as back-up support when someone is out, their workloads can be balanced, teamwork is encouraged, and duties considered routine can be rotated. Occasionally, people can even be assigned to duties they especially enjoy doing. Among the most important advantages of the centers system is the possibility of upward mobility for support center staff as they learn new, higher-level functions.

One of the early support centers was organized in NSF's Division of Electrical, Communications, and Systems Engineering; its success has served as a model for other divisions. And the center serving the Office of Legislative and Public Affairs has received one of the Foundation's Commendable Service Awards for its design, structure, and successful operation.

Electronic Advances. NSF's Office of Information Systems began to implement a new electronic mail system to replace those which have been in use throughout the Foundation. Among the features of the new NOTE mail system are: access to the national and international computer networks BITNET, ARPANET, and CSNET; the ability of staff to reach the mail system using a local phone number while on travel; and the ability to query local and national electronic bulletin board services. (See also "Improving the Proposal Process," in chapter 1.)

ORGANIZATIONAL CHANGES

New Directorate. As of May 1, 1986, NSF established the Directorate for Computer and Information Science and Engineering, or CISE, bringing the number of its directorates to eight. CISE consolidates programs in computer and information science and engineering from throughout the Foundation. The Division of Computer Research (formerly in the Directorate for Mathematical and Physical Sciences), the Division of Information Science and Technology (formerly in the Directorate for Biological, Behavioral, and Social Sciences), the Office of Advanced Scientific Computing (which handles supercomputer centers and networks), and certain computer engineering and communications/signal processing activities from the Directorate for Engineering are now housed in the same organizational unit. CISE aims to prevent overlap between programs and to link the disciplines that practice computer science.

The new directorate is headed by C. Gordon Bell, former professor of computer science at Carnegie Mellon University and former vice-president for engineering at Digital Equipment Corporation. Bell is well-known as an innovative computer architect; he and his wife Gwendolyn are co-founders of the Computer Museum in Boston, MA.

Internal Moves. The Division of Astronomical Sciences moved to the Directorate for Mathematical and Physical Sciences. The move reflects the tendency of academic departments of astronomy to be associated with departments of physics. The former Directorate for Astronomical, Atmospheric, Earth, and Ocean Sciences, now minus astronomy, has changed its name to the Directorate for Geosciences, or GEO for short.

The Office of Equal Opportunity (OEO) moved from the Office of the Foundation's Director to become part of the Directorate for Administration. OEO provides advice, training, and guidance to NSF staff to promote the full participation in science and engineering of women, minorities, and disabled or handicapped persons.

NSF OPERATIONS AND ORGANIZATION

New Engineering Office. Engineering as a field depends especially on cooperation between industry, academia, and the federal government. The Directorate for Engineering established the Office for Engineering Infrastructure Development (OEID) to coordinate activities affecting more than one of that Directorate's divisions. Among the office's responsibilities is a program to identify and develop research potential in engineering at the undergraduate and graduate levels, in order to encourage more students to go on to doctoral degrees in engineering.

New Name. In the Directorate for Biological, Behavioral, and Social Sciences, the Office of Biotechnology Coordination changed its name to the Office of Interdirectorate Research Coordination. It continues to be responsible for maintaining NSF's activities in biotechnology. In addition, the office now coordinates Foundationwide activities related to ethical issues in science and engineering.

SENIOR FOUNDATION AND BOARD OFFICIALS, FY 1986

Erich Bloch
NSF Director

John H. Moore
NSF Deputy Director

Roland W. Schmitt
Chairman
National Science Board

Charles E. Hess
Vice Chairman
National Science Board

CHAPTER 6

The National Science Foundation is convinced that the nation's international competitiveness in this highly technological era can be maintained only by having a vital, well-supported, and well-equipped community of scientists, mathematicians, and engineers doing forefront basic research. Many factors affect our ability to compete economically in the modern world, but basic research and education for a technology-oriented age are unquestionably vital. Without them, we can neither maintain a competitive posture nor advance our knowledge base.

