National Science Foundation

Annual Report 1987

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 32,000 proposals each year for research, graduate fellowships, and math/science/engineering education; it makes more than 15,000 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 advisers, 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.

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

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

National Science Foundation
Annual Report 1987

Annual Report for Fiscal Year 1987

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Letter of Transmittal

Washington, D.C.

DEAR MR. PRESIDENT:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1987 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

As we look back on 1987 and ahead to the last years of the twentieth century, the most striking feature on the landscape of science and engineering is imbalance between the supply and demand for new knowledge.

On the one hand, the supply of new knowledge seems unlimited. Superconductivity has captured our imagination with the possibility of much more efficient transportation and electrical power systems. Supercomputers and "chaos theory" in mathematics promise to help us understand such complex phenomena as weather patterns, turbulence in fluid systems, and the distribution of biological resources.

Biotechnology is already a growing industry, driven by basic research in biology and especially in genetics. It is already clear that these sciences will create continuing revolutions in agriculture and health care.

American manufacturing, which is essential to our economic well-being, is beginning to make a comeback as new materials, robotics, computer-aided engineering design, and other technologies emerge from basic research and find application.

Is this "supply" of new knowledge enough? Is it even too much? Some critics argue that knowledge is developing too rapidly, that we should slow down and give our social systems time to adapt. Yet the demand for new knowledge is much greater than the supply.

Our rapidly developing knowledge of the effect of chlorofluorocarbons on the ozone layer is a good example: only intensive use of the most advanced

science can help us understand this problem in time to solve it before permanent damage is done to the environment.

"Increasing the supply of knowledge requires solving two serious problems. First among them is education . . . The second problem is to devote the necessary resources to basic research."

Economic competitiveness is another example. New knowledge created through basic research is the source of new products and manufacturing processes for the international marketplace—and thus the key to maintaining American prosperity and our standard of living.

Ozone and economic competitiveness are only two current examples of the problems our civilization will face in coming decades. We have no way of knowing what new problems will appear tomorrow, or next year. But we can be certain that we will need still more knowledge to cope with these problems. In an uncertain world, knowledge—along with the scientists and engineers who produce it—is our most important resource.

Increasing the supply of knowledge requires solving two serious problems. First among them is education: we must find the ways and the means for our schools to teach all our young people basic concepts in science and mathematics. And many more students—especially women and minorities—must be encouraged to go beyond the basics into preparation for careers in science or engineering. In an increasingly technological world, many more of our leaders in industry, in government, and in academia must have technical training if we are to control events.

The second problem is to devote the necessary resources to basic research. We spend about two-tenths of one percent of our GNP on such research—not much, when we consider its importance. And the fraction has not changed significantly in 20 years, although science and engineering have become vastly more important.

There are no easy solutions to these problems. But the search for solutions deserves our best efforts, and it defines the mission of the National Science Foundation as we move toward the 21st century.

Erich Bloch
NSF Director

Then ye who now on heavenly nectar fare,
Come celebrate with me in song the name
Of Newton, to the Muses dear; for he
Unlocked the hidden treasures of Truth:
So richly through his mind had Phoebus cast
The radiance of his divinity,
Nearer the god no mortal may approach

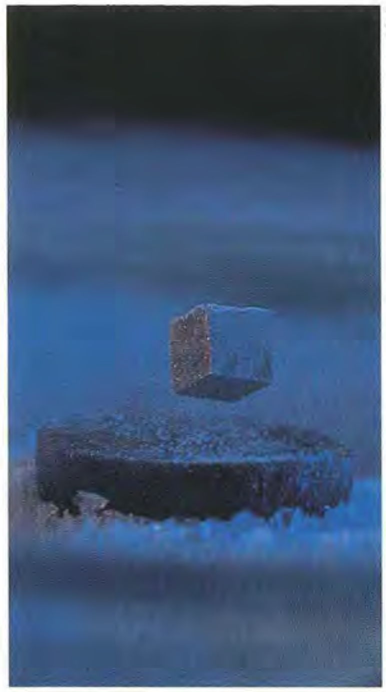
—Edmund Halley in his preface
to Isaac Newton's *Principia*

In 1687, Isaac Newton revolutionized the natural sciences with the publication of his landmark book, *Philosophiae Naturalis Principia Mathematica*, more commonly known as the *Principia*. Among Newton's achievements in his *Principia*, written in only 18 months, were mathematical expressions for the laws of motion and gravitational attraction. A new universe of information opened up to scientists: Newton explained the orbits of the planets around the sun, irregularities in the moon's orbit, and the cause of ocean tides.

In 1987, the 300th anniversary of Newton's *Principia*, new discoveries once again made news in the natural sciences, especially in astronomy and materials science. Astronomers detected supernova 1987A, the brightest exploding star visible from earth since 1604. And the discovery of materials that conduct electricity without resistance or energy loss at higher temperatures than few dreamed possible has been called the most important scientific finding of the latter half of the twentieth century.

