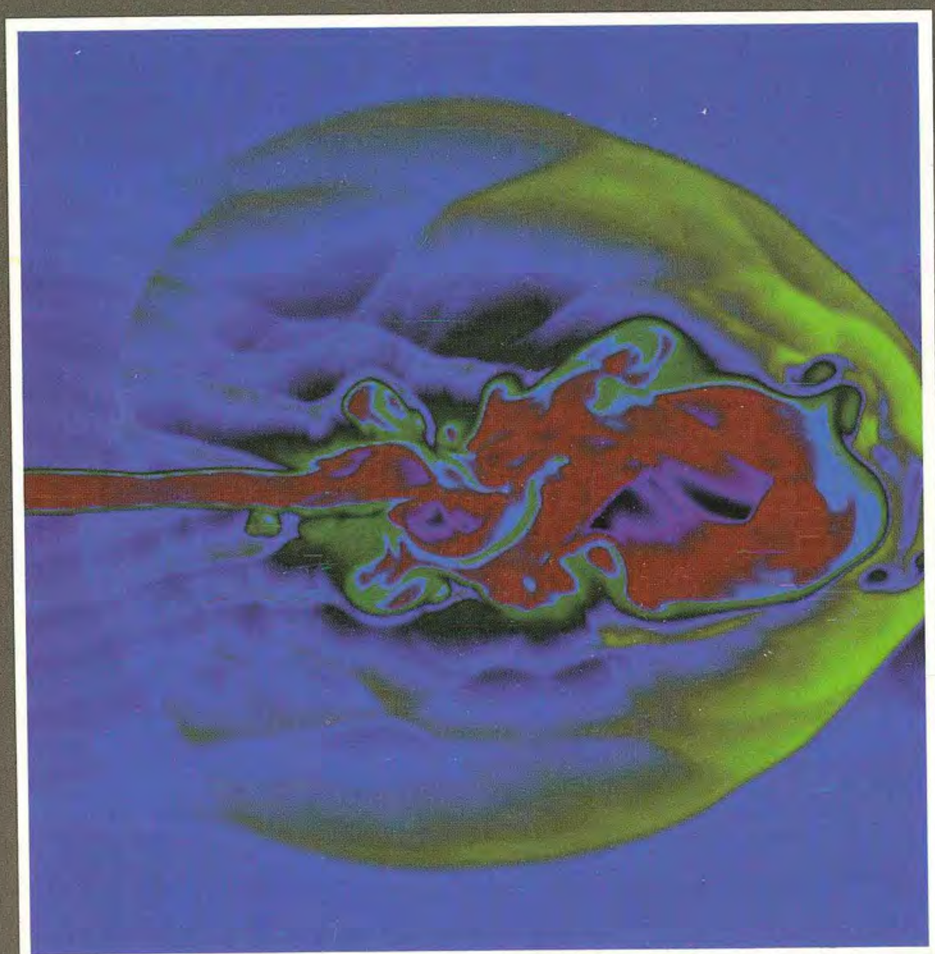
# National Science Foundation
## Annual Report 1988



# About the National Science Foundation

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

*NSF funds research 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 37,500 proposals each year for research, graduate fellowships, and math/science/engineering education; it makes more than 16,000 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.*

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

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

* * * *

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

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

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

*Cover: "Instabilities in Supersonic Flow" (image showing development of instability in a supersonic gas jet). This is from an animated sequence of 400 images; the animation was computed in about 15 hours on a CRAY supercomputer at the National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign. Principal investigators: David A. Clarke, Donna Cox, Philip E. Hardee, Michael L. Norman*

# *National Science Foundation*

# *Annual Report 1988*

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

# *Letter of Transmittal*

Washington, D.C.

DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1988 of the National Science Foundation, for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

Erich Bloch
*Director, National Science Foundation*

*The Honorable*
*The President of the United States*

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# *Director's Statement*

The end of 1988 is also the end of the Reagan Administration. This has been a period of growth for NSF, one in which new missions have been accepted and integrated with traditional activities and a basis laid for further development. The new Administration will enter office already committed to improving American research and education in science and engineering, and NSF is ready.

Congressional action in 1988 was especially important for NSF. Early in 1987 the Administration had asked Congress to double the NSF budget over the succeeding five years. This was unprecedented. It recognized the importance of science and engineering to economic competitiveness, and especially the importance of university basic research. But it was also a hard thing to ask of Congress in a time of financial constraints. After the stock market collapse of October 1987 forced a budget "summit" between Congress and the Administration, NSF's appropriation for 1988 showed little real gain.

The Administration's five-year doubling strategy was reaffirmed in January 1988, and this time we were able to achieve tangible results. In late 1988, with strong bipartisan support in both House and Senate, the Congress passed a five-year authorization bill for NSF, and it was signed into law by President Reagan. This multi-year authorization — the first such authorization the Foundation has ever had — will provide a much firmer basis for planning than has been available before. Congressional endorsement of specific future budget targets will make it easier to defend the Foundation's appropriations request in each of the next several years.

NSF's appropriation increase for 1989 was almost 10 percent — a very good result in a year when domestic programs were limited to 2 percent overall. We will be able to strengthen the basic disciplinary programs and also move ahead with major initiatives.

All Foundation activities are doing well. Our education programs are growing vigorously, with excellent support from the Administration and both parties in Congress. Science and technology centers* will become a reality in 1989, with normal review in the annual budget competition. We expect to fund 11 of these centers in 1989, with total first-year funding of about $25 million.

* See Chapter 4.

Because demographic trends demand it, we will renew our efforts to attract larger numbers of women and minority-group individuals to science and engineering. Women and minorities must be recruited more successfully if we are to have the people we need in science and engineering. This is absolutely crucial.

Our FY 1989 bill also contains an authorization to establish a program designed to help modernize the nation's academic research facilities. In response to this, NSF has begun to explore the roles and responsibilities of the various parties involved in the support of research facilities.

In addition to a new Administration, 1989 will see important changes in Congressional leadership. There will be new chairs of both the House and Senate appropriations subcommittees responsible for NSF. But in spite of these shifts, support for basic research is likely to remain stable and strong. Leaders in both parties have recognized the economic importance of science and engineering and appear prepared to put increasing resources behind our efforts.

The nation needs to do much better in many areas. Education is a particular challenge. Industrial support of basic research is inadequate, and industrial application of new knowledge is insufficiently aggressive. The Federal research and development (R&D) budget needs a better balance between development and basic research.

Priorities need to be set among competing research projects. And we must enhance industry-university relationships to improve the transfer of knowledge. All these problems require action.

But at NSF, we have a strategy in place and are starting to get results. We will be able to do our part in solving these problems. That is a good position to be in as we look to the challenges of the new Administration.

*Erich Bloch*
*NSF Director*

# Highlights

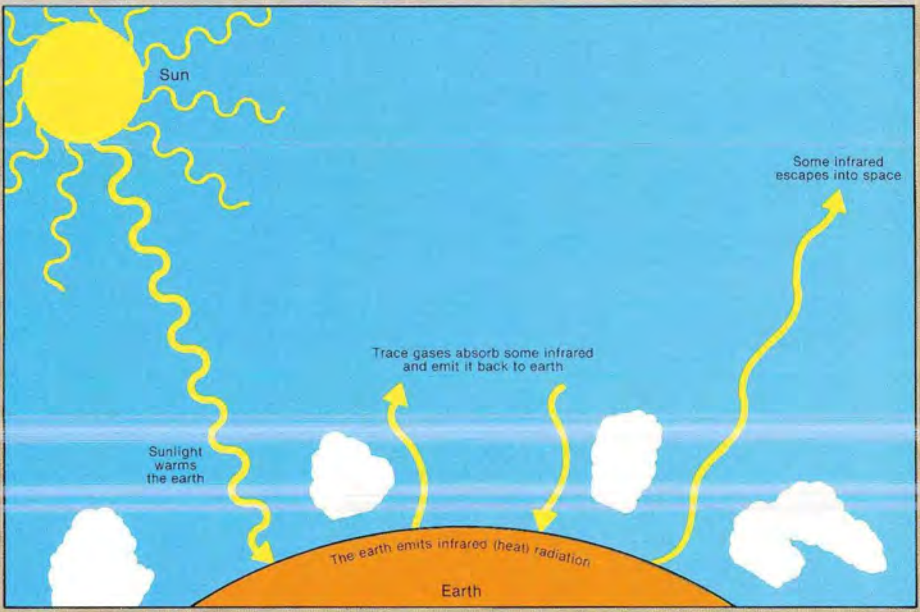
## *Global Change*

The greenhouse effect. Those were the buzzwords heard on the news, in Congress, and in daily conversation as a wave of blistering heat and an unrelenting drought swept across the United States in the summer of 1988. In the Midwest cornstalks shrivelled, and parts of the Mississippi River became a wading pool.

In response, some scientists cautioned that the heat wave might be only a meteorological aberration and have nothing to do with the greenhouse effect—the global warming of the earth caused by the accumulation of atmospheric gases that trap solar radiation. Still, the high temperatures seemed to fit a disturbing pattern to some observers. The 1980's have so far included the four hottest years of the past century. Moreover, the earth's temperature has risen nearly one degree in the past 30 years, leaving the planet warmer today than at any time since measurements began 130 years ago. Even so, many scientists caution that all of this could be within the natural variability of the earth's climate system.

NSF did not wait for the summer heat of 1988 to begin examining climate, the greenhouse effect, and a myriad of related issues that affect life on earth. The Foundation's International Biological Program, a research effort that thrived in the late 1960's and early 1970's, included modelling of large-scale ecosystems. Results of this work helped forge many of the interdisciplinary relationships among natural science researchers that are crucial to understanding the delicate balance of the earth and its environment. Moreover, NSF began support for the carbon dioxide measurement program at Mauna Loa, Hawaii in 1957, during the International Geophysical Year. It is this record that indicates the continuing rise of carbon dioxide in the atmosphere. Mauna Loa serves as the benchmark station for the world.

Building on these efforts, NSF more recently began a new global geosciences program, designed to support studies of the earth as a system of interrelated physical, chemical, and biological processes that regulate our ability to thrive on our planet (see box).




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

# Highlights

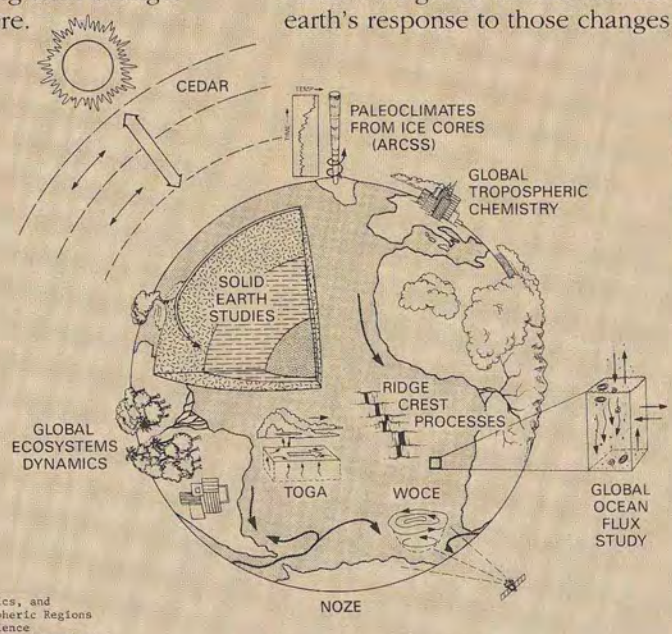
### ***Geosciences: The Global Picture***

The greenhouse effect, the death of rain forests, the hole in the ozone layer. In trying to find the most accurate model for understanding these problems and their worldwide impact, scientists think of the planet as a complex puzzle, where the pieces form a system of interrelated physical, chemical, and biological processes that regulate the way we live. The goal of NSF's Global Geosciences effort is to understand these processes —how they function and how they interact to cause major changes on earth.

NSF is coordinating its research program on global change with many other federal agencies and with other countries. For example, the World Ocean Circulation Experiment receives support from the World Meteorological Organization and the United Nations organization UNESCO. Through this experiment, researchers seek to understand the circulation of the oceans well enough to model their present state and evolution in relation to long-term changes in the atmosphere.

Another project, Global Ecosystems Dynamics, investigates the land-based and freshwater parts of the biosphere and how they interact with the earth as a whole. These ecosystems form an intricate and fascinating feedback loop: The decay of a major forest, for example, can alter the chemical composition of the atmosphere, modify the climate, and change the pattern of elements that circulate in the biosphere. In turn, changes in the atmosphere can further alter the forest. NSF supports ecosystem research in areas ranging from the lush tropical rain forests to the extreme climate of deserts and tundra.

Other projects include an ice drilling program that is reconstructing the history of the climate in the arctic and antarctic. In these regions, ice cores represent the best source available for records of past climate. Ultimately, such studies help scientists to improve predictions of future changes in climate and the earth's response to those changes.




CEDAR = Coupling, Energetics, and Dynamics of Atmospheric Regions
ARCSS = Arctic Systems Science
TOGA = Tropical Ocean Global Atmosphere
WOCE = World Ocean Circulation Experiment
NOZE = National Ozone Experiment

Radiation theory predicts a smooth, black-body profile for light emitted by a radiating body such as the earth. But satellite observations and laboratory experiments indicate gaps in the spectrum that coincide with absorption in the infrared by greenhouse gases, the most prevalent of which is water vapor. Were a rise to occur in the earth's average temperature—caused by an increase in these gases—the climate would be affected in dramatic ways.

Research teams supported by NSF are seeking to understand and quantify these climatic changes and their effects on various regions of the globe. Most of the greenhouse gas results quoted in the press come from computer-based simulations of the atmosphere; however, those computer simulations are based on numerical models that contain many uncertainties. Years of research will be needed before such models can simulate the oceans and atmosphere accurately.

Scientists have learned that such diverse systems as forests, the oceans, and the atmosphere all interact to produce or alter phenomena such as the greenhouse effect. NSF's overall global geosciences program is an outgrowth of this important realization. At the same time, NSF supports specific studies of the greenhouse effect itself.

Uncertainties about the greenhouse gases abound. Where do they come from? In what amounts? How long does each gas reside in the atmosphere and how might they be removed or their concentration reduced? There appear to be no easy answers, but researchers are discovering that understanding feedback mechanisms among the earth's ecosystems is a major step toward finding solutions.

Methane is a case in point. The gas is emitted by wetlands and marshes, the flatulence of grazing cattle, and seepage from natural gas pipelines. Rice paddies and termites may also be major contributors. But the problem is even more complex, because rising temperatures and changing climate could alter the amount and location of methane. Wetlands may disappear in one part of the globe and emerge elsewhere. Human populations shift, and the grazing patterns and numbers of cattle are expected to change. All of these will affect the pattern of methane emission, which in turn further alters the greenhouse phenomena.

Although scientists may be uncertain as to whether current conditions are harbingers of global climatic problems to come, the basic theory of the greenhouse effect is no mystery. When certain gases are released into the atmosphere, they hover there like a blanket, blocking the escape of heat. Nevertheless, the earth usually manages to keep a delicate balance between hot and cold. There is no reason at present to believe that such would change over the long haul.

The release of carbon dioxide from the burning of fossil fuels appears to be a chief culprit, accounting for an estimated half of the increased atmospheric concentration of greenhouse gases. Complicating the greenhouse problem is the increasing destruction of rain forests, which naturally absorb carbon dioxide. With fewer trees, more carbon dioxide remains in the air.

Three other gases—methane, nitrous oxide, and chlorofluorocarbons—account for much of the rest of the greenhouse problem. Methane has various sources, as discussed above. Nitrous oxides are derived from the breakdown of chemical fertilizers and liquid fuel emissions. And many scientists believe that chlorofluorocarbons, human-made chemicals, probably are responsible for the destruction of atmospheric ozone (see below).

## *Ozone Depletion: Hole Story Continues*

The verdict is in on the "hole" in the ozone layer that occurs over Antarctica every September through November. The hole, or stratospheric ozone depletion, is largely caused by the action of chlorofluorocarbons (CFC's), human-made chemicals widely used in refrigeration and foam plastics, as well as unique meteorological conditions. During the late austral winter, thin layers of nearly normal ozone concentrations alternate with layers of nearly total depletion, so that on average about half of the ozone disappears. Scientists also have found preliminary evidence that ozone destruction on a smaller scale may be occurring over the North Pole, and possibly in more temperate climates as well.

A chemical cause was originally suggested by the first National Ozone Expedition (NOZE), which travelled to Antarctica in 1986 and was sponsored by NSF, the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration (NASA), and the Chemical Manufacturers' Association. But it was evidence gathered by the 1987 NOZE expedition—and by instrumented NASA aircraft—that confirmed those early speculations.

The 1987 measurements showed that the ozone hole contained large concentrations of chlorine monoxide—a key finding because the compound is produced by the breakdown of CFC's and is known to trigger chemical reactions that can destroy ozone.

On the rise. Researchers at the South Pole launch a balloon carrying ozone-measuring instruments. Similar balloons have been used near the North Pole, where chlorine from CFC's also plays a key role in ozone depletion.

According to the scenario constructed by researchers and verified by experiments, CFC's that reach the upper atmosphere are adsorbed on ice particles that form during the dark winter at high altitudes and at temperatures colder than 112 degrees F. below zero. When sunlight returns, the chlorine atoms released from CFC's destroy ozone, converting it into diatomic oxygen. Although this is a more common variety of oxygen than is ozone, it lacks the ozone's capacity to absorb ultraviolet radiation.