The discoveries, inventions, and principles of basic research underlie existing technologies and open the way for future ones. Investment in research and education has been the source of much of our economic progress over the past four decades; that investment continues to be the best single way to provide for the future.

CONCLUSION

J. Latham

Einstein statue at National Academy of Sciences, Washington, DC

APPENDIX

A

NATIONAL SCIENCE FOUNDATION STAFF AND NATIONAL SCIENCE BOARD MEMBERS (FISCAL YEAR 1986)

NATIONAL SCIENCE FOUNDATION STAFF

(as of September 30, 1986)

Director, Erich Bloch
Deputy Director, John H. Moore
Senior Science Advisor, Mary E. Clutter
General Counsel, Charles Herz
Director, Office of Legislative and Public Affairs, Raymond E. Bye
Controller, Office of Budget, Audit, and Control, Sandra D. Toye
Director, Office of Information Systems, Constance K. McLindon
Assistant Director for Biological, Behavioral, and Social Sciences, David T. Kingsbury
- *Executive Officer,* Alan I. Leshner
- *Head, Office of Interdirectorate Research Coordination,* (Acting) Thomas S. Quarles
- *Director, Division of Behavioral and Neural Sciences,* Richard T. Louttit
- *Director, Division of Biotic Systems and Resources,* John L. Brooks
- *Director, Division of Cellular Biosciences,* (Acting) Bruce L. Umminger
- *Director, Division of Molecular Biosciences,* James H. Brown
- *Director, Division of Social and Economic Science,* Roberta B. Miller

Assistant Director for Computer and Information Science and Engineering, C. Gordon Bell
- *Executive Officer,* Charles N. Brownstein
- *Director, Office of Advanced Scientific Computing,* John W. Connolly
- *Director, Division of Computer Research,* Kent K. Curtis
- *Director, Division of Information Science and Technology,* (Acting) Yi-Tzuu Chien
- *Director, Division of Computer and Information Engineering,* Bernard Chern

Assistant Director for Engineering, Nam P. Suh
- *Deputy Assistant Director for Engineering,* Carl W. Hall
- *Head, Office for Engineering Infrastructure Development,* William S. Butcher
- *Director, Division of Cross Disciplinary Research,* Lewis G. Mayfield
- *Director, Division of Engineering Science in Chemical, Biochemical, and Thermal Engineering,* Marshall M. Lih
- *Division Director, Division of Engineering Science in Electrical, Communications, and Systems Engineering,* Frank L. Huband
- *Director, Division of Engineering Science in Mechanics, Structures, and Materials Engineering,* (Acting) Win Aung
- *Director, Division of Fundamental Research in Emerging and Critical Engineering Systems,* Arthur A. Ezra
- *Director, Division of Science Base Development in Design, Manufacturing, and Computer-Integrated Engineering,* Michael J. Wonzy

Assistant Director for Geosciences, William J. Merrell, Jr.
- *Executive Officer,* Kurt W. Sandved
- *Director, Division of Atmospheric Sciences,* Eugene W. Bierly
- *Director, Division of Earth Sciences,* James F. Hays
- *Director, Division of Ocean Sciences,* M. Grant Gross
- *Director, Division of Polar Programs,* Peter E. Wilkniss

Assistant Director for Mathematical and Physical Sciences, Richard S. Nicholson
- *Executive Officer,* M. Kent Wilson
- *Director, Division of Astronomical Sciences,* Laura P. Bautz
- *Director, Division of Chemistry,* Edward F. Hayes
- *Director, Division of Materials Research,* Lewis H. Nosanow
- *Director, Division of Mathematical Sciences,* John C. Polking
- *Director, Division of Physics,* Harvey B. Willard

Assistant Director for Science and Engineering Education, Bassam Z. Shakhashiri
- *Executive Officer,* Peter E. Yankwich
- *Head, Office of College Science Instrumentation,* Robert F. Watson
- *Head, Office of Studies and Program Assessment,* William H. Schmidt
- *Director, Division of Teacher Preparation and Enhancement,* Arnold L. Strassenburg
- *Director, Division of Materials Development, Research and Informal Science Education,* George W. Tressel
- *Director, Division of Research Career Development,* Terence L. Porter