Superconductors

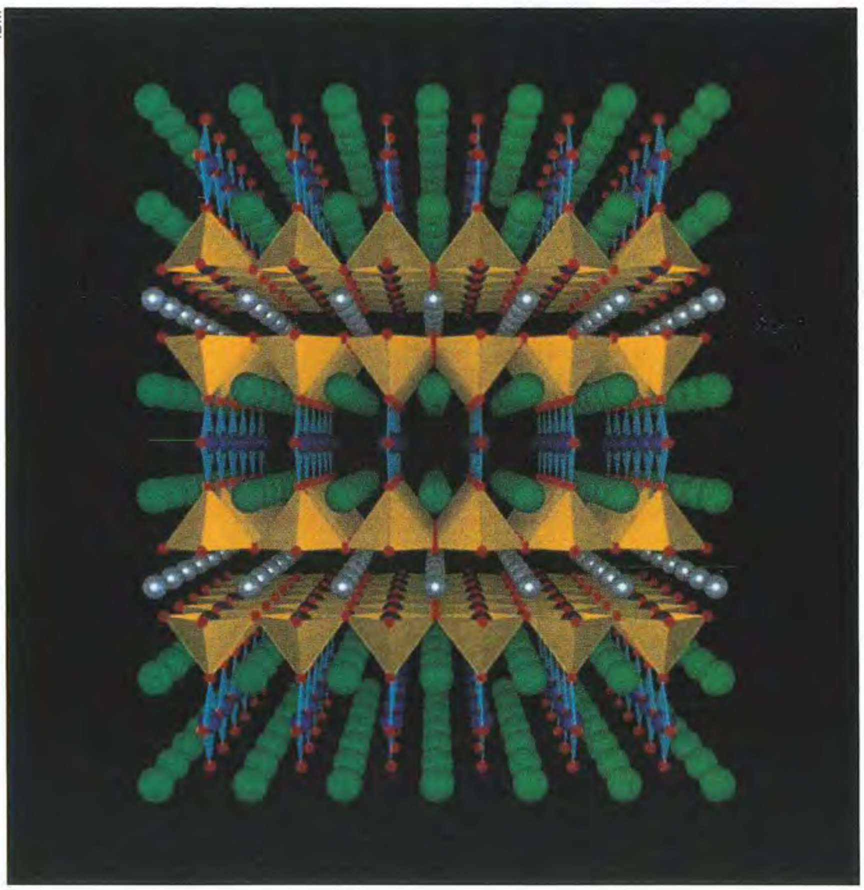
The year 1987 could be dubbed "the year of the supers" — a time of supercomputer applications, supernova sightings, superconducting materials discovered. But among all the scientific stories of the year, the discovery of new types of superconductors led the way. Ever since a Dutch scientist in 1911 found that a pure crystal of mercury lost all resistance to electric current when cooled to ultracold temperatures — 4 degrees above absolute zero or -460 Fahrenheit — scientists have searched for materials that are superconducting at higher temperatures. For 75 years that search turned up materials that required only slightly less cooling to become superconducting. A steady and costly supply of liquid helium was needed for superconducting magnets and circuits to operate.



IBM

High-Temperature Superconductor. This solid model of a crystal structure was produced using software developed by IBM. As modeled here, the ingredients of this compound are barium (green), yttrium (silver), copper atoms (blue), and oxygen atoms (red). The compound generated great interest because of the observation of superconductivity with a critical temperature above the boiling point of liquid nitrogen.

Magnetic levitation. A modern permanent magnet floats above a yttrium-barium-copper oxide superconductor at liquid nitrogen temperature (−321F). In order to expel the permanent magnetic field from the superconductor, a current flows near the surface of the superconductor to produce the opposing field.



IBM

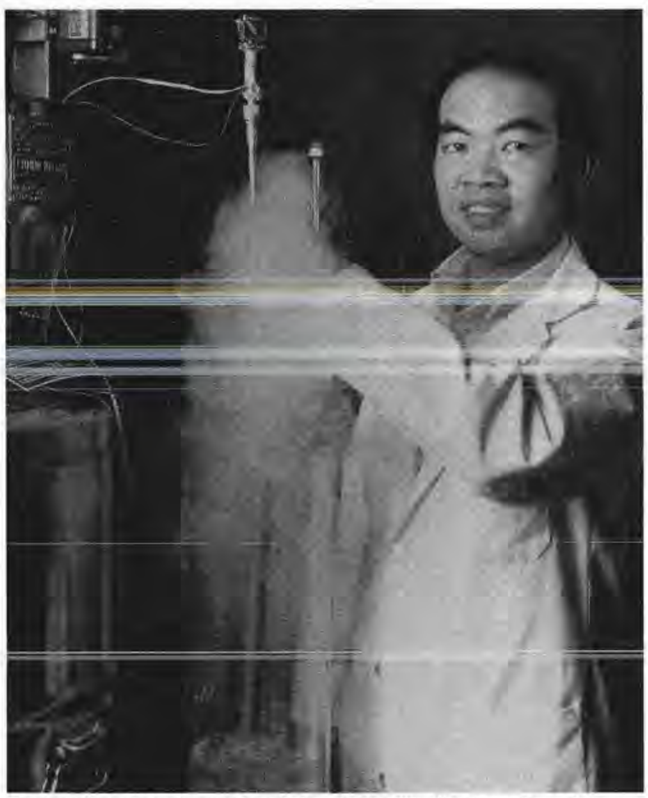
Then, in 1986, IBM researchers in Zurich reported the onset of superconductivity in a ceramic compound at a temperature a few degrees higher than previously observed.* The report sparked the interest of a number of research teams, including one headed by solid-state physicists *Paul Chu* at the University of Houston and *M.K. Wu* at the University of Alabama at Huntsville. The team reproduced the Zurich results and in early 1987 took a giant leap forward: using a new ceramic compound of their own concoction, Chu and Wu achieved the superconducting state at temperatures more than a hundred degrees higher (in Fahrenheit) than ever before.

The finding sent puzzled theorists back to the blackboard and experimentalists rushing to their laboratories. The discovery also meant that an important economic barrier had been crossed. Since ceramic superconductors become superconducting using only liquid nitrogen (at about 40 cents a gallon a cheap and plentiful coolant), potential applications to daily life may be enormous. For example, if the new materials can be fashioned into circuits or wires that can carry large currents without losing their superconducting properties, they may result in such applications as power generators and transmission lines that do not experience power loss, or large magnets that could be used for more precise medical imaging.

Creating powerful magnetic fields and electric currents, high-temperature superconductors would provide energy at a fraction of the cost needed to operate older superconducting circuits. Levitating trains, floating in a superconducting magnetic field above the tracks, could glide effortlessly at hundreds of miles per hour without encountering friction from the metal rails. Brookhaven National Laboratory on Long Island, NY, has demonstrated that a cable made of one of the older, low-temperature superconductors, although only 16 inches thick, could carry one-eighth of the electricity needed by New York City on the hottest day of the year.

Paul Chu was serving as a year-long director in the NSF solid-state physics program when his discovery was announced, and he is a long-time recipient of NSF research funds. M.K. Wu's laboratory in Huntsville is supported by an NSF activity called Experimental Program to Stimulate Competitive Research (EPSCoR).

*The Zurich team was among the 1987 Nobel Prize winners, based on this superconductivity work.