Atmospheric ozone shields the earth from the sun's harmful ultraviolet rays. With a diminished ozone layer, more ultraviolet radiation reaches earth, exposing humans, plants, and animals to an increased risk for skin cancer, damage to the immune system, and a possible increase in some genetic mutations.

Now a similar depletion phenomenon may be occurring over the North Pole. Research balloons released from a Canadian base near the Pole revealed that a vast atmospheric "crater" forms there in winter months, due to the disappearance of ozone. And measurements over Thule, Greenland showed significantly increased amounts of chlorine gas, a tell-tale sign of ozone destruction by CFC's. Although the chlorine levels were only between one-half and one-fifth of those over the Antarctic, the seasonal depletion of atmospheric ozone at the North Pole is believed to be well underway.

## *Astronomy News*

An international group of astronomers has discovered a galaxy about 15 billion light-years from earth, the most distant ever sighted.

The finding is important because the galaxy is believed to be only slightly younger than the universe itself. If many such galaxies exist, they could bring into question a popular theory of galaxy formation.

Most scientific ideas about the origin of the universe incorporate a version of the "Big Bang" theory, which holds that a giant explosion hurled matter into empty space, creating an expanding universe. In this scenario, galaxies slowly form around dense clumps of dark, cold matter and do not reach maturity for billions of years. But this picture may be at odds with recent observations of distant galaxies that appear to be mature, yet in some cases are no older than one to two billion years.

The newly sighted galaxy, designated 4C41.17, is one of several extremely distant galaxies discovered over the past several years by Ken Chambers, a Johns Hopkins University graduate student; Wil van Breugel, an astronomer at the University of California at Berkeley; and George Miley, an astronomy professor at Leiden University in the Netherlands.

The astronomers initially found the galaxy because of the enormous power and unusual spectrum of radio wave signals it emitted. They studied the radio emissions at the NSF-supported National Radio Astronomy Observatory in Socorro, New Mexico. The team followed up its radio study with optical observations at Kitt Peak National Observatory near Tucson, Arizona, which also receives NSF funding.

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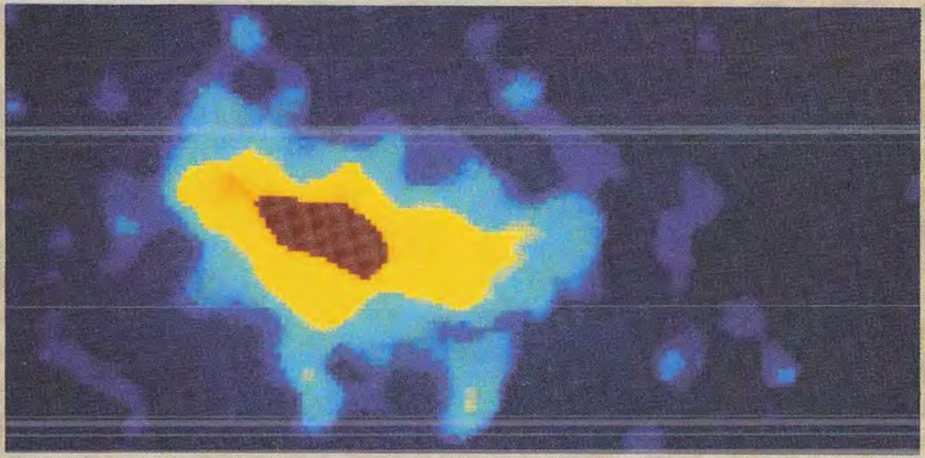
Burning with the light of 100 million suns, supernova 1987A was the brightest supernova observed since the time of Galileo. One year after its appearance in 1987, astronomers were observing at optical, infrared, and x-ray wavelengths—hoping to glimpse

# Highlights

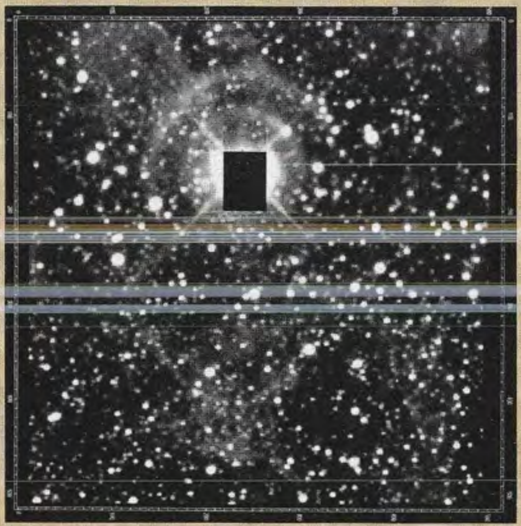


NOAO

*Most distant galaxy. Glowing hydrogen gas is seen in the most distant galaxy found to date. The gas is more than 100 thousand light years across; the light which produced this picture has been travelling through space for about 15 billion years. This picture was taken through the 4-meter Mayall telescope at the Kitt Peak National Observatory.*

the dense, residual core of the explosion. With the rapid fading of the supernova's brilliant but overpowering surface light, new details are emerging about the supernova and the dust clouds that surround it.

Intriguing features detected in the aftermath of the explosion are "echoes" of the supernova—reflections of supernova light from dusty clouds in the Large Magellanic Cloud. These echoes appear as arcs or rings of light from the clouds; they afford scientists a unique opportunity to map the interstellar medium around the supernova and also provide a kind of photographic record of the supernova explosion. If telescopes can precisely resolve details of the reflections, scientists may be able to trace the evolution of the supernova across the width of the rings.



*Supernova echoes. The circular arcs are light echoes from Supernova 1987A. The overexposed region close to the supernova has been masked in the image. This picture was taken at Cerro Tololo Inter-American Observatory (CTIO) in March 1988, using the 1.5-meter telescope and a Charged Coupled Device (CCD).*

The supernova is only visible in the Southern Hemisphere, and observations of the rings have taken place in Chile at the NSF-supported Cerro Tololo Observatory, the Carnegie Institution's Los Campanas Observatory, and at the European Southern Observatory.

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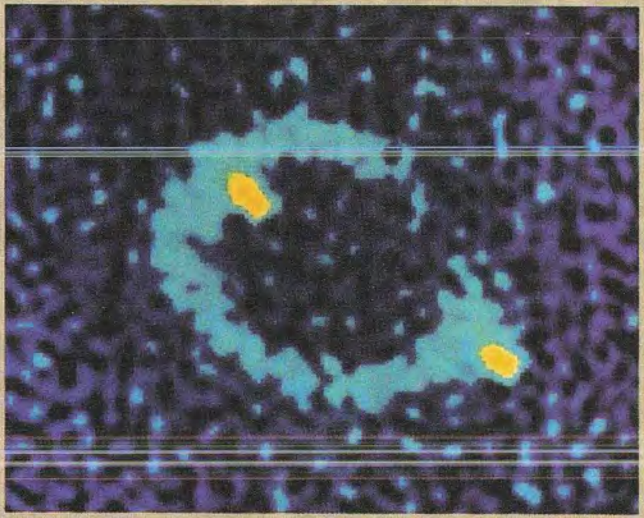
Another type of ring also figured in astronomical observations made during 1988. Jacqueline Hewitt, a Princeton astronomer then working at MIT, was analyzing data from a telescope survey of radio wave sources when she spotted a fuzzy, circular image on her computer screen. Further checking indicated that she had likely discovered a celestial phenomenon predicted by Albert Einstein in 1936 but dismissed by him as hopeless to detect.

Einstein said that when light or radio waves from a distant galaxy or quasar pass by a massive object on their way to earth, the object's gravity deflects or bends the light, producing one or more distorted images of the distant source. The distortion is know as a gravitational lensing effect. A number of such distorted images—usually incomplete rings or arcs of light—have been discovered over the past decade. But, as Einstein pointed out, in the unusual case where the earth, the nearby massive object, and the distant source are precisely aligned, the resulting image should be a complete ring. Until Hewitt's discovery, no observation had revealed evidence for an entire Einstein ring.

Hewitt used the Very Large Array radio telescope, a collection of 27 telescopes at Socorro, New Mexico, to conduct her original radio survey in 1986. Working with researchers from MIT, Princeton, and Caltech, she has conducted further experiments to confirm her finding—including the use of an optical telescope.



NRAO/AUI

*Gravitational lensing. This radio source was observed at the Very Large Array radio telescope in Socorro, New Mexico. It has a very unusual structure, which strongly suggests that the source is due to gravitational lensing by a foreground massive object, which may be a giant radio galaxy. If so, the source represents an "Einstein Ring," a particularly symmetric case of gravitational lensing first proposed by Einstein in 1936.*

## *Superconductors: The Quest Continues*

*Paul Chu (center) and his superconductor research team at the University of Houston*

Superconductors are materials which lose all resistance to electric current below a certain temperature. The phenomenon was first demonstrated in 1911 by a Dutch physicist who cooled a crystal of pure mercury to 4 degrees Kelvin (4 degrees above absolute zero or –460 degrees Fahrenheit). For 75 years, an extensive search by physicists turned up materials that would become superconducting at only slightly higher temperatures. In 1986, J. Georg Bednorz and Karl Alexander Muller of IBM's Zurich laboratory measured superconductivity in a copper oxide at 35 degrees Kelvin—12 degrees higher than had ever been observed.

Results of the IBM research team were confirmed and higher temperatures were achieved. (The IBM researchers received the 1987 Nobel Prize in physics for their efforts.) In February 1987, a team headed by Paul Chu at the University of Houston and M.K. Wu at the University of Alabama at Huntsville discovered superconductivity at 98 degrees above absolute zero.

These and other discoveries meant that superconducting circuits no longer had to be cooled with a steady and costly supply of liquid helium (about $4 a quart). Instead, liquid nitrogen, only about 40 cents a quart, would suffice to cool the material to the superconducting state.

While claims of higher temperature superconductors continue to surface (some scientists report seeing the phenomenon at room temperature), scientists are uncertain as to how those materials, most of them copper oxides, work. Researchers do know from neutron-scattering studies that the compounds belong to a common class of ceramics known as perovskites. The oxygen content of the superconducting copper oxides differs from conventional perovskites, and scientists believe that the arrangement of oxygen atoms plays a key role in creating high-temperature superconductors.

Reports of the new superconductors have sent puzzled scientists back to the blackboard and computer terminal. There are now as many as 10 to 20 theories that describe what is happening inside copper oxides to make them lose all resistance to electricity.

While searching for the definitive answer to superconductivity, researchers must also contend with some practical requirements before a myriad of possible applications of the new technology can be achieved. One of these is the maximum amount of current that can be carried through a superconductor before its resistance reappears. Additionally, the stability of the copper oxides when exposed to air, water, or other compounds is not fully known.

Still, some applications do seem possible. High-temperature superconductivity may result in new microcircuitry; new semiconductor-superconductor hybrids; and more sensitive measurements of tiny magnetic fields (needed for medical imaging, biomagnetism studies, and the search for gravity waves). It may take many years before other possibilities, such as magnetically levitated trains and electric cars, can ever become reality, if they do at all.

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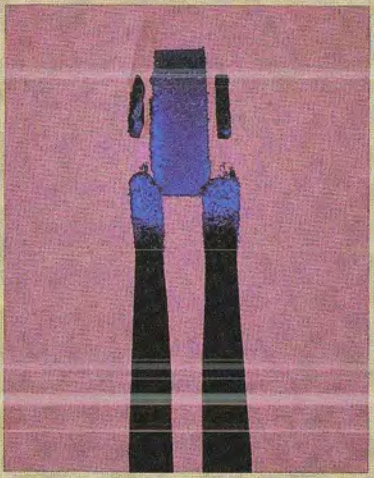
In January 1988, American and Japanese scientists independently discovered a new high-temperature superconductor that differs dramatically from the family of materials that had previously been the focus of intense research. The majority of high-temperature superconductors under study had contained rare earth elements, but Paul Chu and his colleagues succeeded in making a copper oxide superconductor from less expensive elements: bismuth, aluminum, strontium, and calcium, along with copper and oxygen. A similar finding was reported by the Institute of Metallic Material Research in Japan.

The bismuth superconductor, which is stable and easy to reproduce, loses all resistance to electricity at about 114 degrees Kelvin (-254 degrees Fahrenheit), 16 degrees warmer on the Kelvin scale than the rare earth-copper oxide superconductor discovered by Chu's research team in 1987.

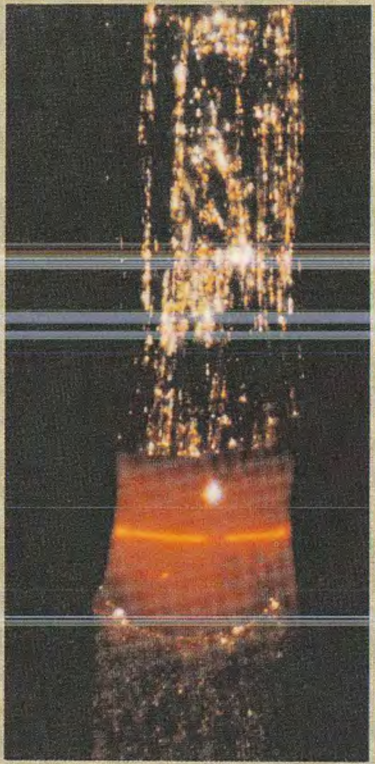
In a related development, Allen Hermann and his colleagues at the University of Arkansas discovered an even warmer high-temperature superconductor copper oxide. It contained thallium, rather than a costly rare earth element. The compound achieves the superconducting state at 120 degrees Kelvin. Most recently, Hermann announced a new method for producing the superconductor— one that avoids contact with thallium powder, a compound which is poisonous if inhaled or absorbed through the skin.

And at Stanford University, Robert Feigelson and other researchers developed a laser technique to make high-temperature superconducting fibers that eventually can be used as wire. Using a laser to provide a steady, focused source of heat, the scientists produced short wires or fibers from a bismuth-copper oxide superconductor. The fibers may serve as a prototype for studying the properties of the superconductor, a basic and necessary step in determining if magnets and other large devices can be built from the material.



U. of Ark.—Fayetteville

*Arkansas Superconductor. This superconductor is unique in that two samples levitate at the same time, with one floating above the magnetic field while the other is suspended beneath it. This unusual levitation occurs even when the magnet and both superconducting samples are held in a vertical plane.*



*Superfibers. Stanford University materials researchers used a laser technique to make superconducting fibers (magnified here) for use as wires.*

## *Imaging an Insect Virus, Knowing the DNA Coil*

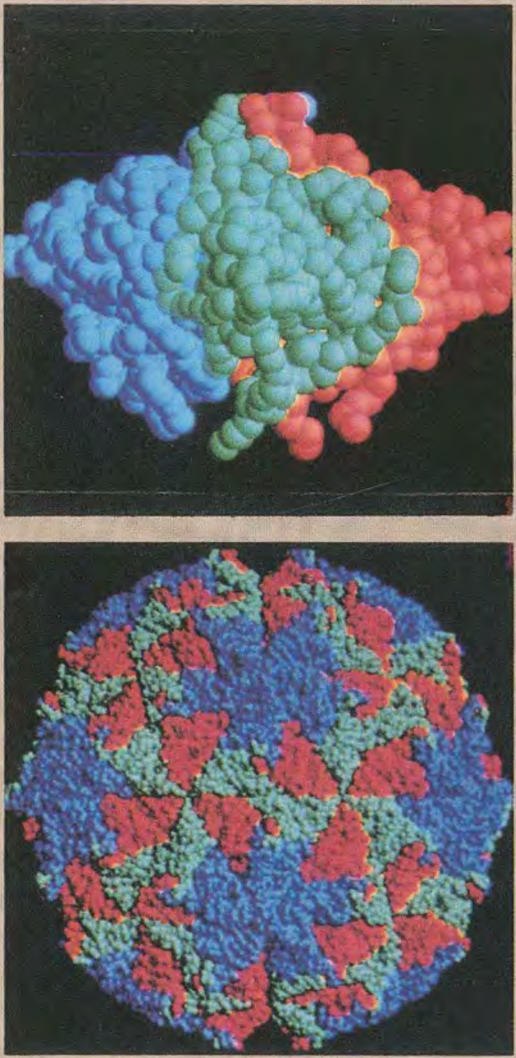
Applying new advances in x-ray diffraction techniques, scientists have determined the three-dimensional atomic structure of an insect virus. The achievement provides clues to understanding the evolution of viruses, and could lead to ways of genetically altering the viruses so that they attack only insect pests without poisoning other life forms.

Examination of the black beetle virus demonstrated that it was strikingly similar in overall size and shape to simple mammalian and plant viruses whose structures had only recently been determined by the same x-ray technique. The proteins that provide the outer coats of the beetle virus were also similar in size and shape to the individual proteins that coat other viruses.

According to Jack Johnson, a Purdue University biochemist who led the research team, the similarities are strong evidence that viruses infecting plants, animals, and insects may have evolved from a common genetic ancestor. Two years earlier, Johnson was part of the Purdue research team, led by Michael Rossmann, that made the first structural determination of a common cold virus called rhinovirus 14. (See FY 1985 and 1986 NSF annual reports.)

So far the imaged viruses number only a few, and in each case the protein coats resemble microscopic soccer balls—each has the symmetry of an icosahedron, a geometric shape with 20 equilateral triangular faces.