Assistant Director for Scientific, Technological, and International Affairs, Richard J. Green
- *Executive Officer,* Richard R. Ries
- *Director, Office of Small Business Research and Development,* Donald Senich
- *Director, Office of Small and Disadvantaged Business Utilization,* Donald Senich
- *Director, Division of Industrial Science and Technological Innovation,* Donald Senich
- *Director, Division of Research Initiation and Improvement,* Alexander J. Morin
- *Director, Division of International Programs,* (Acting) Richard J. Green
- *Director, Division of Policy Research and Analysis,* Peter W. House
- *Director, Division of Science Resources Studies,* William L. Stewart

Assistant Director for Administration, Geoffrey M. Fenstermacher
- *Director, Office of Equal Opportunity,* Brenda M. Brush
- *Director, Division of Financial Management,* Kenneth B. Foster
- *Director, Division of Grants and Contracts,* William B. Cole, Jr.
- *Director, Division of Personnel and Management,* Margaret L. Windus
- *Director, Division of Administrative Services,* Gaylord L. Ellis

NATIONAL SCIENCE BOARD

Terms Expire May 10, 1988

WARREN J. BAKER, President, California Polytechnic State University, San Luis Obispo, CA
ROBERT F. GILKESON, Chairman of the Executive Committee, Philadelphia Electric Co., Philadelphia, PA
CHARLES E. HESS (Vice Chairman, National Science Board) Dean, College of Agricultural and Environmental Sciences, University of California at Davis, Davis, CA
CHARLES L. HOSLER, Vice President for Research and Dean of Graduate School, Pennsylvania State University, University Park, PA
WILLIAM F. MILLER, President and Chief Executive Officer, SRI International, Menlo Park, CA
WILLIAM A. NIERENBERG, Director Emeritus, Scripps Institution of Oceanography, University of California at San Diego, LaJolla, CA
NORMAN C. RASMUSSEN, McAfee Professor of Engineering, Massachusetts Institute of Technology, Cambridge, MA
ROLAND W. SCHMITT (Chairman, National Science Board) Senior Vice President and Chief Scientist, General Electric Company, Schenectady, NY

Terms Expire May 10, 1990

PERRY L. ADKISSON, Chancellor, Texas A&M University System, College Station, TX
ANNELISE G. ANDERSON, Senior Research Fellow, The Hoover Institution, Stanford University, Stanford CA
CRAIG C. BLACK, Director, Los Angeles County Museum of Natural History, Los Angeles, CA
RITA R. COLWELL, Vice President for Academic Affairs and Professor of Microbiology, Central Administration, University of Maryland, Adelphi, MD
THOMAS B. DAY, President, San Diego State University, San Diego, CA
JAMES J. DUDERSTADT, Vice President for Academic Affairs and Provost, University of Michigan, Ann Arbor, MI
K. JUNE LINDSTEDT-SIVA, Manager, Environmental Sciences, Atlantic Richfield Company, Los Angeles, CA
SIMON RAMO, Director, TRW Incorporated, Redondo Beach, CA

Terms Expire May 10, 1992

E. ALBERT COTTON, W.T. Doherty-Welch Foundation Distinguished Professor of Chemistry and Director, Laboratory for Molecular Structure and Bonding, Texas A&M University, College Station, TX*
MARY L. GOOD, President, Engineered Materials Research, Allied-Signal Corporation, Des Plaines, IL*
JOHN C. HANCOCK, Executive Vice President and Chief Technical Officer, United Telecommunications, Inc., Westwood, KA*
JAMES B. HOLDERMAN, President, University of South Carolina, Columbia, SC*
JAMES L. POWELL, President, Franklin and Marshall College, Lancaster, PA*
HOWARD A. SCHNEIDERMAN, Senior Vice President for Research and Development and Chief Scientist, Monsanto Company, St. Louis, MO

(Two vacancies)