Research on superconductivity. M.K. Wu (University of Alabama at Huntsville) studied superconductivity through an NSF grant designed to stimulate competitive research in certain states.

Super researchers. Paul Chu (center) and his research team at the University of Houston have made important breakthroughs in discovering new high-temperature superconductors.

Other research teams, including those at AT&T Bell Labs, IBM, and in Japan, Switzerland, and China have also reported superconductivity at record high temperatures.

The almost weekly announcements on superconducting materials created a flurry of new activity in the scientific community worldwide. An evening session devoted to superconductivity at the March 1987 meeting of the American Physical Society turned into an all-nighter with standing room only; scientists still talk about the session as "the Woodstock of Physics." And at a Spring 1987 meeting of the National Science Board, 15-year-old Heidi Grant, the daughter of IBM superconductor researcher Paul Grant, demonstrated one of the ceramic materials she had made for just a few dollars in her father's laboratory.

For all the excitement, the reasons why materials become superconducting at high temperatures are not well understood. That certain materials lose all resistance to electric current at any temperature is a startling concept: even good "normal" conductors, such as copper wire, usually require a battery or other source of energy to keep current moving.

At the submicroscopic level, the electrons that make up current normally collide with atoms and impurities in the conducting material. These collisions waste energy and the electric current is slowed. But in the old, low-temperature superconductors, according to an accepted theory, electrons pair off at lower temperatures and shield one another from these energy-depleting collisions. At higher temperatures, however, the electron pairs break and superconductivity is lost. Theoreticians, aware of the existence of high-temperature superconductors, are now puzzling over the physical mechanism that makes superconductivity possible at those temperatures.*

At a government-sponsored conference on superconductivity held during the summer of 1987, President Reagan announced an 11-point plan to promote further work in superconductivity and ensure U.S. readiness to take the lead in commercial applications of the new research. NSF support in this area has approximately doubled, to about $10 million. Included in this amount is $1 million that NSF added to its support of materials research at three of the Materials Research Laboratories it funds. NSF also set aside $600,000 for rapid start-up grants for engineers working on processing the new superconducting materials.

*In January 1988, Paul Chu announced the discovery of yet another compound that became superconducting at about 254 degrees below zero Fahrenheit. This compound is made of bismuth, aluminum, strontium, calcium, and copper oxide.

Astronomy also had a remarkable year in 1987—a year of both illuminating discoveries and puzzling results. From the sighting of the brilliant supernova explosion known as 1987A to surprising evidence for the existence of seven new galaxies in a region thought to be empty space, astronomers were deluged with new information about the universe.

"Super" Star Draws Worldwide Research Effort

Astronomers will long remember the night of February 23, 1987. On a desolate mountaintop in northern Chile, a Canadian astronomer glimpsed an unfamiliar bright spot on a freshly exposed photographic plate of the Magellanic Cloud, a galaxy a billion billion miles from earth. The spot was no chemical aberration: an object so brilliant it could be seen with the naked eye had suddenly appeared in the galaxy. Scientists glimpsed nature at its most explosive: supernova 1987A, the first of its kind sighted in 1987 and the brightest visible from earth since 1604, had been born.

Supernovas are the glowing clouds of gas and dust particles hurled into space when stars several times as massive as the sun collapse under their own gravitational pull. Such explosions are not rare, but because most are too far and too faint to be observed in detail, the quest to understand how they happen has largely been limited to theoretical analysis and computer modeling. But supernova 1987A, a living model burning with the light of 100 million suns in a neighboring galaxy, put many existing theories to the test. And since the explosion was visible only from the Southern Hemisphere, observatories in the clear mountain air of Chile, including the NSF-funded Cerro Tololo Inter-American Observatory, became the focus of worldwide research efforts.

Only hours after announcement of the discovery, Cerro Tololo telescopes captured some of the first detailed images of the new supernova. Analysis of these images and the light produced by the February explosion revealed that the supernova was caused by the collapse of a star known as a supergiant. Further studies found that the supergiant was of a type commonly believed to be too hot to give rise to a supernova, forcing scientists to revise their theories somewhat.

NOAO

Observing the supernova. Astronomers used the Curtis-Schmidt telescope at Cerro Tololo to photograph and observe supernova 1987A.

Supernova 1987A. Located in the Large Magellanic Cloud near the Tarantula nebula, the brilliant supernova 1987A burns with the light of 100 million suns and is the closest supernova seen since the invention of the telescope. This wide-field photograph was taken by the Curtis-Schmidt telescope at the Cerro Tololo Inter-American Observatory in Chile.

National Optical Astronomy Observatories (NOAO)

Supporting evidence that a supergiant had given rise to the supernova came from photographic plates of the Large Magellanic Cloud taken two decades ago at Cerro Tololo. *Nicholas Sanduleak*, then a staff astronomer, had analyzed the light and catalogued the position of a number of stars from the galaxy, including a supergiant now known as Sanduleak -69 degrees/202. Twenty years later, the location of the supernova closely matched the position of the Sanduleak star. And ultraviolet studies revealed that the star had disappeared after the supernova explosion. The close connection between the two was unmistakable.

Other unusual features of supernova 1987A were also uncovered at Cerro Tololo. Using a special rapid exposure photographic technique, astronomers discovered an unexpected, glowing companion near the supernova. And while light from most supernovas reaches a peak intensity quickly, supernova 1987A increased its brilliancy for three months, equalling the brightness of a star in the Big Dipper before slowly fading from view.

Scientists have since turned their attention to exploring the dense, collapsed star that is the burned out remnant of the explosion, along with the gases still racing outward into space — there to mingle with gases left over from the time when the star was formed. In fact, NASA's Solar Maximum Satellite and two Australian balloon experiments have already provided additional evidence that exploding stars such as the supernova create key heavy elements, including metals, from lighter elements.

The balloon-lofted instruments involved were highly sensitive detectors of gamma radiation; they made the first clear detection of gamma-ray emissions from a stellar explosion and helped scientists deduce the elements that produced the radiation.