Although similar to the other viruses, the black beetle virus is less complex. It belongs to the noadvirus family, among the simplest known reproducing objects in nature. The simplicity of the noadviruses make them useful for examining the way viral structure is related to the ability to infect certain insect species.



*Insect virus structure. This atomic resolution structure of the black beetle virus was determined using x-ray crystallography techniques. The green, red, and blue subunits occupy quasi-equivalent positions in the 60 triangular clusters that make up the icosahedral symmetric structure of the virus.*

The investigators found the structure of the black beetle virus through a technique called x-ray crystallography. The technique uses high-energy x-rays to bombard a single pure crystal containing about 100 billion virus particles. Atoms within the crystal scatter, or diffract, the x-rays in a characteristic pattern that is unique for each kind of molecule. The scattering pattern is recorded by special electronic detectors or captured on photographic film to reveal the structure of the virus.

The Purdue team relied on an intense x-ray source located at Cornell University's High-Energy Synchrotron Source (CHESS), which has helped provide the first structural images of many biological molecules. The x-rays available from this NSF-supported source provide a high-resolution structural image of the virus 100 times more rapidly than do x-rays from conventional sources. The scientists also used Purdue's powerful Cyber 205 supercomputer and graphics facility, both partially NSF-funded, to analyze patterns and to construct images of the virus.

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DNA is the molecule that fundamentally controls the life of a cell. But to fit within the cell, DNA, which is often shaped like a circle, must twist and coil itself into the familiar double helix until it is as small as one ten-thousandth of its original size. Like a strand of spaghetti wound tightly around a fork, DNA wraps around proteins inside the cell; the wrapping or helical winding provides a geometric shape for selected enzymes to recognize and also is critical for the expression of genetic information.

Now, researchers have discovered a mathematical formula that describes, for closed loops of DNA, how its helical structure determines its ability to twist and coil.

The formula is helpful in describing DNA, because it ties together two facets of the molecule's complex geometry. As DNA wraps around a protein, the axis about which it winds tilts slightly, much like a spiral staircase whose angle of ascent changes every few steps. Mathematicians discovered that although DNA packed inside a cell undergoes two kinds of coiling, characterized by separate numbers, the two terms sum to a constant value. If one term is known, the formula allows the other term to be simply calculated, enabling researchers to describe more completely the geometry of the DNA molecule.

This finding has important applications that go far beyond a deeper understanding of DNA and its workings. Because DNA coiling is crucial to normal cellular processes, substances that prevent coiling can be deadly to cells. For example, drugs that interfere with DNA coiling are under development as antibiotic and anticancer drugs.

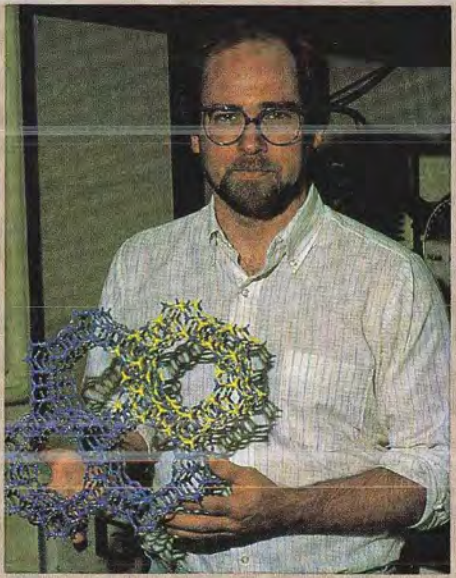
The new mathematical formula was applied by mathematician James H. White at the University of California at Los Angeles, biologist William Bauer at the State University of New York at Stony Brook, and biologist Nicholas Cozzarelli at the University of California at Berkeley.

C. Boles, UC-Berkeley

*Electron micrograph showing DNA coil*

# Highlights

## *Better Sieve, New Generation of Tiny Motors*



*Molecular sieve. Mark Davis, a 1985 Presidential Young Investigator, holds model of a very-large-pore molecular sieve. The fruit of a Virginia Tech and Dow Chemical Company collaboration, the sieve has larger openings than most and allows for greater yields of gasoline from a barrel of oil. The new sieve may also enable researchers to purify drug compounds previously impossible — or too costly — to filter.*

Mark Davis, professor of chemical engineering at Virginia Polytechnic Institute (and a 1985 winner of an NSF Presidential Young Investigator Award), collaborated with Juan Garces of the Dow Chemical Company to prepare a crystal laced with holes so that it can separate small molecules from large ones. The material, which looks and feels like clay, acts like a molecular sieve and has important applications in increasing the yield of gasoline obtained from a barrel of oil and in separating and purifying drug compounds.

Analogous to a flour sifter, the sieve allows only certain-sized particles to pass through its molecular openings or pores. The new design by Davis and Garces represents the first increase in the size of molecular sieve pores in nearly 150 years. Molecular sieves previously available would not allow scientists to isolate any molecule of oil larger than about 8 angstroms (about eight times the diameter of a hydrogen atom). But the new device has openings about 75 percent larger, allowing a much higher yield of gasoline to be sifted or filtered from a barrel of oil. In addition, by using the sieve as a catalyst, the oil industry may be able to crack larger molecules of oil into smaller molecules of gasoline.

Other uses for the sieve may be in the separation and purification of biological and human-made compounds—the larger pores of the new device are in the range of certain drug compounds that could not previously be purified, or done so only at great cost.

Davis is one of some 750 Presidential Young Investigators in the United States. NSF awarded him a five-year grant to pursue his research.

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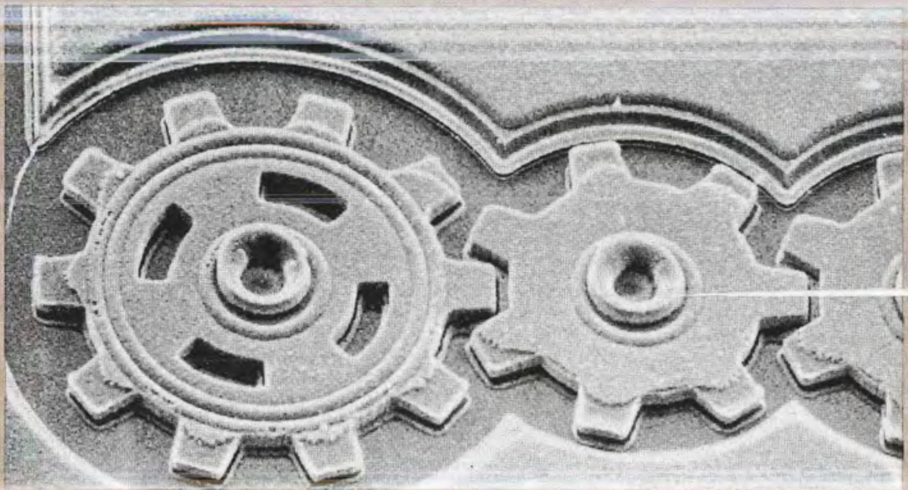
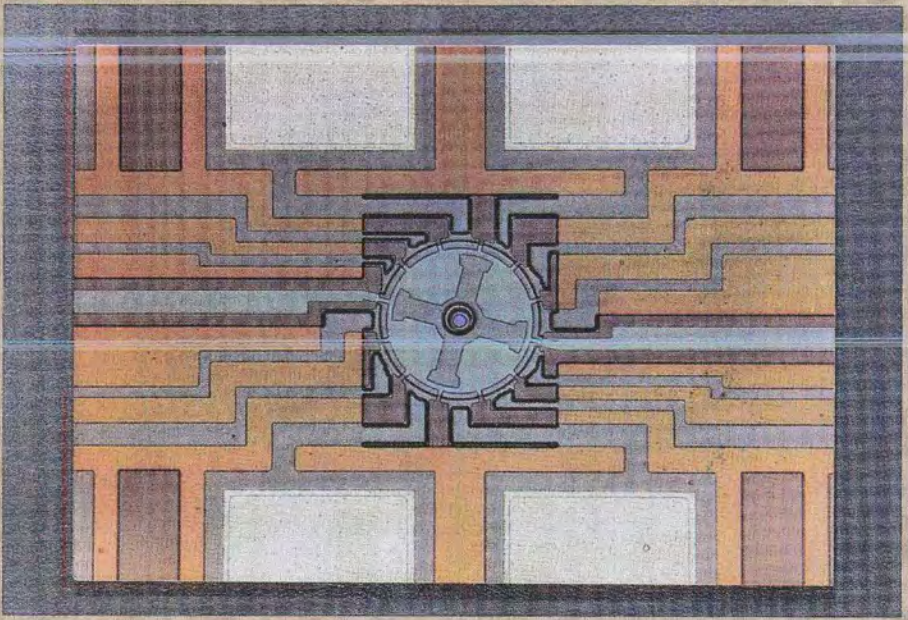
Imagine an electric motor the size of a human hair, gears with teeth the size of blood cells, and springs,

*Gearing down. Miniature gears, about the width of a human hair, are driven by air forced through their ports. NSF supports research in emerging technologies such as micromechanics, which is expected to be a multimillion dollar business in a few years.*



AT&T Bell Labs



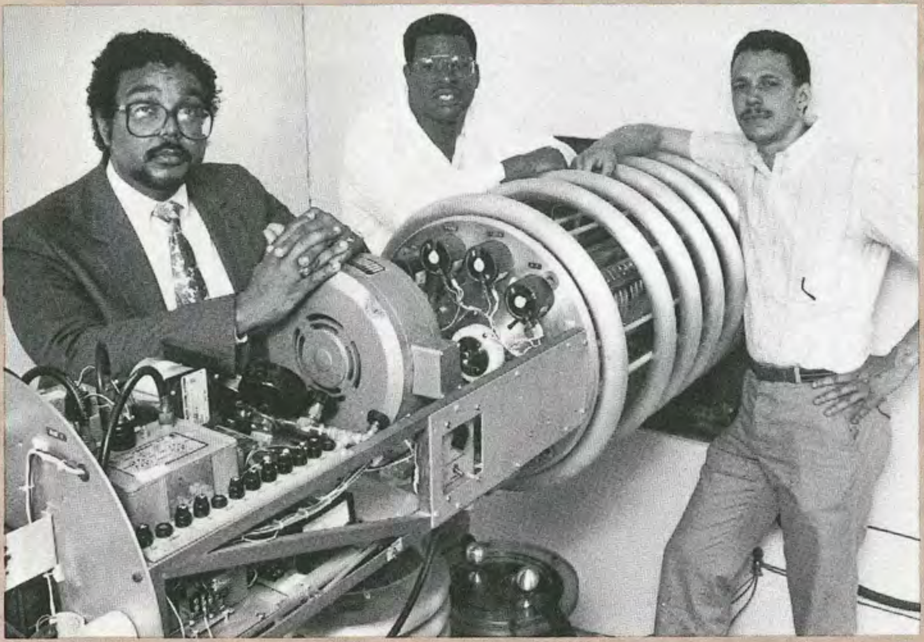
*UC-Berkeley micromotor, seen in video.*

cranks, and tongs so small they might accidentally be inhaled. These devices are part of a new class of microscopic machines that may one day have the same revolutionary impact as the tiny integrated circuit used in computer chips. In the minds of many engineers and scientists, this miniature equipment promises to alter radically such areas as manufacturing process and medical practice.

To shrink tools to microscopic dimensions, engineers rely on the same technology used to make tiny integrated circuits. Gears, motors, and other components are made by depositing ultra- thin layers of material on one part of a silicon chip and etching material away from another part.

At Bell Laboratories in New Jersey, Kaigham J. Gabriel and William S. Trimmer have used the silicon-chip technology to make turbines and working gears 125 microns in diameter. Gear teeth are 15 microns wide, less than one-fifth the thickness of a human hair. At the University of California at Berkeley, Richard S. Muller and his colleagues have fabricated miniature levers, cranks, and springs, using the chip technology. More recently, they have fabricated a working electric motor no larger than the width of a human hair.

At MIT's Artificial Intelligence Laboratory, scientists are working toward the goal of making "gnat robots," miniaturized versions of the big and expensive robots currently produced in research laboratories. To demonstrate the potential for computer control of a "gnat," the MIT researchers built "Tom" and "Jerry"—computerized, mobile robots that sit in toy cars. Rather than responding to complex computer-programmed instructions, the robots depend on microscopic sensors to react to their environment.


C.S. Smith

*Cutting edge. A team of Howard University researchers engaged in semiconductor research has discovered a mechanism that could advance computer laser-printer technology. These and other Howard University researchers received a boost from NSF through the creation of a Materials Science Research Center of Excellence at Howard.*

## *Minority Centers*

In October 1987, NSF announced the first two awards of a program designed to boost the participation of leading minority institutions and researchers in areas of vital scientific and engineering importance. Howard University in Washington, D.C. and Meharry Medical College in Nashville, Tennessee each received $5 million over five years to establish research centers under the Minority Research Centers of Excellence program. The centers provide funding for research, scholarships, instrumentation, new courses, industrial affiliate projects, and efforts to attract talented high school students to the sciences. Howard's program focuses on materials science research, while Meharry's concentrates on cellular and molecular biology.

In the summer of 1988, four more excellence centers were funded by NSF—in Texas, Alabama, New York, and Puerto Rico.

The University of Texas at El Paso center focuses on three areas: the study of corrosion, an examination of iron-niobium-chromium alloys, and the chemistry of organic compounds known as nonplanar aromatics. At the Alabama A&M University center, researchers investigate quantum optics and optical electronic systems. Work at the City College of New York center includes studies of silicon transition metals and materials and the structure and dynamics of the interface between dyes and substrates. Capitalizing on its unique location, the center at the University of Puerto Rico at Rio Piedras specializes in research on the tropical and Caribbean environment.

A recent NSF-supported study found that Black and Hispanic students in Montgomery County, Maryland, one of the nation's most respected school systems, began to trail whites and Asians on math tests as early as the second grade. The two-year study, which tracked the progress of 28,000 school children, indicated that these children are unlikely to catch up to their peers unless "extraordinary" steps are taken.

# Highlights

An initial step may have been the creation of the first NSF Comprehensive Regional Centers for Minorities, established in 1988 in Atlanta, Puerto Rico, and New York City. Aimed at minority students in science programs from kindergarten through college, these centers encourage partnerships among community groups, universities, and state and local governments to help solve the critical nationwide problem of underrepresentation of minorities in the scientific and technological fields. In addition to the three major awards, NSF gave Los Angeles, Philadelphia, St. Louis, and Norfolk, Virginia more modest awards to begin activities at sites that may become regional centers in the future.

The award to Clark/Atlanta University—which is leading a cooperative effort among the Atlanta University center, Georgia State University, Georgia Technical University, and the Atlanta public schools—is typical of the new NSF effort. Activities for elementary school students include Saturday programs and summer science schools that emphasize student-run experiments and demonstrations. For minority college engineering students who have completed their freshman studies, the center offers a six-week summer program designed to encourage students to stay enrolled. In addition, the Atlanta center is developing a new five-year master's degree program for students enrolled in a science teaching program. Atlanta-area youth clubs and community groups are attracted through center-sponsored museum activities and the use of portable science education modules.

Each of the three regional centers is developing a computerized tracking system to follow the participation of individuals over time. In addition, a national advisory committee of recognized experts in science and science education has been appointed by each center to provide advice and to assist NSF in evaluating and disseminating project results.

## *Small Business Innovation Research*

During the oil crisis of 1973, NSF launched research on the aerodynamic drag of trucks through its Research Applied to National Needs (RANN) program. The result of this research is visible today on all our major interstate highways in the form of air deflectors on the roofs of tractor cabs. Use of these deflectors has reduced fuel consumption by approximately 10 percent. Now an NSF project has addressed the aerodynamic drag at the rear of the tractor-trailer combination—this time under NSF's Small Business Innovation Research Program. Preliminary findings indicate potential fuel savings of up to 10 percent again. Full-scale validation of these findings is in progress at this writing.

Continuum Dynamics, Inc., the small business involved, has signed a contract with Fruehauf Corporation, the world's major manufacturer of semi-trailer vans, for exclusive use of this drag-reduction technology. With usage by an estimated 2.4 million semi-trailer vans, each covering 50,000 miles per year, fuel savings alone could approximate 1 billion gallons, or $1 billion per year at 1988 fuel prices. While the introduction of this technology into the marketplace would occur over a five- to seven-year period, the aggregate fuel savings represent significant economic benefit to the nation's trucking industry.