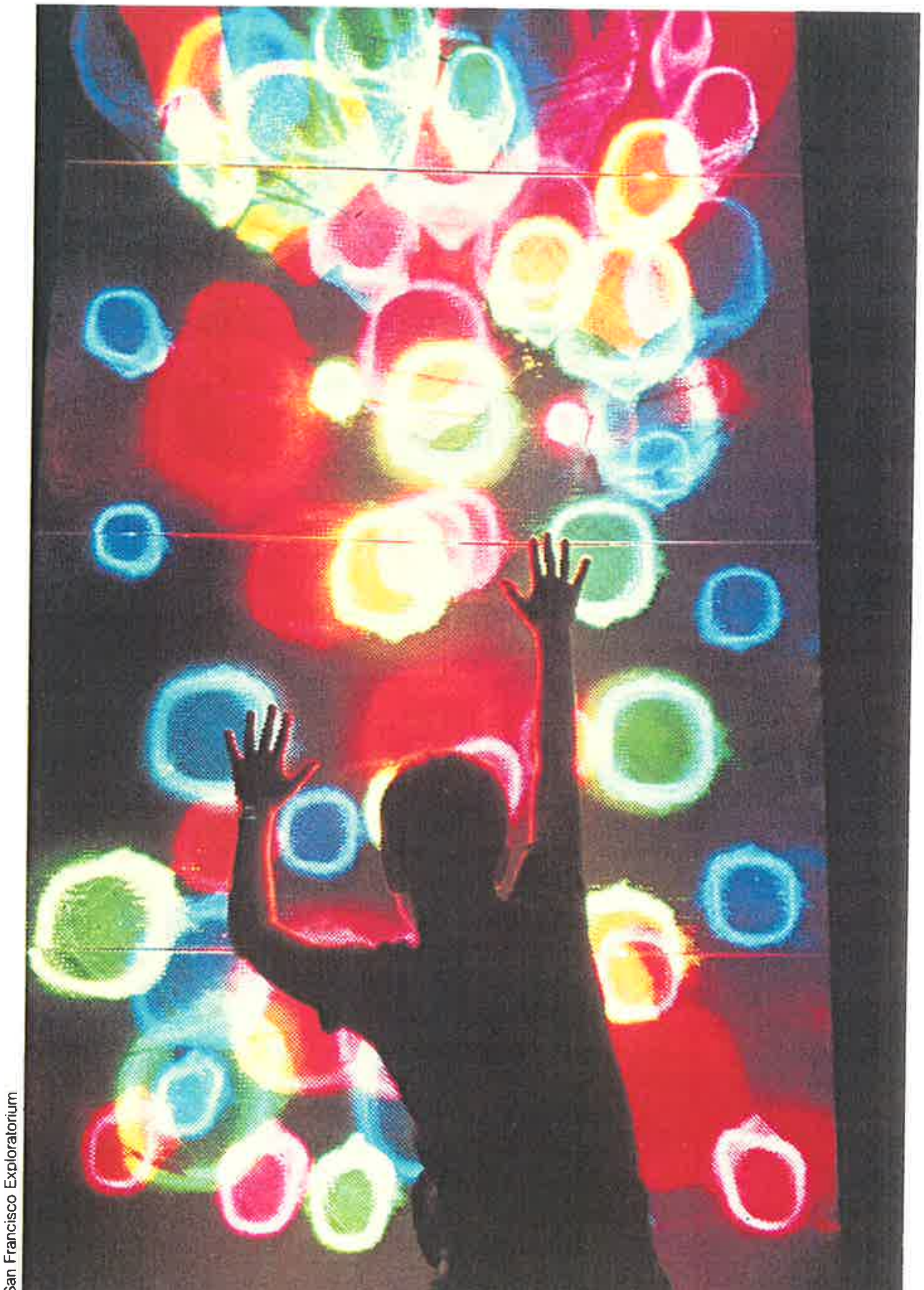
*Confirmed 10-21-86
**nomination pending Senate confirmation as of 2-87