The supernova attracted both astronomers who study the large scale and scientists who search for subatomic relics of the stellar explosion. In a salt mine far below ground in Lake Erie, in the Kamioka lead and zinc mine in Japan, in the Mont Blanc Tunnel linking France and Italy, and in another tunnel under Mount Elbrus in the Soviet Union, physicists monitored detectors for the elusive subatomic particles called neutrinos. They are predicted to be produced during a supernova, preceding the emission of visible light. Neutrinos were detected, affirming our understanding of how supernovas occur.

Largest Galaxy Discovered

Astronomers discovered in 1987 the largest galaxy yet known in the universe, a giant spiral 13 times as big as our own Milky Way galaxy.

Known as Markarian 348, the galaxy had first been observed by optical telescope more than 20 years ago, but was thought to be the size of the Milky Way. More recently, Markarian 348 drew the attention of *Susan Simkin*, an astronomer at Michigan State University. Simkin was making a study of very bright galaxies, including Markarian 348.

National Radio Astronomy Observatory

Image of MKn 348. Astronomer Susan Simkin examines a computer-enhanced image of Markarian 348.

Simkin and her collaborators studied the radiation from the galaxy using both the optical telescope at Mount Palomar Observatory in California and the Very Large Array (VLA) radio telescope, an NSF-supported facility in New Mexico. The data from the radio telescope surprised the research team. Markarian 348 had a diameter of 1.3 million light years, the largest single galaxy yet observed. A light year is the distance light travels in a year, about six trillion miles.

According to Simkin, the high resolution of the VLA telescope — actually an assemblage of 27 radio antennas that move on railroad tracks — was crucial to accurate measurement of the distant galaxy's size.

Simkin's collaborators were *Jacqueline van Gorkom*, a staff astronomer at the National Radio Astronomy Observatory; *John Hibbard*, a former summer student at the VLA; and *Su Hong-jun* from the Purple Mountain Observatory in the People's Republic of China.

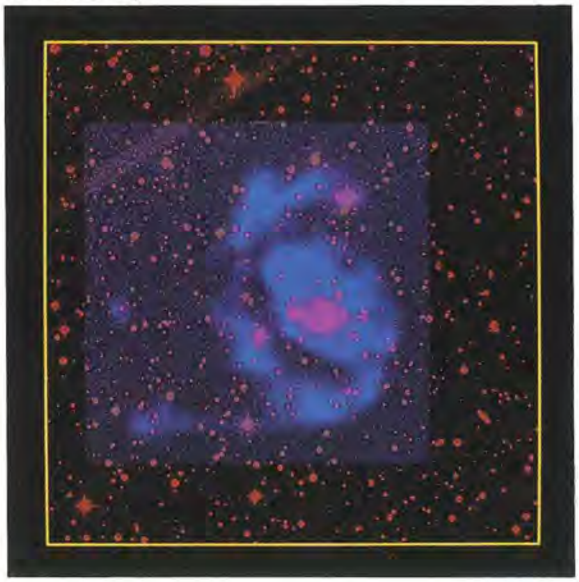
Other Astronomy Findings

Astronomers from several institutions — using a variety of optical telescopes — have discovered seven rare galaxies in a portion of the universe that was presumed to be empty space. Their work was done at Kitt Peak National Observatory, an NSF-supported facility in Arizona. The galaxies, unusual because they include energetic gases that indicate they may be giving birth to new stars, are located in the direction of the constellation Bootes. The "empty" region where the galaxies were found is so vast that 2,000 galaxies the size of the Milky Way would be expected in that space.

Discovery of the galaxies has important repercussions for theories on the formation and clustering of galaxies and on the way matter is distributed in the universe.

In a separate research effort, a team of British and American astronomers has found that our own galaxy, the Milky Way, and thousands of its neighbors are speeding across space at the rate of 400 miles per second. The finding intrigued and baffled the scientific community, since none of the theories that explain the formation and structure of the universe can account for the observed motion. One of many conjectures about the unexplained motion, known as large-scale streaming, is that the galaxies are being pulled by the gravitational force of some huge, as yet undiscovered object. Research that led to the discovery was conducted at observatories worldwide, including the Kitt Peak National Observatory.

Largest galaxy. Astronomers in 1987 found that Markarian 348, a giant spiral galaxy first sighted more than 20 years ago, is the largest galaxy yet known in the universe. It is 13 times as large as the Milky Way. (In this composite optical image, cold, neutral hydrogen is shown in blue; stars in the galaxy and surrounding field are red.)



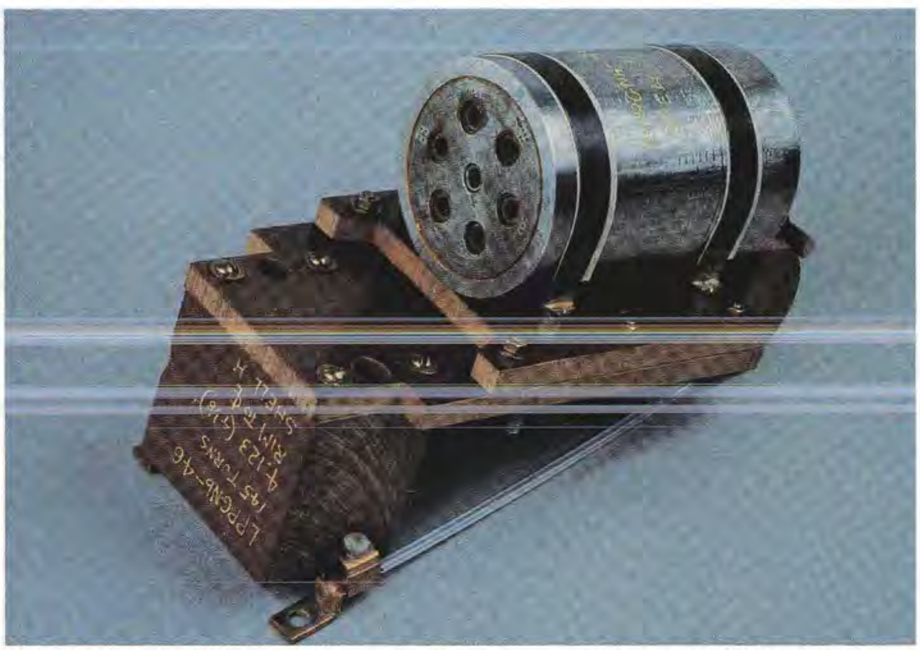
Collaborative effort. Su Hong-jun, at the Purple Mountain Observatory in the People's Republic of China, was a collaborator in Markarian 348 research.