*Small Business Innovation Research Program (SBIR). Two staff members of Mosaic Industries, Inc., discuss the design of a new generation of computer-controlled gas delivery instruments for the rapid testing of chemical sensor responses. The Foundation has awarded an SBIR grant to Mosaic Industries (of Mountain View, CA) for research on chemical microsensor arrays using neural network analysis.*

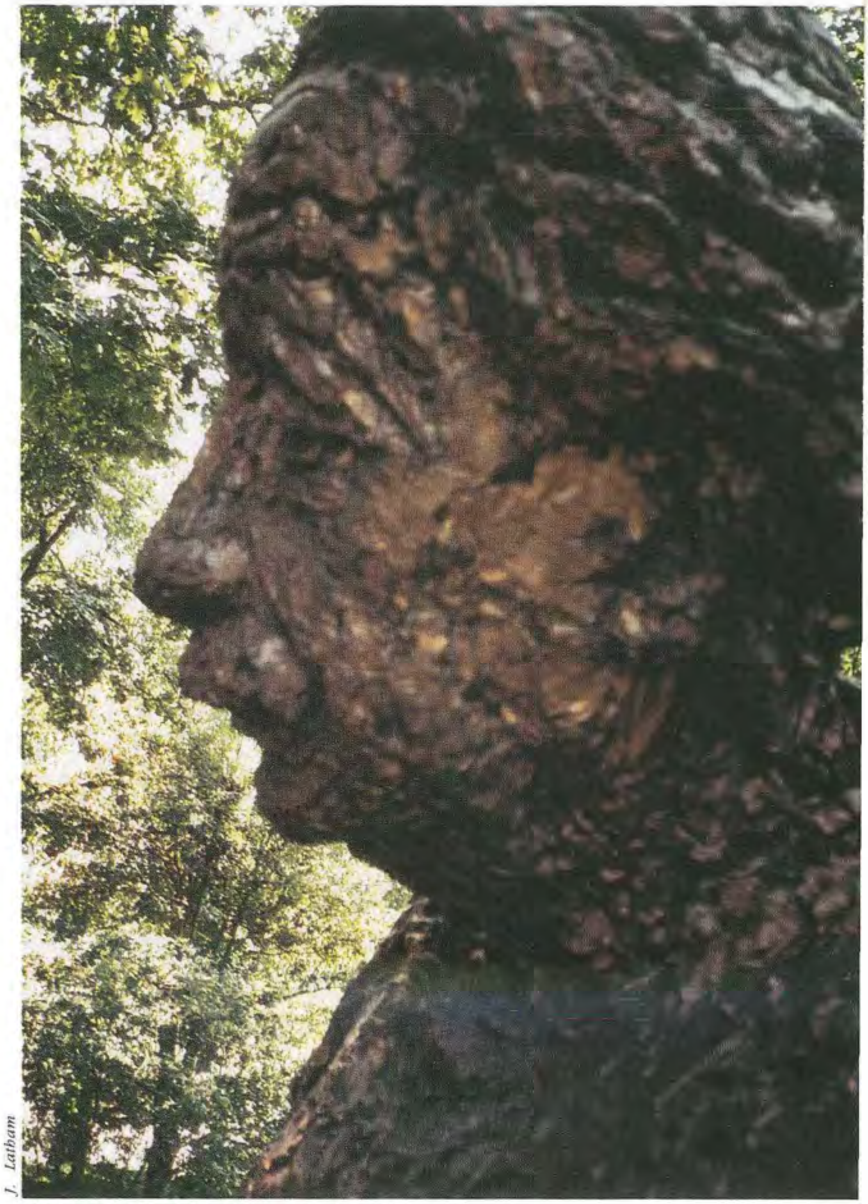
# Chapter 1

## Introduction

The mission of the National Science Foundation is to support and encourage research, both collaborative and independent. NSF also promotes broad-based science and mathematics education programs, as well as special efforts to ensure that a continuing supply of talented scientists and engineers is available for research.

In addition, the Foundation supports the basic equipment needs of researchers and the institutions in which they work. Such projects include a major upgrade of the University of Michigan cyclotron, use of an x-ray crystallography technique to obtain some of the first images of viruses, and operation of a wide array of radio, x-ray, and light telescopes.

All these activities, described in this report, aim to boost economic competitiveness as well as nurture the intellect and awaken our natural curiosity.



J. Latham

*Statue of Albert Einstein at National Academy of Sciences, Washington, D.C.*

# Chapter 2

# People: The Urgent Need

> A professor can never better distinguish himself in his work than by encouraging a clever pupil, for the true discoverers are among them, as comets amongst the stars.
>
> *Quoted in biography of Linnaeus by Benjamin Daydon Jones*

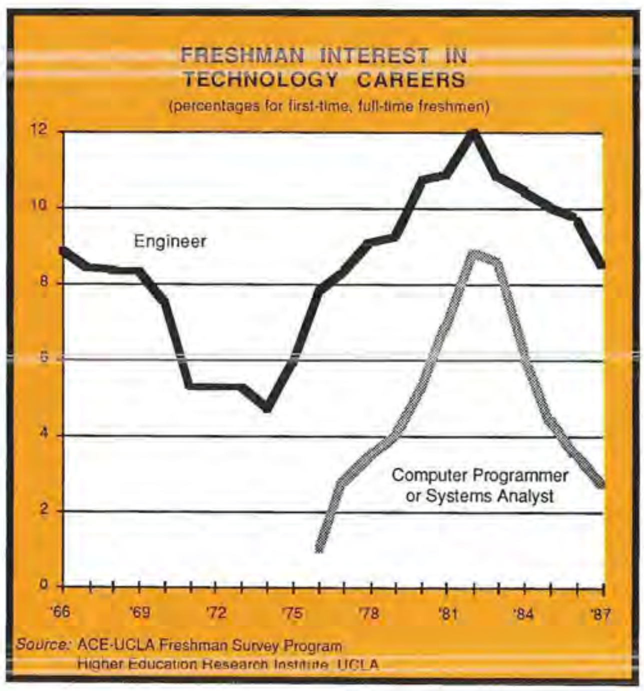
The scientific and technical education of our young people is one of the nation's most important responsibilities. Yet nearly half of American 17-year-olds cannot solve math problems normally taught in junior high school, according to a survey of the National Assessment of Educational Progress. (1) Some 30 percent of the nation's 23,000 public and private high schools offer no physics courses, 18 percent have no chemistry, and 8 percent no biology. Moreover, an NSF-sponsored study by North Carolina's Research Triangle Institute found that less than a third of elementary school teachers felt competent enough to teach biology, chemistry, geology, physics, or space sciences. The same study also found that more than half of all secondary school science teachers never had a college computer course and felt unprepared to use a computer in the classroom.

An NSF-supported survey suggests some of the reasons for the teachers' reluctance: While 85 percent of elementary school science teachers had taken college biology courses, only about a third had taken a college chemistry course and only one-fifth a college physics course. Only about 25 percent of all junior high school and high school science teachers had ever taken an earth or space science course in college.

Students have problems of their own, the Research Triangle study found. About one-third of the nation's 11th graders said they often do not understand what their math teachers are teaching; nearly a third of 13-year-olds could not perform math work usually taught in elementary schools.

In the international arena, U.S. students rated poorly in a study comparing science achievement in 17 countries. American fifth graders placed eighth among students from 15 countries according to international tests based on science curriculum. U.S. ninth graders ranked 15th in a field of 17 countries, and high school seniors studying "advanced placement" chemistry and physics ranked 11th and 9th, respectively, out of 13 countries surveyed by the International Association for the Evaluation of Educational Achievement.

Not only were the average scores of American students unimpressive, but results from different U.S. schools included in the study varied widely, suggesting substantial disparities in resources and standards within the American educational system.




1. "The Science Report Card," Summer 1988

## Some Solutions

To help remedy these mounting problems—and to boost the quality of science education and literacy—NSF during 1988 began several new programs, increased funding for existing fellowships, and continued its efforts in public outreach.

### Sparking Student Interest

A 22-year study of incoming college freshmen has found that their interest in majoring in math, engineering, and the "hard sciences"—biology, chemistry, and physics—has dropped by a third since 1966. (Source: American Council on Education-UCLA Cooperative Institutional Research Program). Interest in mathematics among freshmen fell by 90 percent and in the physical sciences by nearly half. Freshman interest in engineering increased by a modest 4 percent. The figures do not bode well for the future supply of technical specialists and scientists needed in the nation's workforce.

In an effort to attract young people to science careers, NSF has created several programs designed to spark natural curiosity about science long before students enter college. Efforts range from grants targeting specific groups of young people to the widely publicized events of National Science and Technology Week (see below).

In 1988, the Foundation began a $3.7 million effort to establish enrichment programs in science, mathematics, and engineering; it did so by making awards for more than 2,500 promising secondary school students in 34 states, the District of Columbia, and Puerto Rico. The Young Scholars Program emphasizes student participation in the process of scientific discovery. Projects combine teacher instruction and problem-solving with laboratory work and field trips. Each project includes follow-up activities, often with parents and additional students, that are designed to sustain the excitement generated by the students' initial efforts. Actually, these projects will reach many more students and adults than just the 2,500 direct participants, and will also enhance parents' interest and understanding of science.

One of the first Young Scholars awards went to Gallaudet College in Washington, D.C., an educational institution for deaf and hearing-impaired persons. Gallaudet sponsored a four-week science competition for gifted secondary school students who are hearing impaired. Intended as a model to attract young people to the sciences throughout the United States, the Gallaudet program invited students to work on a variety of physics and engineering projects. These included designing and constructing a solar collector, evaluating the energy requirements of a new building, and predicting the path of a moving object.

*Young Scholars 1988. Under NSF's Young Scholars Program, these high school students are studying wildlife and fisheries sciences at Texas A&M University.*

*Young scholars from the University of Wisconsin, Milwaukee, at work on biological sciences projects*

On a broader scale, the Foundation's fourth annual National Science and Technology Week attracted thousands of young people from across the country (and their parents and teachers) through live and televised science events. During the last week of April 1988, in scores of communities, there were laboratory open houses and special science exhibits. Science-fair project winners and their teachers also were honored, along with noted scientists and authors of children's science books.

During the same week, the American Chemical Society distributed via satellite three hours of television programming featuring outstanding chemists reporting on chemistry news for young people. The programs were available free to cable and public broadcasting stations. And at a special reception of the Association of Science Technology Centers held in Washington, D.C., participants from 20 research institutions offered hands-on exhibits and demonstrations for the public.

## Educating Teachers

In 1988, NSF announced the first 27 awards of a new program to help upgrade the teaching of undergraduate science, mathematics, and engineering. The Undergraduate Faculty Enhancement Program provides for national and regional workshops and seminars for faculty who wish to learn about recent developments in their fields of science.

One innovative workshop took place at the University of Montana. Twenty-five college biology and applied mathematics teachers learned first-hand about the uses of mathematical and computer models in studying the biology of conservation. In the first of two summer sessions, the teachers attended lectures, seminars, and workshops; made forays into wilderness areas in Montana; and worked on a group project aimed at modelling the local environment. During the following academic year, the teachers worked on projects modelling the environment near their own colleges or universities. At a follow-up session in the summer of 1989, these faculty participants will report on their work and how they integrated the material into their undergraduate teaching.

## Education Partnerships

In 1988, NSF also announced four awards to upgrade science education for children in kindergarten through grade six. The awards mark the second phase of a program that has forged partnerships among scientists, teachers, and textbook publishers. The partnerships guarantee wide distribution and effective use of the materials developed—a problem with previous curriculum projects. For the publishers involved, NSF's investment provides "seed" money, enabling them to invest in innovative materials that may not necessarily fit traditional guidelines.

One of the awards went to the Life Lab Science Program, Inc., of Santa Cruz, California, which will work with the Addison-Wesley Publishing Company to expand a life sciences program that focuses on school vegetable gardens. By performing chemical experiments and analyzing the nutrients in soil in their own gardens, children learn how plants, like the human body, need nourishment from a variety of sources. Addison-Wesley, like other publishing firms involved in these projects, will market the curriculum and dedicate a share of the profits to training teachers in its use.

*Art of Science. Dirk McVeigh Lough of St. Joseph, Missouri won first place in an Art of Science competition for "Thoughts," artwork depicting the fusion of a neuron and a computer chip. In addition, some 50 U.S. high school juniors and seniors exhibited original artwork expressing their views of science and technology. This competition was part of the National Science and Technology Week celebration.*

*N.Y. Academy of Sciences*


*Hugh Moore & Associates*

*Precollege education. Gil Lopez, director of the Comprehensive Math and Sciences Program, watches students at Brooklyn Technical High School perform computer calculations. This pilot program creates and tests models for high school math and science curriculum and technical career guidance. Such efforts reflect some of the ways that NSF is addressing science and math education needs in the precollege years.*

*Nature nurture. It's elementary for children tending school vegetable gardens as part of the Life Lab Science Program in California. While their gardens grow, these children also learn about soil nutrients and chemicals.*

The elementary school projects will be joined later by others aimed at middle schools, as NSF and the private sector continue to build on the so-called Publishers Program.

### A New Partnership With Business

A projected shortfall, by the year 2000, of 430,000 college graduates in the natural sciences and engineering has provided a strong incentive for U.S. industry to invest in science and mathematics education. Under an innovative program sponsored by NSF, corporations and business

**Publishing Partners**

- Addison-Wesley, Menlo Park, CA/Life Lab Science Program, Inc., Santa Cruz, CA
- Houghton Mifflin, Boston, MA/Florida State University, Tallahassee, FL
- Kendall-Hunt, Dubuque, IA/ Biological Sciences Curriculum Study, Colorado Springs, CO
- The National Geographic Society, Washington, D.C./ Technical Education Research Centers, Inc., Cambridge, MA
- Ohaus Scale Corp., Florham Park, NJ/Lawence Hall of Science, Berkeley, CA
- Scholastic Inc., New York, NY/An Advisory Coalition
- Silver, Burdett & Ginn, Morristown, NJ/Houston (TX) Museum of Natural Science
- Sunburst, Pleasantville, NY/ Educational Development Center, Inc., Newton, MA

associations in 17 states have joined with primary and secondary schools, colleges, universities, and museums in a series of projects to improve science and mathematics teaching.

The 27 projects already funded demonstrate the variety of ways through which industrial scientists and engineers can work directly with teachers and students, bringing examples of the newest applications of science into the classroom. Some of these researchers educate teachers, some serve as mentors for students, and some help develop new teaching materials.

At the Cupertino Union School District in California, accountants, stockbrokers, and bankers work with teachers and students in grades 4-6 to illustrate practical everyday applications of mathematics. In Jefferson County, Kentucky, high school students use equipment and technology provided by Apple Computer to convert computer software into an audible form that can be used by visually impaired students unable to work with visual material. The NSF award also provides funds to train teachers to use these specially designed materials.

### Engineering and the Disabled

One new NSF program unites young engineering students and disabled persons in a common research effort. Both groups work together in community-centered programs that are expected to broaden the careers of the students, create new contacts between universities and their surrounding communities, and produce custom-designed equipment and special computer software for use by persons with disabilities.

Under this program for Undergraduate Bioengineering Design Projects, senior researchers in engineering departments at 15 universities each supervise 10 or more research projects. NSF support for the first two years of this program totals $379,000, with an additional $578,000 available for three more years.

### Undergraduate Initiative

In addition to ongoing programs and activities, NSF has expanded support for undergraduate science and engineering. This initiative is Foundation-wide, with activities funded by the research directorates and by the Directorate for Science and Engineering Education (SEE) as well. SEE also plays a coordinating role through its Division of Undergraduate Science, Engineeering, and Mathematics Education.

Under this initiative, programs have been developed in these major areas: students, laboratories, faculty, curriculum development, and career access.

### Increase in Graduate Fellowships

As a first step toward the goal of doubling, over the next several years, the number of graduate fellowships it awards, the Foundation in 1988 announced that 685 outstanding college and university students had been offered graduate fellowships—an increase of 108 over 1987. The awards give students an annual stipend of $12,300 for full-time graduate study. In addition, NSF offers to the U.S. university selected by the fellow an annual allowance of $6,000 in lieu of fees and tuition. In 1988 more than 5,100 students applied for these fellowships.

The Foundation also awarded 75 Minority Graduate Fellowships in 1988, 20 more than during 1987. As with its goal for the Graduate Fellowship Program, NSF plans to double the number of minority fellowships it grants over the next several years.

Programs like this aim to address the serious underrepresentation of minorities in science and engineering. That shortage has been documented in several recent studies, including the July 1988 interim report of the federal Interagency Task Force on Women, Minorities, and the Handicapped. NSF was a key member of that task force.

UCSF News Service, A.J. Balderson

*Minority Graduate Fellow. Rosemarie Soliven Lara, a bioengineering graduate student at the University of California, San Francisco, received one of NSF's Minority Graduate Fellowships for 1988. These awards help full-time graduate students studying science, math, and engineering.*

*Young engineer. Graduate student Eduardo L. Acuna studies electrical engineering at the University of Illinois at Urbana-Champaign, thanks to an NSF Minority Graduate Fellowship.*

## Postdoctoral Fellowships

With tenure-track teaching and research positions growing scarcer, it is increasingly difficult for new science and engineering Ph.D.'s to remain on campus. Postdoctoral fellowships provide financial support to help young scientists maintain their close ties to the university; such ties may be critical for encouraging innovative research. During 1988, NSF awarded several new and ongoing postdoctoral fellowships. Some examples follow.

### *Environmental Biology, Plant Sciences*

After a nationwide competition sponsored by NSF, the Foundation awarded 16 new fellowships in environmental biology. Research interests of the award winners include molecular phylogenetics, populations and community ecology, and general ecosystem studies. Fellowship recipients in 1988 conducted research at 13 U.S. universities, at two institutions in Australia, and at one in Panama.

In plant sciences, a postdoctoral research program began in 1983, in response to a need to attract outstanding young biologists to that field. This rapidly advancing research area has a shortage of scientists trained in state-of-the-art technology.

For 1988, 20 persons received the two-year fellowships. Among them was Sara M. Machlin, a Ph.D. recipient from the University of Minnesota. The host institution for her work, on characterizing a certain agrobacterium, was the University of Washington.