Member Ex Officio

ERICH BLOCH, Director, National Science Foundation, Washington, DC

* * *

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



San Francisco Exploratorium

APPENDIX

B

PATENTS AND FINANCIAL REPORT FOR FISCAL YEAR 1986

I. Patents and Inventions Resulting from Activities Supported by NSF

During fiscal year 1986, the Foundation received 123 invention disclosures. Allocations of rights to 49 of those inventions were made by September 30, 1986. These resulted in dedication to the public through publication in 13 cases, retention of principal patent rights by the grantee or inventor in 37 instances, and transfer to other government agencies in 2 cases. Licenses were received by the Foundation in 56 patent applications filed by grantees and contractors who retained principal rights in their inventions.

II. NSF Financial Report

Research and Related Activities Appropriation

Fund Availability

Fiscal year 1986 Appropriation	$1,294,060	
Unobligated balance available, start of year	197	
Adjustments to prior year accounts	4,639	
Fiscal year 1986 availability		$1,298,896

Obligations

Biological, Behavioral, and Social Sciences:		
Molecular Biosciences	59,645	
Cellular Biosciences	49,965	
Biotic Systems and Resources	58,265	
Behavioral and Neural Sciences	43,623	
Social and Economic Sciences	27,794	
Subtotal, Biological, Behavioral, and Social Sciences		$ 239,292
Computer and Information Science and Engineering:		
Computer and Computation Research	$ 33,482	
Information, Robotics, and Intelligent Systems	15,093	
Microelectronic Information Processing System	7,278	
Advanced Scientific Computing	36,468	
Networking and Communications Research and Infrastructure	8,558	
Subtotal, Computer and Information Sciences and Engineering		$ 100,879
Engineering:		
Chemical, Biochemical, and Thermal Engineering	$ 27,708	
Mechanics, Structures, and Materials Engineering	22,674	
Electrical, Communications, and Systems Engineering	19,813	
Design, Manufacturing and Computer-Integrated Eng.	12,775	
Emerging Engineering Technologies	10,356	
Critical Engineering Systems	23,846	
Cross-Disciplinary Research	27,735	
Subtotal, Engineering		$ 144,907
Geosciences:		
Atmospheric Sciences	$ 92,580	
Earth Sciences	46,827	
Ocean Sciences	119,424	
Arctic Research Program	8,035	
Subtotal, Geosciences		$ 266,866
Mathematical and Physical Sciences:		
Mathematical Sciences	$ 51,928	
Astronimical Sciences	80,151	
Physics	113,172	
Chemistry	85,745	
Materials Research	104,314	
Subtotal, Mathematical and Physical Sciences		$ 435,310

Scientific, Technological, and International Affairs:		
Industrial Science and Technological Innovation	$ 15,224	
International Cooperative Scientific Activities	10,222	
Policy Research and Analysis	1,828	
Science Resources Studies	3,853	
Research Initiation and Improvement	7,096	
Subtotal, Scientific, Technological, and International Affairs		$ 38,223
Program Development and Management		$ 71,836
Subtotal, obligations		$1,297,313
Unobligated balance available, end of year		1,472
Unobligated balance lapsing		$ 111
Total, fiscal year 1986 availability for Research and Related Activities		$1,298,896

U.S. Antarctic Program Activities Appropriation

Fund Availability		
Fiscal year 1986 appropriation	$ 110,151	
Unobligated balance available, start of year	59	
Adjustments to prior year accounts	31	
Fiscal year 1986 availability		$ 110,241
Obligations		
U.S. Antarctic Research Program	$ 11,016	
Operations Support	99,145	
Subtotal, obligations		$ 110,161
Unobligated balance available, end of year		$ 80
Total, fiscal year 1986 availability for U.S. Antarctic Program Activities		$ 110,241

Special Foreign Currency Appropriation

Fund Availability		
Fiscal year 1986 appropriation	$ 957	
Unobligated balance available, start of year	2	
Adjustments to prior year accounts	232	
Fiscal year 1986 availability		$ 1,191
Obligations		
Special Foreign Currency	$ 1,098	
Unobligated balance available, end of year	25	
Unobligated balance lapsing	68	
Total, fiscal year 1986 availability for Special Foreign Currency Program		$ 1,191