Researchers at the Francis Bitter National Magnet Laboratory at MIT have built a magnet that produces pulses of magnetic field twice as strong as the largest steady-state device. Previous research at the laboratory led to creation of the world's largest steady-state magnetic field (described in NSF's FY 1986 annual report).

This new tool, which generates a magnetic field that peaks in strength every few minutes, gives scientists a highly accurate and inexpensive probe for studying the magnetic and electronic properties of metals, semiconductors, and superconductors — including the new superconducting materials only recently discovered.

Working in collaboration with Supercon, Inc., a small company in Massachusetts, *Simon Foner* of the MIT laboratory developed a copper-niobium wire whose mechanical strength and high electric and thermal conductivity were used to create a magnetic field of 68.4 tesla, more than a million times as large as the earth's field. The high intensity and relatively long duration of the magnetic pulse — about five-thousandths of a second — allow researchers to extend the measurements with a weaker steady-state magnet. One important application is in measuring the "critical field" of a superconductor, the magnetic field beyond which the material no longer allows no-resistance flow of electric current. Measuring the critical field of each of the new superconductors aids scientists in understanding these exciting and sometimes puzzling materials.

Bitter National Magnet Laboratory, MIT



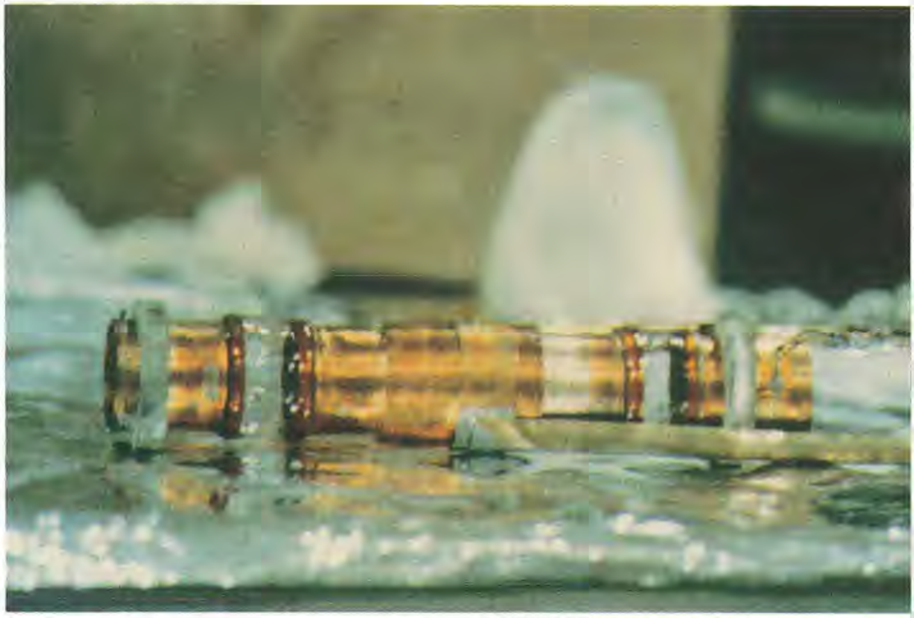
Pulsed magnetic field. This MIT magnet produces a pulsed magnetic field twice as strong as the largest steady-state device. It gives scientists a highly accurate and inexpensive tool for probing the properties of many materials, including the new superconductors. Hardened steel shell contains the highly stressed magnet.

Antiparticles are the mirror images of subatomic particles such as the proton or electron, possessing nearly identical properties, but with the opposite electric charge. An antiproton, for example, is the equivalent of a proton with a negative charge. Although the study of antiparticles is crucial for testing fundamental theories about how the universe was formed, antiparticles can be created in large quantities only at high energies and high velocities. Scientists have been unable to slow down these particles long enough to analyze them precisely.

The antiproton has proved particularly elusive. But a collaboration of U.S. and West German researchers led by experimental physicist *Gerald Gabrielse* at Harvard University found a method for trapping these particles for periods up to 10 minutes in a container the size of a matchbox. The researchers began with a beam of energetic antiprotons produced by the large accelerator at the European Center for Nuclear Research (CERN) in Switzerland. A CERN apparatus called the Low Energy Electron Ring removed large amounts of energy from the beam, but the researchers were still faced with capturing antiprotons possessing millions of electron-volts of energy. And due to tight scheduling, they had only 24 hours to perform the experiment.

First the scientists passed the antiproton beam through a thick metal disc, causing the beam to lose energy by collision with electrons inside the metal. Next, the researchers used powerful electric and magnetic fields to confine the energetic antiparticles inside a vacuum chamber only a few inches long. A large negative voltage applied alternately to electrodes placed at the front and back of the chamber kept the antiparticles bouncing back and forth, while a strategically placed magnetic field prevented the antiparticles from slipping out from the chamber sides.