### *Chemistry*

Twenty young scientists were selected as 1988 chemistry fellows from among the 114 who applied. This program aims to attract outstanding young chemists to careers in research and teaching, to enhance their education, and to ease their entry into the field. The program encourages recent doctorate recipients to broaden their skills and expertise through further research in areas of contemporary chemistry different from their doctoral research areas.

### *Mathematics*

The Foundation also announced 26 fellowships for postdoctoral work in the mathematical sciences. Under this 10-year-old program, new Ph.D.'s can choose research environments best suited to their scientific development. The fellowship provides two academic years and three summers of support. However, research fellows have the option to teach part-time, extending the lifetime of the fellowship. Among the 1988 winners was Susan E. Landau, from Connecticut's Wesleyan University. Her fellowship institution was Cornell University.

*Research opportunities. Carole L. Hom uses computer programs to run simulations of genetics equations at the University of California, Davis. Hom received one of NSF's Fellowships for Postdoctoral Research in Environmental Biology.*

### *NATO-NSF*

NSF supports the bulk of its overseas commitments to postgraduate research through the NSF-NATO (North Atlantic Treaty Organization) Postdoctoral Fellowships. Initiated by NATO in 1959, the fellowship program seeks to boost progress in science and technology and to foster closer collaboration between NATO member countries. Each such country administers the program separately for its own citizens; at the request of the U.S. Department of State, NSF administers the program in the United States. During 1988, NSF-NATO awarded 57 of the new awards.

*Sara Machlin, a 1988 plant biology postdoctoral fellow*

**Other Programs**

The photos in this section show awardees in other NSF programs designed to boost science/engineering education and careers in those fields.

*Visiting Professorships for Women. Chair of the Bryn Mawr College geology department, Maria Luisa Crawford will spend a year as a visiting scientist at the University of Wisconsin in Madison. There she will lecture and conduct research on geology and geochemistry. A special NSF grant for women enabled her to expand her research horizons at the institution of her choice.*

*Presidential Young Investigator. Janis C. Weeks will study insect nervous systems at the University of Oregon, Eugene. She is one of 148 outstanding young Ph.D.'s who received NSF's 1988 Presidential Young Investigator award. The awards are intended to help universities attract and retain scientists and engineers who might otherwise pursue nonteaching careers.*

*Minority Research Initiation grantee. Donella J. Wilson (left) is Assistant Professor of biology at Meharry Medical College in Nashville. Here she supervises a graduate student in a DNA sequencing experiment.*

*Research Initiation in Minority Institutions (RIMI). Zvi Weisz (right) is project director of a 1988 RIMI grant to the University of Puerto Rico, Rio Piedras. Oscar Resto (left) is a technician working on the thin films and surface fabrication facilities developed through this grant. Here they inspect a Tunneling Microscope made at the university in collaboration with the University of Jerusalem.*

## Outreach Activities

NSF also promotes scientific literacy and awareness by the general public. In addition to National Science and Technology Week (described earlier), activities include the following:

### *Working with States*

In 1988 NSF continued to work with state governments on research and education issues. As part of that effort, NSF joined the Michigan Strategic Fund in Ann Arbor on June 9 & 10, 1988, for a national conference on how research and development (R&D) programs can benefit state and regional economies. State planners and academic and business leaders from 31 states attended the two-day meeting.

NSF director Erich Bloch joined governors James J. Blanchard of Michigan and Richard F. Celeste of Ohio for a discussion of the long-term benefits of R&D-based economic development strategies and how states can strengthen and expand their science and technology bases. Director Bloch called for renewed national support of basic research and for new efforts to improve the transfer of research products to business. He also noted that lack of adequate financial backing for research is hurting America's ability to compete with other countries.

On June 29, 1988, Lincoln, Nebraska became the site of the first "NSF Day," a special event drawing attention to the importance of research and education and the states' role therein. The Foundation's Director met with Nebraska governor Kay Orr and spoke to a crowd of several hundred researchers, policy makers, and business people on the role states can play in promoting economic competitiveness. NSF staff were available throughout the day to discuss the Foundation's programs and plans for individual investigator research, centers and groups, and human resources in science and engineering.

### *Museums, Media, Clubs*

If attendance at science museums is any indicator, the public's interest in science is booming. According to preliminary findings of an international study conducted by the Association of Science Technology Centers, the number of people visiting U.S. science centers jumped 38 percent from 1979 to 1986. Among centers that were surveyed, 16 percent of respondents said they had been founded only within the past seven years; four out of five said they planned to expand or move to a new facility during the next five years. Among the newest exhibits at some of these museums:

- The Girls Club of America has been funded for efforts to attract girls to science. The Club has put together an educational program through which girls visit laboratories and guest lecturers in turn visit local clubs.
- Milwaukee Public Museum—After a three-month safari to a tropical rain forest, museum staff recreated the forest at their museum and developed special educational materials for children.

*Maria Bastone, Girls Clubs of America*

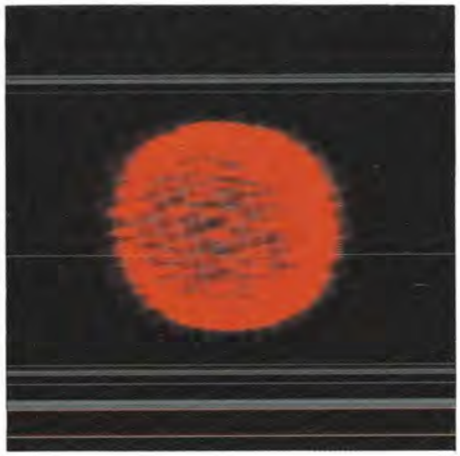
*Girls in science. Imagination and a sense of design combine as Girls Club members study triangulation and support.*

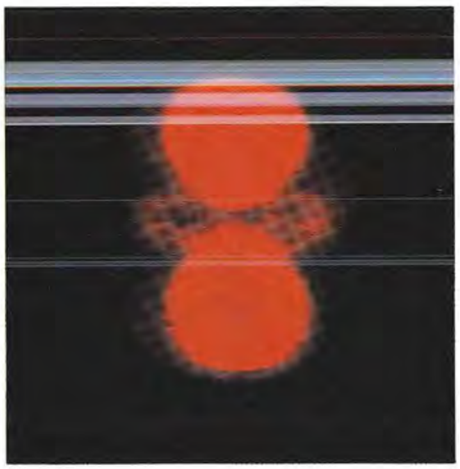
*J. Kelley, Milwaukee Public Museum*

*Diversity of life. In this sketch, museum guests stroll through the Milwaukee Public Museum's replication of a Central American tropical rain forest. An NSF grant made possible this addition to the Museum's permanent exhibit halls.*

• The Realm of the Atom—At the New York Hall of Science, NSF helped fund the most realistic and detailed replica of the atom ever constructed. An offshoot of this widely acclaimed project has been development of a working microscope that can be used by three people at once.

NSF also supports such shows as "Square One TV," a math program for students in grades 3 to 6, and "The Mind," a followup to public television's earlier series on the brain. And "3-2-1 Contact," the popular public television show for young people, worked with NSF to design a poster and booklet about the South Pole. These materials will be sent to secondary schools nationwide.

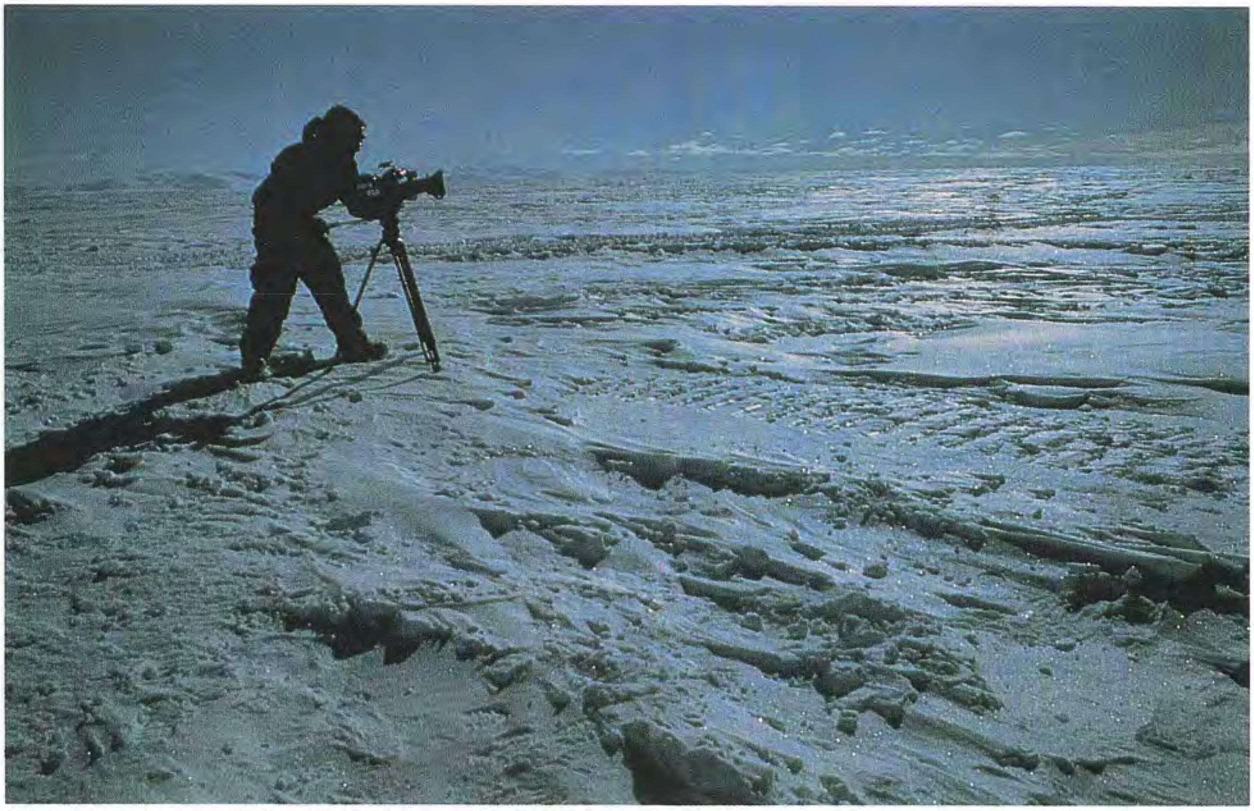




*How atoms behave: first-ever three-dimensional dynamic exhibit model of an atom. Atoms change their appearance in quantum leaps from one state to another. Shown here are three possible shapes of a hydrogen atom at different energy levels, as demonstrated in the New York Hall of Science exhibit, "Realm of the Atom."*

*Richard Tanco*

*"The Mind." Students from the Roberto Clemente Middle School in the South Bronx participate in the nine-part TV series, "The Mind," which premiered on the Public Broadcasting System in October 1988. Included in the series are programs that explore the psychology of addictive behavior, the violent mind, and the aging process.*





*Exploring Antarctica. "3-2-1 Contact" films at the South Pole.*

### *FACTS FROM "3-2-1" POSTER*

• Antarctica is a continent. It's as big as the U.S. and Mexico combined.

• Antarctica is the world's coldest place. The record low was 128.6 F. below zero.

• Antarctica is the windiest continent on Earth. Along the coast, winds blow up to 200 mph.

• In summer, it's light in Antarctica for 6 months. In the winter, it's dark for 6 months.

• Antarctica has mountains. Its highest peak is 16,066 feet, just over three miles high.

• Scientists have discovered fossils of plants, reptiles, and mammals in Antarctica. That's because about 10 million years ago, Antarctica was warm.

• Antarctica has never had a war. A treaty protects it for scientific research and other peaceful activities.

• Only 7 different kinds of penguins live in Antarctica. They're birds, but they can't fly. A penguin uses its wings to swim.

• The male Emperor penguin is in charge of hatching its young. It keeps the egg warm in a pouch near its feet.

# *Chapter 3*

# *Instrumentation and Equipment*

In 1988 NSF acted on several fronts to address pressing equipment and instrumentation needs. For example, the Foundation expanded the College Science Instrumentation Program to include two-year colleges. And through its support of a wide range of projects, some of them described below, NSF reaffirmed its commitment to the importance of equipment in basic research.

## Equipment Grant Extended to Two-Year Colleges

In the first three years of its College Science Instrumentation Program, the Foundation granted $18.8 million in 778 awards. During 1988, NSF expanded the program to include two-year and community colleges. Equipment purchased must be used primarily for undergraduate teaching, but students and faculty also may use the equipment for research purposes. Each grant is for a maximum of $50,000 and colleges must match the award dollar for dollar.

Participants say that the value of the awards goes far beyond their cash value. According to David Domozych, an assistant professor of biology at Skidmore College who received a $9,000 grant in 1985, the program spurred his institution to spend a quarter-million dollars over the next five years to purchase new light microscopes for the biology department. Robert Caverly, an associate professor of electrical and computer engineering at Southeastern Massachusetts University, used an equipment grant to strengthen a new course on the electrical properties of materials. Caverly's $11,000 award from NSF bought automated testing equipment for his sophomore-level courses.

## NSFNET: Major Upgrade

Since the 1970's, many computer networks have sprung up in the United States. These networks transmit data differently, and communicating information to researchers using different networks can be a logistic nightmare.

To simplify communication, NSF announced in 1988 a project to upgrade, expand, and manage NSFNET, a backbone network that links various regional computer networks and supercomputer centers supported by NSF. The project is expected to speed data communication greatly among the nation's research institutions.

The five-year project involves government, industry, and academic groups. It establishes additional connections among communication networks limited to one region of the country, among the five supercomputing centers that NSF supports, and among national networks serving particular scientific disciplines. For example, new and upgraded communication lines will transmit more than 1.5 million bits of data per second, the equivalent of about 50 single-spaced typewritten pages per second.

Easier and faster communication will speed the pace at which basic knowledge is applied to the development of new technology. The supernetwork also will make it easier for scientists to share software and other tools and products of their research, encouraging greater collaboration among experts in diverse fields. In addition, the expansion of NSFNET enables the Foundation to play a key role in helping to organize the many networks used by federal agencies.

**NATIONAL SCIENCE FOUNDATION HIGH BANDWIDTH DATA NETWORK**
**(1.5 mbits/sec)**


*Expanding the research network. NSFNET, a national network that links regional computer networks and NSF-supported supercomputing centers, will offer faster and more extensive communication to researchers over the next five years. Via NSFNET, researchers who before had no access to advanced computing facilities can now connect and collaborate with the nation's leading centers.*

A major part of the project is NSF's five-year, $14 million grant to MERIT, Inc., a consortium of eight Michigan universities, to upgrade and manage NSFNET. In addition to NSF support, the state of Michigan contributed $4 million to this effort, and International Business Machines contributed software and hardware valued at $20 million. MCI Communications Corp. provided fiber optic communication lines and support services.

In a related development, NSF began a five-year agreement with the National Aeronautics and Space Administration (NASA) to share high-speed networking facilities. The agreement will link university researchers now connected to NSF's national computer communications network with databases and supercomputers at three NASA laboratories, saving thousands of dollars that might otherwise be wasted in duplicated efforts by the two agencies. The Goddard Space Flight Center in Greenbelt, Maryland is linked to the Southeastern Universities Research Associates Net; the Ames Research Center in Mountain View, California is linked to the Bay Area Regional Research Net; and the Johnson Space Flight Center in Houston is linked to SESQUINET, a regional network in Texas.

## Cyclotrons

After more than eight years of planning and construction, the world's most powerful cyclotron began operating in June 1988, hosting some of the most promising experiments ever conducted by nuclear physicists.

The national superconducting cyclotron at Michigan State University can accelerate the nuclei of atoms as heavy as uranium to energies up to an unprecedented 8 billion electron volts, using superconducting magnets chilled to minus 452 degrees Fahrenheit.

The Michigan facility differs from most particle accelerators because it bombards targets with heavy nuclei, rather than with such lightweight charged particles as protons and electrons. The heavy nuclei permit scientists to conduct research not accessible with light ion beams. One example is the creation of elements that normally do not exist in nature, perhaps including superheavy elements predicted by theorists.

Using the high-energy cyclotron, scientists also will study how nuclear material behaves when it is squeezed by high-speed collisions between very heavy nuclei. The compression can lead to densities and temperatures as great as those that cause stars to explode and which are believed to have occurred in the "Big Bang" that scientists believe created the universe. Thus the cyclotron recreates for laboratory study the extreme conditions that prevailed at the birth of the cosmos.

Another instrument, which enables ultra high-precision experiments to probe the structure of nuclei, was dedicated at the Indiana University Cyclotron Facility in Bloomington in 1988. The device, known as a Cooler Ring, is a roughly ring-shaped device 285 feet in circumference that performs three critical functions—cooling, storage, and acceleration of subatomic particle beams.

The Cooler is a post-cyclotron accelerator system that operates on beams of protons and other lightweight subatomic particles that have a wide variation in energy. The Ring boosts the chances of studying rare nuclear events because particles in the beam strike an internal target many thousands of times instead of just once, as with normal beam experiments at the Indiana cyclotron. Because particles in the beam now pass through the target about a million times a second, unusual interactions may be detected that might reveal deeper insights into nuclear structure.

*The Michigan State University's cyclotron and its crew*

*High-voltage terminal of the Electron Cooler at the Indiana University Cyclotron Facility*

## Searching for Gravity Waves

Scientists are developing new equipment to detect a gravitational phenomenon first predicted by Albert Einstein in 1916. According to Einstein's theory of general relativity, moving masses generate waves that ripple through space-time. Rotating bodies would generate gravity waves that would in turn exert a rotational force on another body.