Science and Engineering Education Activities Appropriation

Fund Availablity		
Fiscal year 1986 appropriation	$ 53,161	
Unobligated balance available, start of year	31,494	
Adjustments to prior year accounts	21	
Fiscal year 1986 availability		$ 84,676
Obligations		
Research Career Development	$ 25,938	
Materials Development, Research, and Informal Science Education	24,357	
Teacher Preparation and Enhancement	26,256	
Studies and Program Assessment	2,785	
College Science Instrumentation	5,259	
Subtotal, obligations		$ 84,595
Unobligated balance available, end of year		$ 36
Unobligated balance lapsing		$ 45
Total, fiscal year 1986 availability for Science and Engineering Education Activities		$ 84,676

Trust Funds/Donations

Fund Availability

Unobligated balance available, start of year	$ 1,126	
Receipts from nonfederal sources	13,527	
Fiscal year 1986 availability		$ 14,653

Obligations

Ocean Drilling Programs	$ 12,518	
Miscellaneous Program Activities	284	
U.S.-Spain Scientific and Technological Program	72	
Subtotal, obligations		$ 12,874
Unobligated balance available, end of year		$ 1,779
Total, fiscal year 1986 availability for Trust Funds/Donations		$ 14,653

SOURCES: Fiscal Year 1988 Supplementary Budget Schedules and Fiscal Year 1988 Budget to Congress.

San Diego Supercomputer site

Table 1. Biological, Behavioral, and Social Sciences, Fiscal Year 1986

(Dollars in Millions)

	Number of Awards	Amount
Molecular Biosciences	832	$ 59.65
Cellular Biosciences	765	49.96
Biotic Systems and Resources	789	58.27
Behavioral and Neural Sciences	784	43.62
Social and Economic Science	548	27.79
Total	3,718	$239.29

SOURCE: Fiscal Year 1988 Budget to Congress-Justification of Estimates of Appropriation (Quantitative Program Data Tables).

Table 2. Computer and Information Science and Engineering, Fiscal Year 1986

(Dollars in Millions)

	Number of Awards	Amount
Computer and Computation Research	279	$ 33.48
Information, Robotics, and Intelligent Systems	210	15.09
Microelectronic Information Processing Systems	92	7.28
Advanced Scientific Computing	18	36.47
Networking and Communications Research and Infrastructure	54	8.56
Total	653	$100.88

Table 3. Engineering, Fiscal Year 1986

(Dollars in Millions)

	Number of Awards	Amount
Chemical, Biochemical, and Thermal Engineering	506	$ 27.71
Mechanics, Structures, and Materials Engineering	360	22.67
Electrical, Communications, and Systems Engineering	311	19.81
Design, Manufacturing, and Computer-Integrated Engineering	144	12.78
Emerging Engineering Technologies	145	10.36
Critical Engineering Systems	309	23.85
Cross-Disciplinary Research	59	27.73
Total	1,834	$144.91

Table 4. Geosciences, Fiscal Year 1986
(Dollars in Millions)

	Number of Awards	Amount
Atmospheric Sciences	570	$ 92.58
Earth Sciences	650	46.83
Ocean Sciences	725	119.42
Arctic Research	82	8.03
Total	2,027	$266.86

Table 5. Mathematical and Physical Sciences, Fiscal Year 1986
(Dollars in Millions)

	Number of Awards	Amount
Mathematical Sciences	1,265	$ 51.93
Astronomical Sciences	263	80.15
Physics	506	113.17
Chemistry	986	85.75
Materials Research	875	104.31
Total	3,895	$435.31

Table 6. Science and Engineering Education, Fiscal Year 1986
(Dollars in Millions)

	Number of Awards	Amount
Research Career Development	152	$ 25.94
Materials Development, Research, and Informal Science Education	108	24.35
Teacher Preparation and Enhancement	276	26.25
Studies and Program Assesment	12	2.79
College Science Instrumentation	207	5.26
Total	755	$ 84.59