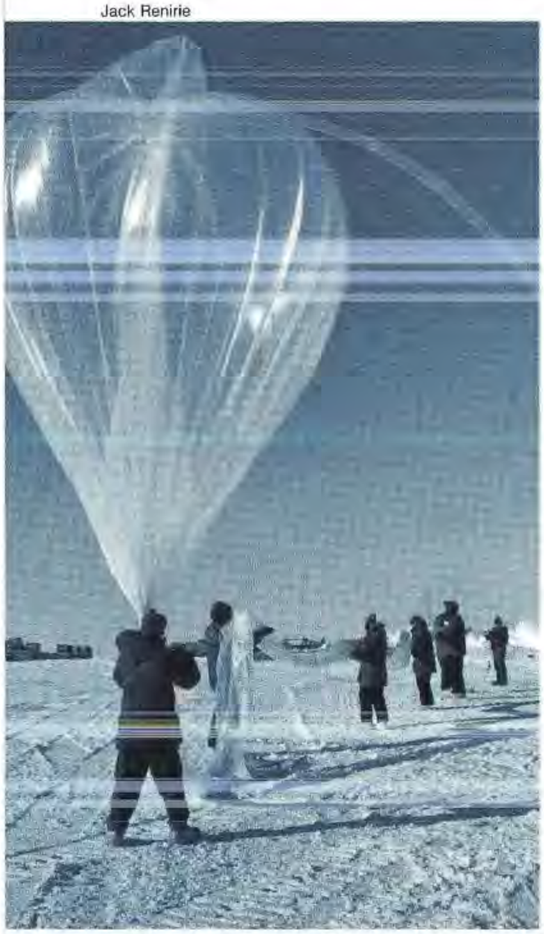
Succeeding in only a day, the investigators for the first time confined thousands of antiprotons in the chamber for tenths of seconds. Five antiprotons were trapped for as long as 10 minutes. As of this writing, the scientists expect to trap antiprotons for more than a day, enabling them to measure the mass of the antiparticles at least 100 times as precisely as ever before. Physical theories about elementary particles — the basis of our understanding about how matter is put together — predict that the mass of the antiproton must be exactly the same as its mirror twin, the proton. But experiments have not ruled out a tiny deviation. If the mass of an antiproton is found to be more or less than that of a proton, it could be one of the most significant discoveries in physics in quite a few years.



Antiparticle research. Shown here are electrodes for the ion trap used by U.S. and West German researchers to capture and hold antiprotons.

Antarctic Ozone Layer: Research Continues

Jack Renirie



Balloon Launch. Scientists launch an instrumented balloon at Amundsen-Scott South Pole Station in November 1987. Measurements showed ozone to be returning to the stratosphere above the South Pole after a depletion over Antarctica of several months during the springtime "ozone hole." The ozone dramatically increased by 25 percent in 24 hours and returned to normal over a period of several days. Scientists relate the hole to chlorofluorocarbons (CFCs) used throughout the world in industrial applications and to atmospheric conditions unique to Antarctica.

Scientists investigating the ozone "hole" that occurs over Antarctica between September and November (see NSF Annual Report for FY 1986) found in 1987 that the depletion of the ozone layer there was more pronounced than in previous years. Preliminary results suggest that both chemical and meteorological factors may produce the phenomenon. Moreover, the ozone hole was evident over the tip of South America as well.

The chemical products suspected of depleting ozone, known as chlorofluorocarbons, are widely used in refrigeration, foam insulation, and some aerosol sprays.

Researchers at McMurdo Station, the U.S. Antarctic Program's station about 840 miles from the South Pole, found in 1987 that the ozone hole contained well over 100 times the usual concentration of the compound chlorine monoxide, which is produced by chlorofluorocarbons and depletes ozone through a complex chain of chemical reactions. Preliminary data analysis also suggests that Antarctica's extremely cold stratosphere and circulation patterns may contribute significantly to the ozone problem.

During the annual depletion or hole, about 35 to 50 percent of the ozone disappears. Recovery usually occurs around late November or early December. The hole, first reported by British scientists in 1985, is about five miles thick and covers an area more than twice the size of the United States. Understanding the depletion process is important, because atmospheric ozone shields the earth from most of the sun's harmful ultraviolet rays, which can cause skin cancer in human beings and can harm both animals and plants.

In August 1987 seven teams of U.S. scientists participated in the second National Ozone Expedition (NOZE). NOZE is a cooperative effort sponsored by NSF (the lead U.S. agency on the continent), the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the Chemical Manufacturers' Association. The scientific leader of the expedition, atmospheric chemist *Susan Solomon* of NOAA, and her colleagues used molecular properties of light absorption to measure concentrations of ozone and chemicals suspected of playing a role in ozone depletion.

Other scientists included the father-son team of *David* and *Frank Murcray* from the University of Denver. The Murcrays analyzed the absorption of the sun's infrared radiation by a number of gases in the antarctic atmosphere. *Bruce Morley* and *Edward Uthe* of SRI International used an instrument (called a lidar) specially designed for the expedition to shoot a fine beam of light at the antarctic stratosphere. Information on the time it took for the beam to return to earth helped the researchers determine the location of polar clouds and layers of aerosols.

In September 1987 two NASA airplanes fitted with special instruments to collect atmospheric data flew into and around the ozone hole. The data they collected complemented results from ground-based investigations at McMurdo Station. Then at the end of 1987 scientists reported that the winter mass of extremely cold air over the White Continent had stayed about three weeks longer than it did the year before — an event that may be directly related to the ozone hole. (The antarctic air may have warmed more slowly because there was less ozone to absorb the sun's heat.)

At this writing, the 1987 data are still being analyzed, and planning for a third NOZE expedition is under way.

New Technique Finds Earth's Core Hotter than Expected

Using a powerful gun that accelerates projectiles to enormous speeds, researchers have determined that the earth's center is thousands of degrees hotter than previously thought.

Geophysicists have long known that the earth's outer core is made of molten iron under high pressure. Since the core must be at least as hot as the temperature to melt iron, discovering iron's melting point at high pressure gives the minimum possible temperature of the core. But previous efforts to determine the melting point relied on extrapolations from measurements of iron melted at much lower pressures. Scientists had estimated that the earth's core was about 7100 degrees Fahrenheit.

But using specially designed guns, the largest 106 feet long and weighing 35 tons, California Institute of Technology researchers, collaborating with the University of California at Berkeley, found a better way to simulate conditions at the earth's center. The guns enabled geophysicist *Thomas J. Ahrens* and his collaborators to fire plastic and tantalum bullets speeding at 16,000 miles per hour at crystals coated with a thin layer of iron. For less than a millionth of a second, the bullets' impact nearly recreated the enormous pressure of molten iron at the center of the earth. With these measurements, the research team estimated that the temperature of the earth's inner core was about 12,000 degrees Fahrenheit—hotter than the surface of the sun.

In past years, Ahrens and his group have used the guns to compress the gemstone garnet into a crystal structure never before seen; fired bullets at hydrogen targets to simulate the environment deep inside Jupiter and Saturn; and found evidence for the hypothesis that a gigantic meteor hit the earth millions of years ago, perhaps leading to the extinction of dinosaurs.

Core of the matter. Thomas J. Ahrens checks procedures for firing Caltech's light gas gun, which simulates the high pressures at the earth's core.