A flying bird, a speeding car, or a marathon runner presumably generate gravity waves, but the waves would be so weak as to make them all but impossible to detect. However, when large amounts of material are suddenly accelerated, such as the fireball explosion that transforms an aging star into a supernova, the resulting gravity waves may be strong enough to be detected as they pass through earth.

NSF has funded an engineering study that is a key step toward building a full-size gravity-wave sensor markedly different from earlier detectors. Test models of the device built at MIT and Caltech (others have been built overseas) rely on laser beams and mirrors to stalk gravity waves. Because gravity waves are believed to compress space in one direction while expanding it in another, physicists usually design these new detectors in an L shape. Mirrors are attached to masses at the ends of the two arms that make up the L and at the corner where the two arms meet. When a wave passes through the detector, it suddenly changes the length of each arm, a distortion that can be sensed and amplified by laser beams that bounce back and forth along each mirrored arm several thousand times. When the laser beams are recombined and compared, their characteristic interference pattern—a series of dark and bright fringes—indicates if a gravity wave has struck.

Experiments with the model systems indicate that their sensitivity approaches that of some of the most advanced bar detectors, which can sense changes in length as small as one part in 10 (-18). The models also promise that full-scale laser interferometer detectors still in the planning stage—Caltech and MIT physicists envision two mammoth devices, each with arms stretching out some three miles—may become the most sensitive gravity wave detectors ever constructed. The NSF-supported feasibility study for these proposed devices takes their promise one step closer to reality.

## Mini-Submarine Helps Underwater Researchers

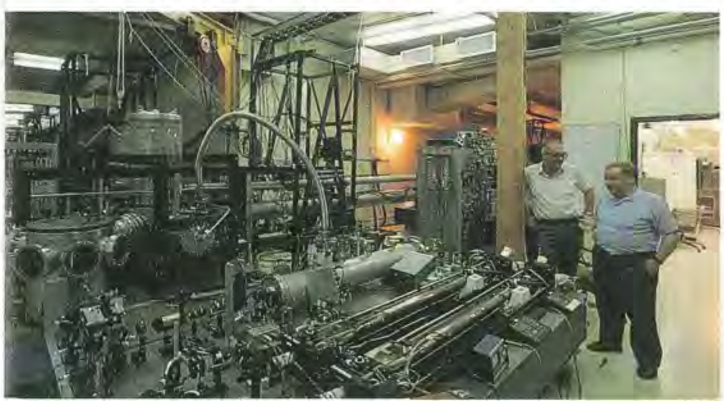
Rising 13,000 feet from the plains of the north-central Pacific Ocean, the growing seamount known as Loihi will emerge over the next 100 to 10,000 years as the newest addition to the Hawaiian islands. Scientists are intrigued by Loihi because it is believed to have originated from material deep in the mantle, the section of the earth between the crust and the heavy liquid core.

In February 1988, scientists using the mini-submarine *Alvin*, a research vessel at the Woods Hole Oceanographic Institution in Massachusetts, measured the volcanically heated water surrounding Loihi at a warm 87 degrees Fahrenheit—compared to the usual 40 degree temperature of the ambient sea. *Alvin* researchers also found that the water contained concentrations of carbon dioxide which were 140 times as high as those in normal seawater. Underwater rocks collected near Loihi had so much carbon dioxide in them that they fizzed and popped like seltzer water when brought to the surface. In addition, oxides of iron and other metals found near Loihi give further clues to the composition and activity of the earth's crust and mantle.

During the summer of 1988, *Alvin* and its crew descended into an underwater crater, part of the undersea mountain range called Juan de Fuca Ridge, located about 300 miles off the coast of Oregon. There researchers sighted new species of animals and uncovered a fissure in the underwater mountain range that may be as long as 20,000 feet. The fissure spouts a plume of water so huge that some have dubbed it "megaplume."

*Detecting gravity waves. Researcher checks the vacuum enclosure for MIT's gravitational wave interferometer. This L-shaped gravity wave sensor is a precursor of the highly sensitive full-scale laser interferometer detector proposed by MIT and Caltech physicists. Such devices detect the gravity waves generated by the sudden acceleration of mass.*

*Caltech prototype gravity-wave detector*



Over the years, *Alvin* researchers have returned to their laboratories with more than 300 new species of sea animals and discovered underwater geological formations never seen on land. In 1977, an *Alvin* crew diving near the Galapagos Islands found hot water vents in the ocean's bottom that serve as a cooling system for the earth's hot interior. The vents or cracks in the ocean bottom send up plumes of warm, mineral-rich water, some of them a dozen feet high. Before the discovery, earthquakes and volcano-like eruptions were the only known ways that the earth's interior heat was dissipated.

In its more than 2,000 dives since 1963, the 18-ton submarine has explored the remains of the *Titanic* in the North Atlantic and recovered a U.S. Air Force hydrogen bomb that had been lost in the Mediterranean. Armed with six directional propellers, two robot arms, and several tubes and bins to collect samples, *Alvin* has brought to the surface never-seen creatures such as giant tubeworms—worms two feet long that apparently thrive in the dark, cold regions near the ocean's bottom.

## Chicago Air Shower Array

Cosmic rays are highly energetic particles that strike the earth periodically from outer space. Although their energy often surpasses that of the world's most energetic particle accelerator, the exact origin of cosmic rays remains a mystery. Recently, two compact binary stars, Cygnus X-1 and Hercules X-1, were reported to be the originators of cosmic rays with energies greater than one-hundred trillion electron volts. But the reports were greeted with some skepticism because not enough of the cosmic rays had been detected to pinpoint accurately the origin of the particles.

*Chicago Air Shower Array. Shown here are some of the CASA scintillation-detector stations installed at Dugway, Utah. The stations are positioned on a square grid and measure discrete sources of ultrahigh energy cosmic rays. The completed array will consist of 1000 such detectors.*

At the University of Chicago, scientists concluded that a more sensitive cosmic ray detector was needed—one that was larger, had improved resolution, and could operate in connection with another type of detector. In a remote section of Utah, NSF support has enabled the researchers to follow through on their vision. James W. Cronin and his colleagues have blanketed the area with an array of detectors that are connected electronically. Known as the Chicago Air Shower Array (CASA), this system is larger than most detectors and thus may be able to capture enough cosmic ray events to identify their origin definitively. If so, CASA will have solved one of the most intriguing problems confronting astrophysicists today.

## Massive Memory Machine

As massive amounts of memory become available to smaller computer systems, the most efficient way to program and operate a computer is changing. While customary supercomputers solve problems by relying on their sheer ability to perform millions of complex calculations rapidly, other machines with less speed but with an extremely large memory may also provide answers just as quickly to some types of problems.

Such computers are the subject of an NSF-supported project at Princeton University on the use of expanded memory. The study may lead to fundamental changes in the way certain classes of problems are solved by computer. The researchers use a conventional computer specially outfitted with memory comparable to that of a supercomputer. The five-year study, also supported by the Office of Naval Research and the Defense Advanced Research Projects Agency, is expected to give new insight into computer programming and hardware for machines with massive memory. The work also may suggest improved methods of posing problems intended to be tackled by computer, possibly translating into orders-of-magnitude improvement in computer performance.

## Biological Instrumentation

Within the Biological, Behavioral, and Social Sciences Directorate, the new Division of Instrumentation and Resources provides funds for multi-user instrumentation, instrument development, methodological development, and biological instrumentation facilities. One program provides funds for single items of equipment, another for large-scale core facilities. Some examples:

- Leroy Hood, at the California Institute of Technology, is developing methodology in the area of microchemistry. The new equipment will increase sensitivity in protein sequencing. He is also automating DNA sequencing and developing a new apparatus for separation of large DNA fragments for the human genome project and other large-scale sequencing of DNA. Hood is also developing new methods for gene analysis and new computer methods for sequence analysis and comparison. This laboratory is at the forefront in developing new instrumentation and methodology that is rapidly exported to the biological community at large.

- In a major multidisciplinary effort, D. Lansing Taylor, Carnegie Mellon University, is integrating the technologies of quantitative fluorescence microscopy, imaging technology, computational sciences, graphics display computer science, and advanced instrumentation development. The goal here is to construct a quantitative fluorescence microscope/imaging system for the biological sciences.

## Computer Visualization

As tools for applying the power of computers to scientific research, computer graphics and imaging techniques offer a way to see the unseen. As a technology, computer visualization promises radical improvements in the way people interact with computers. Although visualization technology has been well integrated into manufacturing, product design, and electronic publishing, scientists and academics have so far missed out on this revolution in computing, according to an NSF-funded report (*Visualization in Scientific Computing,* Nov. 1987).

The panel of university and industry researchers who wrote the report recommended that scientists and engineers team up with visualization experts in order to solve graphics, image processing, or representational problems that pertain to the needs of a particular scientific discipline. The payoffs, the panel noted, are many: Artificial hips custom-designed with the aid of three-dimensional imaging reduce the risk of post-operative rejection from 30 percent to 5 percent. In other scientific disciplines, graphical renditions of DNA sequences, molecular models, brain maps, simulations of airplane flights, and patterns of fluid flow can speed communication of new ideas. Perhaps most significantly, the immediate visual feedback offered by computer graphics and computer imaging techniques can help researchers deluged with data gain insight into scientific processes, help them recognize patterns or anomalies, and aid in pointing out computational errors.

## Plane Rescued

Sixteen years after a specially equipped transport plane crashed on takeoff in a remote section of the antarctic, a team of scientists and engineers rescued the airplane from its icy tomb and restored its flying ability.

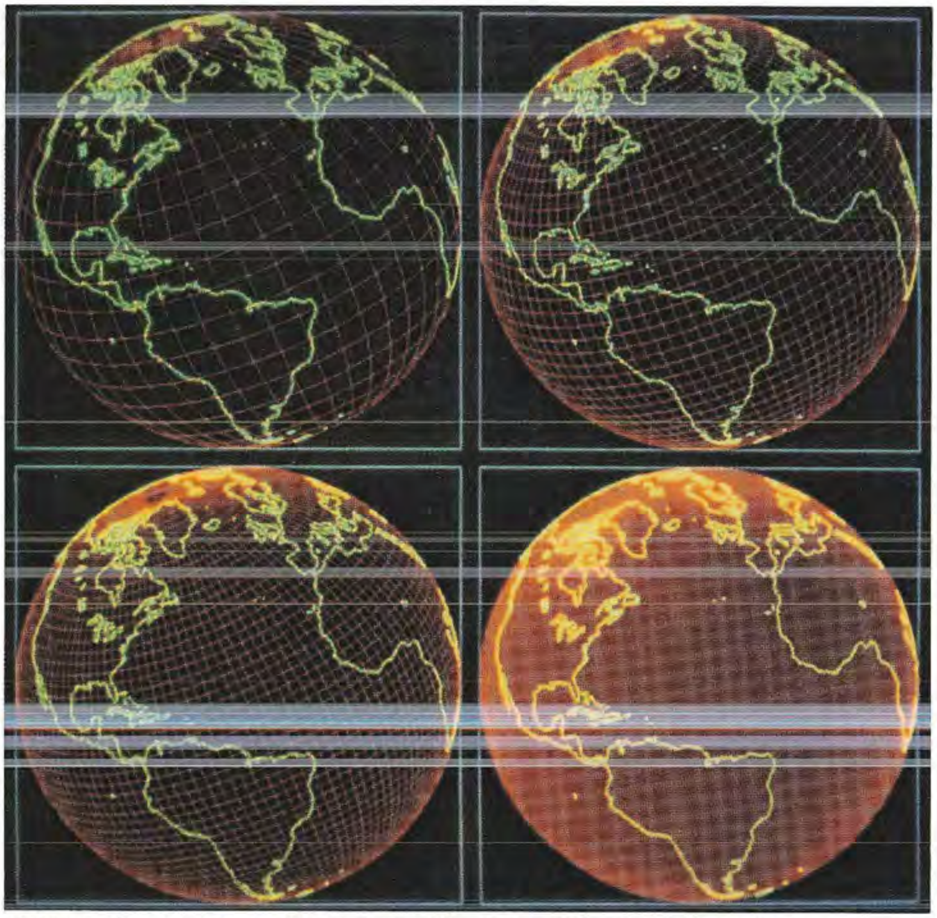
The successful effort to recover and restore the plane, estimated at $10 million, is less that one-third the price of a new, similarly equipped airplane. The LC-130 Hercules is the workhorse of the antarctic program, which is managed and funded by NSF. These versatile planes make wheeled landings on asphalt and prepared ice runways; they use skis to land on the rough surface of the glacier ice and wind-marred snow. The planes transport personnel between Christchurch, New Zealand and Antarctica, as well as to and from McMurdo Station (the main research base), the American Station at the South Pole, and remote field research sites.

The restored plane, known as JD 321, had been flying supplies and scientists when it was damaged during takeoff in 1971 and forced to make an emergency landing. None of the 10

Rotunno and Klemp, NCAR

*Cloud sequence. This supercomputer simulation, one of a series showing the evolution of a thunderstorm, was calculated by plotting velocity, temperature, rain, turbulence, energy, and other storm data.*

Tom Bettage, NCAR



*Mapping climate patterns. Researchers at the National Center for Atmospheric Research use this supercomputer- generated grid of earth for climate and weather research.*

*Retrieved and refitted LC-130*

crew members aboard was injured; however, the airplane was deemed beyond economical repair and abandoned. It later became buried beneath 33 feet of ice and snow. But following the successful recovery of other similarly damaged planes in the 1970's, engineers reconsidered their decision and decided to recover the downed plane. After digging 10 to 12 hours each day for a month, a team from ITT/Antarctic Services, Inc. (an NSF contractor) towed the aircraft from its pit and parked it on the frozen antarctic surface on Christmas Day, 1986.

During late 1987, engineers battling high winds, blowing snow, and temperatures that dropped below minus 22 degrees Fahrenheit installed the plane's rebuilt engines and reinstalled flight controls and other equipment. More than once, fierce snow storms buried the small modular building and tent-like shelters of the recovery team. Then the team's efforts were marred by the tragic crash of another LC-130, which was carrying supplies and parts to the recovery site. Two U.S. Navy personnel were killed and nine others aboard were injured in the accident.

Powered by four engines, three of them salvaged from the 1971 crash, JD 321 performed well throughout its first five-hour flight back to McMurdo Station. After further servicing and modernization outside of Antarctica, the plane—one of 11 LC-130's uniquely outfitted for polar flight—was scheduled for a return to service on the coldest continent. The U.S. Navy operates the antarctic planes, which NSF owns.

# Chapter 4

# Recent Initiatives

As research questions become increasingly complex, so does the equipment needed to help provide answers. But often one research institution alone cannot afford to buy and maintain the costly, sophisticated equipment and facilities that are the core tools of modern research. (1) Moreover, as studies in biotechnology and other fields cross the boundaries between disciplines, the sharing of talent and resources becomes crucial. Indeed, such collaborations spark creative new approaches and insights in research efforts.

By supporting such efforts as science and technology centers and plant research centers, by adding new sites for ecological, engineering, and materials research, by making new instrumentation grants for biological research, and by fostering international cooperative research, NSF in 1988 helped foster important new collaborations among scientists. At the same time, the Foundation continued to support and recognize critical contributions from individual investigators, who receive the largest share of NSF support.

## Centers for Science and Technology, Plant Research

In a 1987 speech to the U.S. Congress, President Ronald Reagan outlined a national policy for science and technology. A key element of this policy was establishing new, university-based research centers that would directly contribute to the nation's economic competitiveness. During 1988, NSF reviewed more than 300 proposals, with the first awards to be announced by late 1988. (2)

1. For more on the facilities issue, see *Scientific and Engineering Research Facilities at Universities and Colleges* (Sept. 1988), available from NSF's Division of Science Resources Studies.

2. At press time, 11 awards were expected.

The creation of these centers reflects some major factors. First, many research problems can no longer be studied by scientists working alone—because of the need for large facilities and/or research support teams, or simply the need to bring together individuals with diverse skills who are from different disciplines and research settings. Second, students benefit from exposure to this method of doing research. Finally, such centers enhance the possibility of extracting from many basic discoveries the information and know-how to realize technical applications.

Another initiative begun in 1988 was the creation of plant science centers to stimulate state-of-the-art research in agriculture and thus ensure the nation's future ability to compete in world markets for food and forest products. This is a federal interagency effort of NSF, the Department of Agriculture (USDA), and the Department of Energy (DOE); its aim is to enable more scientists to use modern technology, including genetic engineering, to gain greater understanding of the structure and function of plants. With such understanding, researchers may be able to improve the quality of food and fiber, as well as increase the efficiency of their production.

In September 1988, an NSF award went to Cornell University's Center for the Experimental Analysis and Transfer of Plant Genes. Simultaneously, USDA announced funding for Michigan State University's Center for Genetic and Biochemical Alteration of Plant Lipids and Starch, and DOE announced support for Arizona State University's Center for the Study of Early Events in Photosynthesis. NSF also granted, under a separate program, an award to Arizona State for scientific equipment to be used in research at the university's Plant Science Center.

## Biological Facilities and Research Centers

In September 1987, NSF awarded 20 grants to provide sophisticated instrumentation to Biological Facility Centers investigating basic problems in such areas as biotechnology, neuroscience, and environmental biology. The awards are the first under NSF's Biological Centers program, established to encourage biologists to share state-of-the-art equipment and to collaborate on research problems requiring insight from different scientific disciplines.