Table 7. Scientific, Technological, and International Affairs, Fiscal Year 1986
(Dollars in Millions)

	Number of Awards	Amount
Industrial S & T Innovation	207	$ 15.22
Internat'l. Coop. Sci. Act.	479	10.22
Policy Research and Analysis	138	1.83
Science Resources Studies	40	3.85
Research Initiation and Improvement	51	7.10
Total	915	$ 38.22

Table 8. U.S. Antarctic Program, Fiscal Year 1986
(Dollars in Millions)

	Number of Awards	Amount
U.S. Antarctic Research Program	129	$ 11.02
Operations Support	16	99.14
Total	145	$110.16

APPENDIX C

ADVISORY COMMITTEES FOR FISCAL YEAR 1986 (ADDRESSES EFFECTIVE AS OF SEPTEMBER 30, 1986)

OFFICE OF THE DIRECTOR

NSF Advisory Council

Victoria Bergin
Deputy Commissioner for Curriculum & Program Development
Texas Education Agency
Austin, TX

Dennis Chamot
Associate Director, Department for Professional Employees
AFL-CIO
Washington, DC

Matina Horner
President
Radcliffe College
Cambridge, MA

William H. Kruskal
Department of Statistics
University of Chicago

John F. Niblack
Vice President
Pfizer, Inc.
Groton, CT

Roger Noll
Professor of Economics
Stanford University
Stanford, CA

Robert Noyce
Vice Chairman of the Board
Intel Corporation
Santa Clara, CA

Gail Pesyna
Biomedical Products Department
E.I. DuPont de Nemours
Claremont, CA

Gerard Piel
Chairman of the Board
Scientific American
New York, NY

Lois Rice
Senior Vice President
Control Data Corporation
Washington, DC

Linda S. Wilson
Vice President for Research
University of Michigan, Ann Arbor

Harry Woolf
Director
The Institute for Advanced Study
Princeton, NJ

Daniel Yankelovich
The Daniel Yankelovich Group
New York, NY

Committee on Equal Opportunities in Science and Technology

Lenore Blum
Department of Math and Computer Science
Mills College
Oakland, CA

Kimiko O. Bowman
Oak Ridge National Laboratory
Oak Ridge, TN

Bernard J. Bulkin
Director, Analytical Sciences Laboratory
Standard Oil Co.
Cleveland, OH

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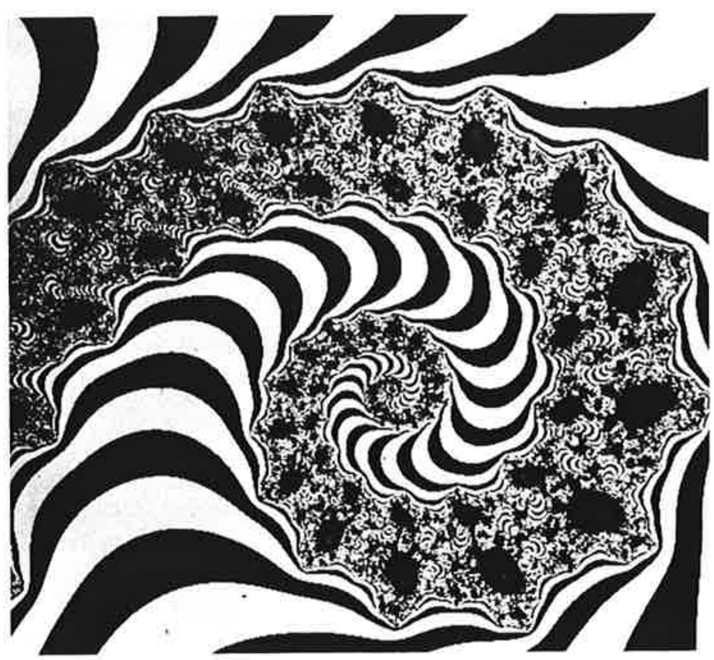

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