Bacterium Is Link to Past

Researchers have discovered in Thai rice paddies a bacterium whose ancient ancestors may have created the oxygen-rich atmosphere that sustains life on earth. The microbe, known as *Heliobacillus mobilis*, belongs to a recently discovered group of bacteria called Heliobacteria.

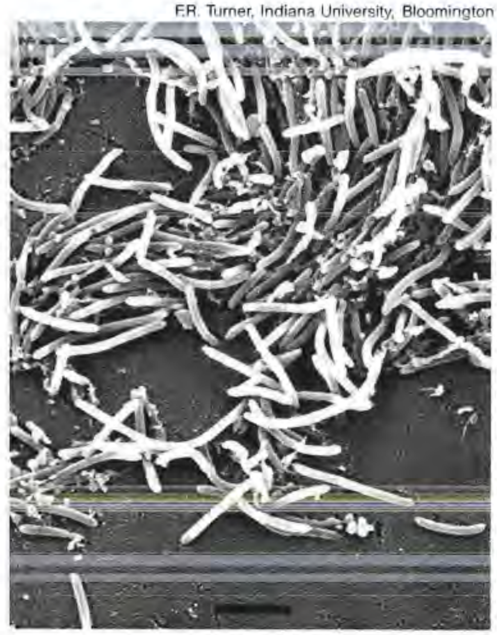
Heliobacteria respond to light and contain a form of chlorophyll which is intermediate to that found in green plants and cyanobacteria — the first bacteria to release oxygen on earth. Current theory holds that early forms of cyanobacteria used energy from sunlight to transform the earth's atmosphere into an oxygen-rich blanket suitable for animal life.

Structural similarities between cyanobacteria and *Heliobacillus mobilis* were only one clue that led an Indiana University research team to suggest that the newly discovered microbe could be the direct descendant of the ancient bacterium that produced cyanobacteria.

Further evidence, according to biologist and research team leader *Howard Gest*, came from the comparison of molecules called ribosomal RNA that are found in heliobacteria and other microbes. Ribosomal RNA, which plays a crucial role in making proteins, has evolved slowly over the years. The type found in *Heliobacillus mobilis* closely matched the ribosomal RNA found in some older bacteria that do not respond to light, the team noted, yet the RNA was strikingly different from that residing in other, more common light-sensitive bacteria. The new bacterium, related to both cyanobacteria and older, more primitive microbes, seemed clearly marked as an evolutionary link.

In addition to its evolutionary significance, the bacterium may also be useful as an efficient nitrogen fertilizer. Unlike other types of bacteria that convert nitrogen into a form useful for plants, heliobacteria live independently and do not attach themselves to a host plant for survival (as do the more common *Rhizobium*, now under intense study in genetic engineering labs). And the particular heliobacteria found in the Thai rice paddies "fix" or convert nitrogen to a useful form 10 times faster than do any other heliobacteria known.

F.R. Turner, Indiana University, Bloomington



Soil research. Scanning electron micrograph shows *Heliobacterium chlorum* cells. This is a slow-moving bacterium isolated from the soil at Bloomington, Indiana. (Bar equals 5 micrometers.)

F.R. Turner, Indiana University, Bloomington

Evolutionary link. Electron micrograph depicts a single cell of *Heliobacillus mobilis*, a bacterium isolated from Thai rice paddy soil. It swims fast by means of hair-like flagella and may be closely linked to the ancient organisms that provided the oxygen-rich atmosphere for life on earth.

Marine Life Research May Yield Insight into Brain Function

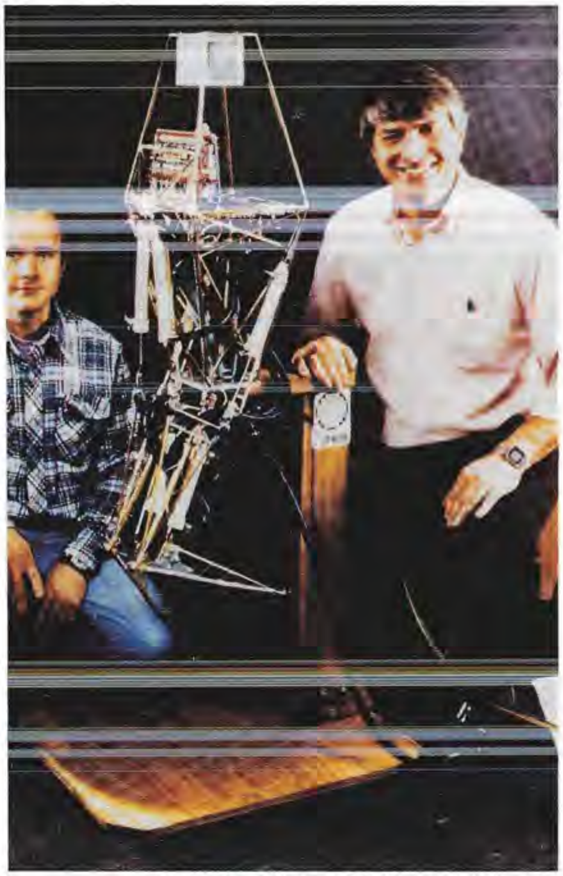
Researchers *Daniel* and *Aileen Morse* at the University of California at Santa Barbara have discovered that some red algae produce chemical signals that regulate metamorphosis of the marine mollusk, the abalone, from its larval stage to its mature form (well known as a seafood delicacy). The chemicals produced by red algae are short chains of amino acids known as peptides. These algal peptides have also been shown to function in the mammalian brain by binding to receptor sites that normally respond to GABA (gamma amino butyric acid), a hormone-like chemical involved in transmission of signals between nerve cells. The red algal peptides actually bind to brain receptors for GABA 100 times more tightly than does GABA itself. Conversely, GABA functions similarly to the algal peptides in stimulating the metamorphosis of the abalone larvae.