These grants fund the purchase of commercially available equipment and in some cases contribute to the development of new instruments. Each center is used by an estimated 10 to 20 scientists whose research depends on access to new front-line equipment.

At the University of Oregon, Margaret A. Lindorfer and her colleagues received an NSF equipment grant to aid in their study of the structure and function of biological molecules. Their new equipment includes a protein sequencer to determine how amino acids, the building blocks of proteins, are ordered along a protein; a peptide synthesizer, which creates experimental chains of amino acids made to the experimenter's specifications; and an x-ray detector to determine the three-dimensional crystal structure of both naturally occurring and human-made proteins.

*Particle bombardment technology. A botany graduate student prepares to use current version of the particle gun developed by Cornell scientists. The gun is one of many state-of-the-art instruments that will be available for use by visiting researchers at the Cornell Plant Science Center.*

Patrick Adams

*Equipment grant. With funds from NSF, the University of Oregon purchased the peptide synthesizer shown here with researcher Margaret Lindorfer.*

NSF also has established three university-based Biological Research Centers devoted to studies pertinent to the growth of biotechnology—including the education of students in an interdisciplinary setting. These centers are:

- Johns Hopkins University in Baltimore (a new institute aimed at understanding the way assemblies of macromolecules—such as nucleic acids and complex proteins—function and work together in the living cell);
- University of California at Berkeley (a center to study plant cell biology);
- University of Arizona (a center for research on insect biology).

## Long-Term Ecological Research

Ecological changes take place over years, decades, or centuries. Long-term studies are needed to understand questions on the intricate relationships among animals, plants, and microorganisms and how the populations of each may shift over time; the influence of the oceans, atmosphere, and earth in cycling nutrients and other chemicals; and the predator-prey relationships between organisms and their environment. Since 1980, NSF has helped advance basic knowledge of ecosystem structure and long-term processes through its Long-Term Ecological Research program. Establishing and maintaining research at precious ecological sites around the country—from the Alaskan tundra to estuaries on the coast of South Carolina— the program is a lasting commitment to long-term study and preservation of ecosystems in the U.S.

During 1988, NSF added five institutions to manage intensive studies of ecological systems. For example, studies of Alaskan coniferous forests, conducted by the University of Alaska at Fairbanks, are helping scientists explain how plant and animal communities develop following natural catastrophes or dramatic climate changes. The research focus is on the growth of organisms on floodplain soils that were previously underwater and on land that suffered severe fire damage. A second Alaskan project is the study of an arctic tundra system, an effort managed by the Marine Biological Laboratory of Woods Hole, Massachusetts. Experiments on the tundra, a site encompassing a landscape of rivers, lakes, and land, focus on the impact of changes in nutrients, heat, light, grazing animals, and predators on the ecosystem. By virtue of their isolation and simplicity, tundra ecosystems provide a good model for research on more complex natural systems.

*Researchers working under NSF's program for Long-Term Ecological Research Centers*

## Focus on Geography

NSF has established a new university-based center for the analysis of maps and other geographic data. The five-year grant went to a three-member consortium consisting of the University of California at Santa Barbara, the University of Maine at Orono, and the State University of New York at Buffalo.

The focus of the National Center for Geographic Information and Analysis is a computerized database called Geographic Information Systems (GIS). GIS converts geographic information from maps and other sources into digital, computer-readable form, allowing mathematical and statistical analyses that were previously difficult or impossible to perform. One advantage of this database is that it combines, displays, and updates different maps of the same area more readily and accurately than could ever be attempted by hand.

In addition to helping mapmakers, the system is expected to aid researchers in artificial intelligence, ecology, meteorology, political science, and resource management. Many researchers predict that the impact of GIS on geographical analysis will be as important as is the telescope's role in astronomy.

Oak Ridge National Laboratory

*Studying chemical levels. Analyst uses a microcomputer-based geographic information system to monitor and map strontium 90 levels in the southeastern United States.*

## New Materials, Engineering Groups

Four teams of university scientists were awarded $7.4 million from NSF to conduct basic research on materials that have great technological potential. The awards bring to 15 the number of Materials Research Groups funded by NSF since the program began in 1985.

A materials research award to Rhode Island's Brown University is supporting a three-year study on how materials deform and fracture. Research focuses on understanding the effects of temperature and stress rates on materials, and the relationship of microscopic activity to large-scale, easily visible deformities. Scientists at the University of California at San Diego have embarked on a study of the microscopic properties of magnetic materials, including those used for storing computer data on tape and disk. Montana State University's grant is directed toward better understanding of gallium arsenide, a compound used to make integrated circuits imprinted on computer chips. A grant to the University of Michigan helped establish a group to study ways of toughening glassy polymers, a critical issue in developing new plastics and related compounds. In this study, scientists from the field of ceramics will work with experts in polymers.

Four new Engineering Research Centers were funded by NSF in 1988. They are:

- University of Minnesota/Engineering Research Center for Interfacial Engineering, which will focus on ways to improve products and manufacturing processes whose success depends on the chemical and physical phenomena that occur between matter in different gas, liquid, or solid states.
- North Carolina State University/ Engineering Research Center for Advanced Electronic Materials Processing (research on low-temperature processing techniques that will aid in the development and manufacture of the next generation of silicon and compound semiconductors).
- Texas A&M University-University of Texas at Austin/Engineering Research Center for Offshore Technology, an effort to learn how best to build structures for the recovery of oil and other resources at ocean depths greater than 2,000 feet.
- University of Wisconsin-Madison/ Engineering Research Center for Plasma-Aided Manufacturing. Plasma-aided manufacturing techniques use electrically charged particles for precise and reliable etching, deposition, polymerization, and for changing surface characteristics of materials on a microscopic level.

NSF also supports an older center, based at the State University of New York (Buffalo), which is headquarters for a national research effort on earthquake engineering. During 1988, participating researchers from Cornell, Lehigh, and Carnegie Mellon Universities worked to develop three knowledge-based expert systems. These systems are intended for use by architects and structural engineers in designing earthquake-resistant buildings or in evaluating the seismic resistance of existing buildings.

## Computers and Supercomputers

Under its Institutional Infrastructure Program, NSF has helped to establish and enhance experimental computer research facilities at four more campuses throughout the United States. The goal of this program is to stimulate experimental computer research and greater faculty and graduate student participation at institutions with an already active core of computer and engineering researchers.

Universities receiving this type of NSF support included Brown, Illinois, North Carolina, and the University of California at Berkeley. The facilities focus on such computer research issues as understanding the fundamental nature of parallel processing.

### Simulating Air Pollution

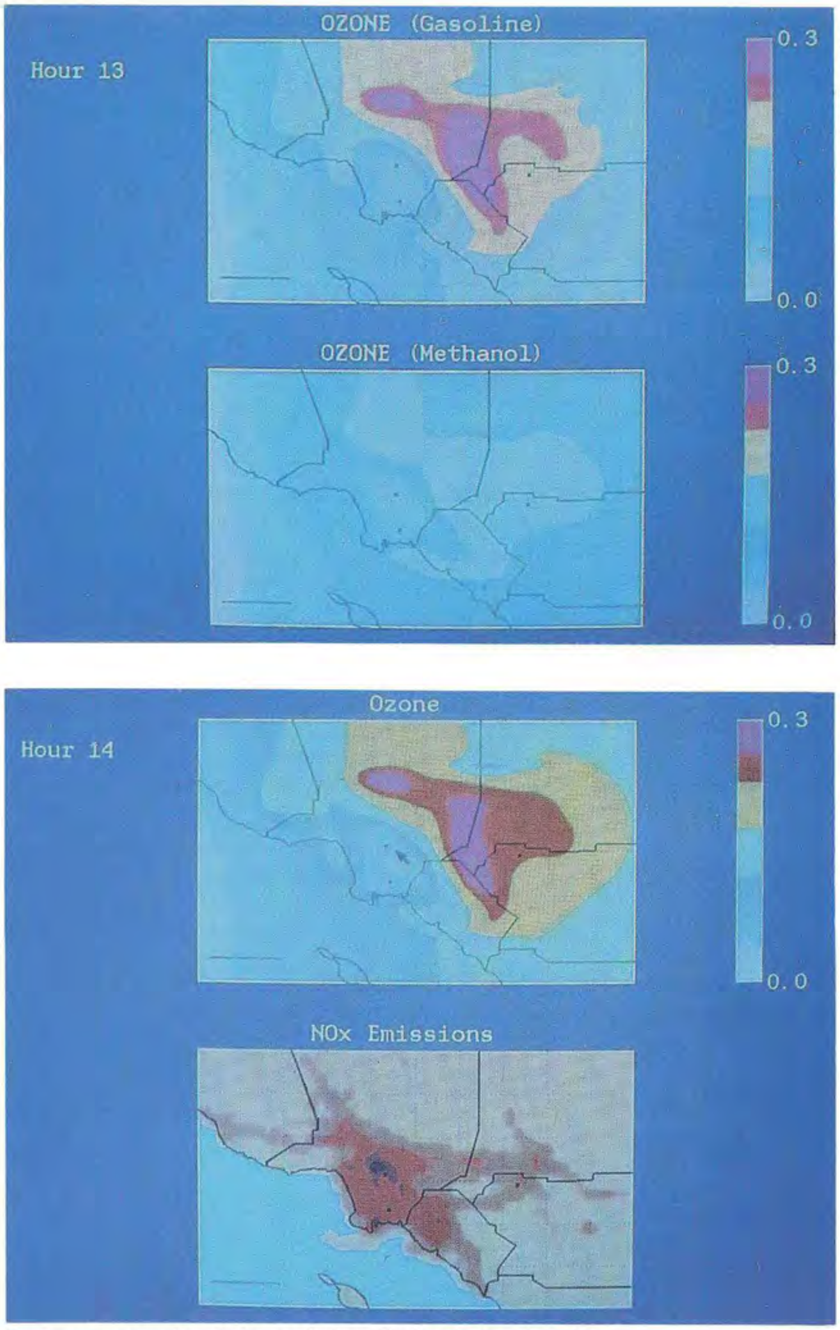
Despite costly efforts to meet federal standards for air quality, many U.S. cities were not expected to meet these guidelines in 1988. How can new strategies for air pollution control be swiftly identified and implemented on a limited budget? Enter the supercomputer.

Researchers Gregory J. McRae, Armistead G. Russell, and Jana Miliord from Carnegie Mellon University used the Pittsburgh Supercomputing Center to solve more than 500,000 equations; they simulated, on a Cray-X/MP 48, the evolution of ozone and 30 other chemicals that pollute the air over Los Angeles. About 70 test cases were studied, each corresponding to different environmental conditions associated with the city. The entire project, which took only weeks on the Cray, would have required several years on a more conventional computer.

Results of the computer study were startling. Researchers found that, contrary to conventional wisdom, unhealthy levels of ozone in the atmosphere do not necessarily decrease if certain types of industrial emissions are reduced. The relationship between the amount of pollution and emissions from power plants, automobiles, refineries, and other sources is so complex, the supercomputer simulation demonstrated, that, in some cases, strategies for reducing particular pollutants could actually cause air quality to deteriorate in neighboring areas.

The study also found that due to the complicated interaction between nitrogen oxides and hydrocarbon emissions in producing pollution, efforts that focus only on control of hydrocarbons are inadequate to reduce pollution.

The project offered alternatives for the future. If a fuel such as methanol were substituted for gasoline in a significant number of Los Angeles vehicles, air pollution in the city could be markedly lowered. The supercomputer study showed that conversion to methanol, even without the addition of other control strategies, could be an effective strategy to improve air quality.




Russell and McRae

*Supercomputer simulations of air pollution in Los Angeles*

## Black Hole Cinema

At the Cornell University supercomputer, Saul Teukolsky and Stuart Shapiro from Cornell have developed a computer code that tracks the evolution of a massive star cluster using Einstein's equations of general relativity. The equations, which are highly nonlinear and difficult to solve, are necessary to describe the motions of stars that move in a strong gravitational field at nearly the speed of light. Scientists watch the computer screen as simulations of unstable star clusters undergo catastrophic collapse into black holes, objects whose gravitational field is so intense that not even light can escape its tug. The collapse of star clusters to form supermassive black holes may explain the origin of quasars, powerhouses of energy that are the most distant objects ever glimpsed in the universe. Using the supercomputer simulation and color graphics, the entire collapse process can be viewed on a movie screen—the ultimate space adventure film come to life.

## Communicating Information About Risk

With support from NSF, the Carnegie Mellon University has established a center for improving the way companies, workers, the public, and regulatory agencies communicate about and handle health and safety hazards. Experts in engineering, psychology, and economics conduct basic research on how people perceive and consider risks. Scientists hope that when communication about risk is tailored to a person's value system, more people will absorb and act on information that could prolong or save their lives. Communication studies at the center range from the use of seat belts and highway safety to radon in homes and cancer risks from chemicals in the environment.

## International News

A maverick approach that leads to a new direction in research, a fresh analysis that sparks new work on an old problem—the flow of scientific ideas and the possibility for meaningful collaboration know no geographic boundary, even among investigators in countries thousands of miles apart. In an effort to boost cooperation between nations, NSF sponsors a number of research activities with other countries.

In 1988, NSF renewed research ties with Poland and established the first U.S. research agreement with Czechoslovakia since World War II. The agreements enable American scientists and engineers engaged in NSF-supported research to seek Foundation funds for collaborations with Polish or Czechoslovak researchers. The "memoranda of understanding" that NSF has negotiated—five years with the Polish Academy of Sciences and three years with the Czechoslovak Academy of Sciences—are expected to make it easier for U.S. researchers to launch and maintain international collaborations with scientists from these countries.

*S. Shapiro, S. Teukolsky, Cornell*

*Birth of black holes and quasars. Researchers used the Cornell University supercomputer to generate this simulation of the collapse of an unstable star cluster to a supermassive black hole. Such catastrophic events may power quasars, the most energetic objects in the universe. Spherical light flashes generated by the computer from the cluster's center initially escape from the cluster, but they are eventually trapped by the strong gravitational field once the black hole forms and all the stars are consumed.*

## New International Links: Japanese and U.S. Researchers

In the past four decades, large numbers of Japanese investigators have come to the United States each year to participate in research visits, while few American researchers have made reciprocal visits to Japan. During 1988, both NSF and various agencies of the Japanese government took several steps to counter this imbalance. Through its Japan Initiative, the Foundation offers the following:

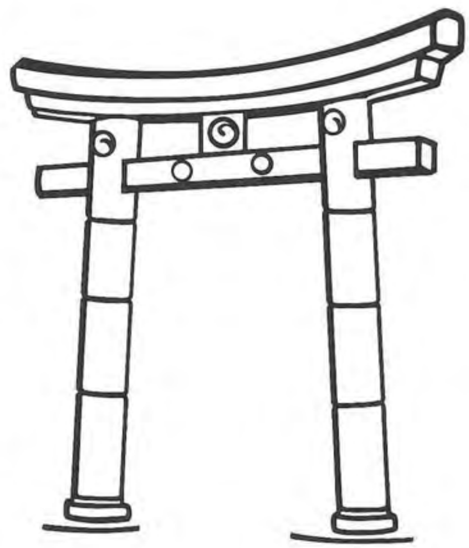
1. *Funds for long-term research in Japan*. Recipients of these grants, which run from 6 to 18 months, will be accommodated in Japanese government, university, and industry labs.

2. *Fellowships to study the Japanese language in the United States*. This program also supports the development of improved course materials for teaching Japanese.

3. *Opportunities for American researchers at Japanese research institutes, including corporate facilities.*

4. *Funding for survey teams to visit Japan* and report on Japanese technical and scientific advances.

The Foundation already helps support a three-year pilot program at MIT that provides intensive training in technical Japanese; the 1988 summer workshop was geared to computer scientists and electrical engineers who have a working knowledge of the language. In addition, NSF supported the initial phases of an effort by Johns Hopkins University to set up a Japanese-American Mathematics Institute. Its goal was to bring Japanese mathematical talent to this country for up to a year at a time to participate in special research activities. Finally, under an agreement between NSF and the Japanese Institute for New Generation Technology (ICOT), NSF also supports U.S. scientists and engineers conducting joint research in advanced computer technologies at ICOT for six months to a year.



# Chapter 5

# Awards/Organizational News

## Awards

### Alan T. Waterman Award

Named for NSF's first director, this annual award goes to an outstanding science, mathematics, or engineering researcher who is 35 years of age or younger and has had a doctoral degree for no more than five years.

Peter Schultz, a professor of chemistry at the University of California at Berkeley, received the 1988 award. At 31, Schultz has already solved a biological puzzle whose answer had eluded scientists for more than 40 years. In the 1940's, Linus Pauling demonstrated that certain proteins, known as enzymes, can speed up or catalyze chemical reactions. Chemists have long suspected that antibodies, proteins manufactured by the immune system, might play a similar role. But no one had been able to prove this hypothesis.

Schultz and his Berkeley research group, along with an independent team of scientists from the Scripps Clinic in San Diego, were the first to show that certain types of chemical reactions can indeed be speeded up by antibodies—which were produced in response to chemicals specifically designed by these research groups. The accomplishment offers the possibility that scientists may one day custom design antibodies to boost production of vital chemicals used in medicine and industry.

*Peter Schultz*

In addition to his work on antibodies that act as catalysts, Schultz (who previously received an NSF Presidential Young Investigator Award) has been studying the possibility of creating new enzymes that could cut the genetic material DNA at specific sites along the length of the molecule. The invention of new enzymes to cut DNA at any desired location would greatly expand the possibilities for genetic engineering and genome mapping.

### Vannevar Bush Award

The National Science Board, the NSF's policy-making body, grants this prestigious award to people who have made outstanding contributions to the nation in science, engineering, and technology. The award is named for the engineer and World War II science administrator who prepared the federal report recommending establishment of the National Science Foundation.

In 1988, the Vannevar Bush Award went to Glenn T. Seaborg, a Nobel Laureate who is a major figure in chemistry and nuclear research, science education, and science policy. Seaborg was recognized for contributions spanning nearly half a century.

In the early 1940's, Glenn Seaborg was one of a cadre of young scientists at the Berkeley campus who had gathered around Ernest O. Lawrence, inventor of the cyclotron. Lawrence's cyclotron made possible experiments to determine if chemical elements heavier than uranium could be produced. Uranium was number 92 on the periodic chart and the weightiest element then known. In 1940, Lawrence's research team identified a new heavy element, number 93, which was named neptunium. Later that year, Seaborg and his colleagues


L.Berkeley Lab

*Glenn T. Seaborg*

pushed farther, identifying and chemically separating element number 94, which they called plutonium.

Seaborg left Berkeley for the University of Chicago in 1942 to oversee the production of plutonium for the Manhattan Project. During the postwar years, he resumed his research at Berkeley. Seaborg and his coworkers synthesized and identified nine additional heavy elements. They also discovered many radioactive isotopes of lighter elements, many of which have been used for industrial and medical applications. Along with these research efforts, Seaborg sought to educate the public about nuclear power and to advocate peaceful uses for nuclear energy.

As Chairman of the Atomic Energy Commission (1960-71), Seaborg was instrumental in negotiations leading to the Limited Test Ban Treaty of 1963 and the Nonproliferation Treaty of 1969. Since 1971, when he became University Professor of Chemistry at UC/Berkeley (the highest distinction bestowed by University of California regents on a faculty member), Seaborg has continued his research on the chemistry of the heavy elements. Additionally, he has launched an ongoing national campaign to stress the importance of basic research and graduate education. Since 1966, he has been President of Science Services, Inc., which administers the annual Westinghouse Science Awards program for outstanding high school seniors.

## Distinguished Public Service Awards

Two members of the United States Congress (both since retired) received NSF's Distinguished Public Service Award in 1988. They were Senator Lawton Chiles (D-Florida), then head of the Senate Budget Committee and a member of the Senate Appropriations Committee, and Congressman Manuel Lujan, Jr. (R-New Mexico), then ranking minority member of the House Science, Space, and Technology Committee.

This award is given periodically to persons who have distinguished themselves through their leadership, public service, and dedication to the support of American science and engineering and of education in those fields. The award is the highest honor conferred by NSF on people not employed by the Foundation.

*Lawton Chiles*

Throughout his senatorial career, Lawton Chiles sought to improve America's scientific and technological position. He was elected in 1970 to the U.S. Senate, where he emphasized stronger education programs—a key to developing future scientists—as well as support for biotechnology.

Manuel Lujan, elected to Congress in 1968, was appointed to the Joint Committee on Atomic Energy. During his tenure, he sought to improve the nation's technical base, strengthen and broaden science and engineering

*Manuel Lujan, Jr.*

education, increase international cooperation in science, and develop national policy in areas such as space exploration and energy research and development.

Both Chiles and Lujan retired from the Congress in October 1988.

## Presidential Teaching Awards

Each year, the Presidential Awards for Excellence in Science and Mathematics Teaching go to outstanding U.S. high school or middle school teachers of math and science. The award is intended to encourage such teachers to enter and remain in those fields. NSF established the honor in cooperation with the White House and scientific and professional organizations in 1983.

Some 1988 awardees are shown below.

*Award-winning teachers. Science teacher Carey S. Inouye, from Iolani School in Honolulu, Hawaii, is shown with two students. The group photo shows awardees and students from St. John's School in Rio Piedras, Puerto Rico. Math teacher Santiago Garcia is in the center; science teacher Adele Gomez is at right.*

## Equal Opportunity Achievement Award

This award by the NSF Director recognizes employees who have demonstrated an exceptionally high commitment to promoting equal opportunity within the Foundation, as well as in the scientific and engineering communities.

In late 1988 this award went to three people who have showed special dedication and commitment:

*Henry N. Blount, III* — for his vigorous support of affirmative action within NSF's chemistry division and his own program, as demonstrated by Research Opportunity Awards (ROAs) to initiate and sponsor targeted developmental sabbaticals, and particularly his creation of the "macro-ROA" award to groups that focus on involving minority students and faculty.

*Alice Moses* — for her past and continuing contributions to the cause of increasing minority participation in science and engineering, and particularly for her role as an advocate of increased science education programs for minority students across the nation.

*Joseph Reed* — for his enthusiastic support of NSF's goal of more fully incorporating minorities into the science and engineering infrastructure of the nation, and for his outstanding efforts in a pilot project to enhance substantially the pipeline "throughput" rate of minority science and engineering students into graduate degree programs and research/education career paths.

## Honors to NSF Distinguished Lecturers

NSF has inaugurated a staff lecture series that brings to Washington some of the best minds currently engaged in scientific and engineering research. Speakers during the first year of the series included Rosalyn S. Yalow, who shared the 1977 Nobel Prize in physiology or medicine for her work on the development of radioimmunoassay methodology and its application to biomedicine; Arno A. Penzias, who shared the 1978 Nobel Prize in physics for his discovery of evidence supporting the "Big-Bang" theory of the universe's origin; Lawrence H. Summers, the first economist to win the NSF Alan T. Waterman Award; and Jacqueline K. Barton, a Waterman Awardee who has earned international acclaim for her creative use of inorganic chemistry to design molecules that recognize and modify DNA.

All of the speakers received Distinguished Lecturer certificates from NSF to honor their participation in this prestigious series.

## Presidential Awards for NSF Staff

Sandra D. Toye, the NSF Controller, and Kenneth B. Foster, head of NSF's financial management division, received Presidential Rank awards in 1988.

Toye's Distinguished Executive Award recognized her long-term career and accomplishments in the federal government, which began with a management internship at the U.S. Information Agency in 1965. Toye joined NSF in 1973, where she held many posts in the ocean sciences division. As NSF's Controller, Toye oversees preparation and allocation of the Foundation's annual budget, which now approaches $2 billion.

*Sandra Toye*

*Kenneth B. Foster*

Foster's award, which confers the rank of Meritorious Executive, also honored his long record of public service. Foster's career began at the Naval Research Laboratory in 1946; he has headed NSF's financial management division for some 20 years. Under Foster's leadership, the division has been cited as an example of the way imaginative use of automation and microcomputers can save time and dollars.

## Arrivals and Departures

NSF welcomed two new assistant directors in 1988.

William A. Wulf, a computer scientist and AT&T Professor of Engineering and Applied Science at the University of Virginia, was appointed the new Assistant Director for Computer and Information Science and Engineering (CISE directorate). Wulf's special interest in computer science research has been the construction of systems—programming languages, operating systems, and the computer architecture that executes them efficiently. Wulf succeeds C. Gordon Bell.

John A. White, an engineer at the Georgia Institute of Technology, became Assistant Director for Engineering. White, who has been honored as both a teacher and an engineer, is the Regents' Professor of Engineering at Georgia Tech's School of Industrial and Systems Planning. He replaces Nam P. Suh, who served as assistant director for more than three years and has returned to the Massachusetts Institute of Technology.

## Board News: New Chairman and Vice Chairman

Mary L. Good and Thomas B. Day were elected Chairman and Vice Chairman, respectively, of the National Science Board, the policy-making body of NSF. Good, who has served on the board since 1980, is Senior Vice President, Technology, at Allied-Signal Corporation. She was Boyd Professor of Chemistry at the University of New Orleans, 1974-78, and Boyd Professor of Materials Science at Louisiana State University, 1978-80.

Since 1978, Day has been President of the San Diego State University. Prior to that appointment, he was Vice Chancellor for Academic Planning and a special assistant to the Chancellor at the University of Maryland in College Park.

copyright Warolin of Georgetown 1987

*William A. Wulf*

*John A. White*

***Senior Foundation and Board Officials, FY 1988***

*Erich Bloch*

*John H. Moore*

*Mary L. Good*

*Thomas B. Day*

# Appendix A

# National Science Foundation Senior Staff and National Science Board Members (Fiscal Year 1988)

NATIONAL SCIENCE FOUNDATIION SENIOR STAFF
(as of September 30, 1988)

*Director,*
Erich Bloch

*Deputy Director,*
John H. Moore

*Senior Science Advisor,*
James F. Hays

*General Counsel,*
Charles H. Herz

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

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

*Director, Office of Audit and Oversight,*
Jerome H. Fregeau

*Director, Office of Information Systems,*
Constance K. McLindon

*Director, Office of Science and Technology Centers Development* (Acting)
William C. Harris

*Assistant Director for Biological, Behavioral, and Social Sciences,*
David T. Kingsbury

*Assistant Director for Computer and Information Science and Engineering,*
William A. Wulf

*Assistant Director for Engineering,*
John A. White

*Assistant Director for Geosciences,*
Robert W. Corell

*Assistant Director for Mathematical and Physical Sciences,*
Richard S. Nicholson

*Assistant Director for Science and Engineering Education,*
Bassam Z. Shakhashiri

*Assistant Director for Scientific, Technological, and International Affairs*
Richard J. Green

*Assistant Director for Administration,*
Geoffrey M. Fenstermacher

NATIONAL SCIENCE BOARD
(addresses as of Sept. 30, 1988)

**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, Director, Maryland Biotechnology Institute and Professor of Microbiology, University of Maryland, College Park, MD

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

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

K. JUNE LINDSTEDT-SIVA, Manager, Environmental Sciences, Atlantic Richfield Company, Los Angeles, CA

KENNETH L. NORDTVEDT, JR., Professor of Physics, Department of Physics, Montana State University, Bozeman, MT

**Terms Expire May 10, 1992**

FREDERICK P. BROOKS, JR., Kenan Professor of Computer Science, Department of Computer Science, University of North Carolina, Chapel Hill, NC

F. 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, (Chairman, National Science Board), Senior Vice President, Technology, Allied-Signal Corporation, Inc., Morristown, New Jersey

JOHN C. HANCOCK, Executive Vice President, Corporate Development and Technology, United Telecommunications, Inc., Westwood, KS

JAMES B. HOLDERMAN, President, University of South Carolina, Columbia, SC

JAMES L. POWELL, President, Reed College, Portland, OR

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

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

**Terms Expire May 10, 1994**

WARREN J. BAKER, President, California Polytechnic State University, San Luis Obispo, CA

ARDEN L. BEMENT, Jr., Vice President, Technical Resources, TRW, Inc., Cleveland, OH*

D. ALLAN BROMLEY, Director, Wright Nuclear Structure Laboratory, Yale University, New Haven, CT*

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

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

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

(Two vacancies)

*NSB Nominee, pending U.S. Senate Confirmation as of late October 1988

**Member Ex Officio**

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

* * *

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

# *Appendix B*

# *Patents and Financial Report for Fiscal Year 1988*

## PATENTS AND INVENTIONS RESULTING FROM ACTIVITIES SUPPORTED BY NSF

During fiscal year 1988, the Foundation received 178 invention disclosures. Allocations of rights to 63 of those inventions were made by September 30, 1988. These resulted in dedication to the public through publication in 23 cases, retention of principal patent rights by the grantee or inventor in 40 instances, and transfer to other government agencies in 4 cases. Licenses were received by the Foundation in 49 patent applications filed by grantees and contractors who retained principal rights in their inventions.

## FINANCIAL REPORT FOR FISCAL YEAR 1988 (DOLLARS IN MILLIONS)

### Research and Related Activities Appropriation

| | | |
|---|---|---|
| **Fund Availability** | | |
| Fiscal year 1988 Appropriation | $1,453.00 | |
| Unobligated balance available, start of year | 1.26 | |
| Adjustments to prior year accounts | 4.77 | |
| Fiscal year 1988 availability | | $1,459.03 |
| **Obligations** | | |
| Total, all directorates: | | 1,373.80 |
| Program Development and Management | | 84.47 |
| Subtotal, obligations | | 1,458.27 |
| Unobligated balance available, end of year | .62 | |
| Unobligated balance lapsing | .14 | |
| Total, fiscal year 1988 availability for Research and Related Activities | | $1,459.03 |

### U.S. Antarctic Program Activities Appropriation

| | | |
|---|---|---|
| **Fund Availability** | | |
| Fiscal year 1988 appropriation | $124.80 | |
| Unobligated balance available, start of year | .00 | |
| Adjustments to prior year accounts | .02 | |
| Fiscal year 1988 availability | | $ 124.82 |

### Science and Engineering Education Activities Appropriation

| | | |
|---|---|---|
| **Fund Availablity** | | |
| Fiscal year 1988 appropriation | $ 139.20 | |
| Unobligated balance available, start of year | .06 | |
| Adjustments to prior year accounts | .44 | |
| Fiscal year 1988 availability | | $ 139.70 |

SOURCE: Fiscal Year 1990 Budget to Congress—Justification of Estimates of Appropriations

### Table 1. Biological, Behavioral, and Social Sciences, Fiscal Year 1988 (Dollars in Millions)

| | Number of Awards | Amount |
|---|---|---|
| Molecular Biosciences | 609 | $ 44.49 |
| Cellular Biosciences | 835 | 53.88 |
| Biotic Systems and Resources | 768 | 58.66 |
| Behavioral and Neural Sciences | 770 | 43.59 |
| Social and Economic Science | 493 | 30.10 |
| Instrumentation and Resources | 279 | 34.36 |
| Total | 3,754 | $265.08 |

### Table 2. Computer and Information Science and Engineering, Fiscal Year 1988 (Dollars in Millions)

| | Number of Awards | Amount |
|---|---|---|
| Computer and Computation Research | 301 | $ 19.85 |
| Information, Robotics, and Intelligent Systems | 251 | 17.73 |
| Microelectronic Information Processing Systems | 177 | 13.29 |
| Advanced Scientific Computing | 29 | 44.70 |
| Networking and Communications Research and Infrastructure | 82 | 11.47 |
| Cross-Disciplinary Activities | 75 | 16.87 |
| Total | 915 | $123.91 |

## Table 3. Engineering, Fiscal Year 1988 (Dollars in Millions)

| | Number of Awards | Amount |
|---|---|---|
| Chemical, Biochemical, and Thermal Engineering | 529 | $ 29.03 |
| Mechanics, Structures, and Materials Engineering | 472 | 26.18 |
| Electrical, Communications, and Systems Engineering | 405 | 23.39 |
| Design, Manufacturing, and Computer-Integrated Engineering | 212 | 15.36 |
| Emerging Engineering Technologies | 219 | 16.63 |
| Critical Engineering Systems | 345 | 25.09 |
| Cross-Disciplinary Research | 94 | 36.39 |
| Total | 2,276 | $172.07 |

## Table 4. Geosciences, Fiscal Year 1988 (Dollars in Millions)

| | Number of Awards | Amount |
|---|---|---|
| Atmospheric Sciences | 609 | $ 96.15 |
| Earth Sciences | 748 | 51.26 |
| Ocean Sciences | 858 | 134.95 |
| Arctic Research | 86 | 8.29 |
| Total | 2,301 | $290.65 |

## Table 5. Mathematical and Physical Sciences, Fiscal Year 1988 (Dollars in Millions)

| | Number of Awards | Amount |
|---|---|---|
| Mathematical Sciences | 1,332 | $ 63.76 |
| Astronomical Sciences | 314 | 85.79 |
| Physics | 579 | 117.90 |
| Chemistry | 1,087 | 94.03 |
| Materials Research | 853 | 110.55 |
| Total | 4,165 | $472.03 |

## Table 6. Science and Engineering Education, Fiscal Year 1988 (Dollars in Millions)

| | Number of Awards | Amount |
|---|---|---|
| Research Career Development | 246 | $ 34.02 |
| Materials Development, Research, and Informal Science Education | 149 | 37.81 |
| Teacher Preparation and Enhancement | 340 | 45.53 |
| Studies and Program Assesment | 25 | 3.24 |
| Undergraduate Science, Engineering, and Mathematics Education | 469 | 19.03 |
| Total | 1,229 | $139.63 |

## Table 7. Scientific, Technological, and International Affairs, Fiscal Year 1988 (Dollars in Millions)

| | Number of Awards | Amount |
|---|---|---|
| Industrial S & T Innovation | 223 | $ 17.37 |
| Internat'l. Coop. Sci. Activities | 449 | 10.66 |
| Policy Research and Analysis | 12 | .85 |
| Science Resources Studies | 35 | 4.01 |
| Research Initiation and Improvement | 101 | 17.16 |
| Total | 820 | $ 50.05 |

## Table 8. U.S. Antarctic Program, Fiscal Year 1988 (Dollars in Millions)

| | Number of Awards | Amount |
|---|---|---|
| U.S. Antarctic Research Program | 168 | $ 13.52 |
| Operations Support | 16 | 85.25 |
| Major Construction and Procurement | 4 | 25.90 |
| Total | 188 | $124.67 |

SOURCE: Fiscal Year 1990 Budget to Congress-Justification of Estimates of Appropriations (Quantitative Program Data Tables).