These biochemical findings are being used by hatchery owners to increase the supply of abalone by enhancing the conversion of larvae to edible adult animals. The information will also lead to a better understanding of the role of chemical signals in reef formation and how the hulls of ships become coated by marine organisms. Such findings also have potential for creating new probes to study the central nervous system. Researchers studying the binding ability of the algal peptides to GABA receptors in the mouse brain hope to learn about the interaction of the peptides and the receptors. In the future such peptides may be used to develop new, more specific drugs for treating GABA-related brain disorders.

Receptor recognition of an environmental signal. In this lab experiment, abalone larvae capable of undergoing developmental metamorphosis have recently settled, and are browsing upon, a red algal surface. The larval surface receptors controlling the events of metamorphosis have been activated by contact with unique peptides at the alga's surface.

Insects, Leg Design, Walking Robots

A research team at Oregon State University has studied the leg motion of insects to help lay the foundation for developing the next generation of walking robots and remote-control moving equipment. According to engineer *Eugene Fichter*, who collaborated on the study with his wife, entomologist *Becky Fichter*, "Insects are magnificent models for walking machines" because of their variety of walking styles and the types of surfaces they travel on. Surfaces insects walk on range from smooth to bumpy, vertical to horizontal, and solids to webs. Some insects walk slowly, while others run rapidly and jump many times their body length.



Robotics. Michael Mulder (right) and Neldon Wagner are seen with the two-legged robot they designed at Oregon's University of Portland.

This type of versatility must become part of the design of walking robots if machines are to achieve the capabilities of animals. Studying spiders or other web-walking insects, for example, could teach important lessons on how inspection machines might crawl between the walls inside a nuclear reactor building or how robots could climb the steel frame of a building under construction. Present walking machines have had some success as engineering models, but their movements are limited.

While other researchers have analyzed the gait of insects to investigate how their feet may be used as sensors, there have been no previous detailed studies of the way insect legs move or how their leg structure limits possible movement. The insect study, an ongoing project, is conducted by recording movement on film, video recorder, and computer vision systems. A computer compares the movements actually taken by the animal with theoretical limits assumed by engineering mechanics. The researchers have measured leg segments, identified types of joints, and studied the way adjacent joints are arranged.

This research effort, which also included Oregon State mechanical engineer *Stephen Albright*, is funded by an experimental program within NSF's engineering division that seeks out creative and novel engineering ideas not being exploited (see chapter 2 for more description).

At Oregon's University of Portland, scientists have taken a different approach to understanding the challenges of controlling complex machinery. The Portland team, headed by *Michael C. Mulder* and senior researcher *Neldon Wagner*, used a two-legged walker that can balance only while moving. The walker relied on an innovative gyroscope-like device to keep its balance, as well as a multiple computer system and sensors to measure its position and adjust for varying terrain. A special hydraulic engine shifted weight from one leg to the other as needed, according to computer instructions.

The multiple computers, known as a parallel processing system, allow the walker to make several decisions about moving swiftly and simultaneously, more akin to the action of the human brain than computers which process information step by step.

In practice, a sensor similar in function to a gyroscope detects how far the walker is leaning over; other sensors in the legs and "feet" monitor the angle of joints and the hardness of the ground. The information is fed back 500 times a second to a computer, which compares the actual position of the robot to a computer model and makes adjustments for the difference by regulating balancing fluid in the legs of the walker. Rather than aiming to create the perfect walking robot, the research team views the walker as a means to learn more about sensor-based control of complex machines.

Infants Imitate Adults from Day 1

Infant imitation of adult behavior has long been recognized as playing a crucial role in the social and cognitive development of children. But until recently, scientists believed that infants could not imitate facial gestures until they reached about one year of age. Developmental psychologist *Andrew N. Meltzoff* and his colleagues at the University of Washington demonstrated, however, that babies who were only 12 to 21 days old mimicked such gestures in adults as sticking out a tongue or protruding the mouth or lips. The youngest baby to mimic the gestures was only 42 minutes old.

The research team also found that infants ranging from 14 to 24 months could recall and imitate an adult activity an entire day after observing the action. Infants who watched adults dismantle and reassemble a dumbbell-shaped toy mimicked the action a day later, even though they had never before touched the toy.

According to Meltzoff, the findings demonstrate that "from the earliest stages, even before they acquire language, infants are exquisitely sensitive to adult actions, and [this] indicates the profound influence that these observations can have on the infant's subsequent behavior."

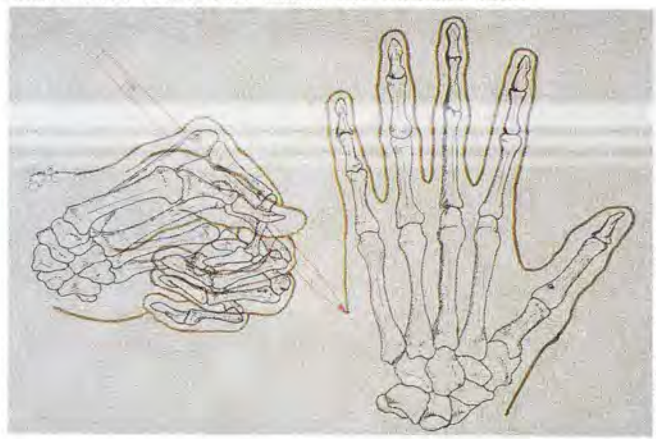
Infant imitation. Photographs from videotape recordings show that infants only two to three weeks old imitate the mouth movements of adults.

Across the country during early April 1987, thousands of schools, community groups, science organizations, museums, and government agencies devised creative ways to focus attention on the role that science and technology play in daily life. Begun in 1985 by NSF, National Science and Technology Week seeks to increase the public's awareness about science, engineering, and mathematics and to encourage young people to consider careers in these areas.

A special feature in 1987 was "The Art of Science" competition, in which high school seniors nationwide contributed paintings, photographs, and other artwork dealing with some aspect of science or technology. Among the winners was *Seong Kim*, from the Bronx (NY) High School of Science. His ink drawing depicted the outline of a hand, showing every bone, in the process of sketching the outline of another skeleton-like hand. *Wendy Brill* at Westlake School in Los Angeles contributed a hand-tinted photograph of open-heart surgery; *Ellen Dare Safrit* at the North Carolina School of Science and Mathematics in Durham won for her silkscreen printing that depicted the cell structure of plant stems. The silkscreens were based on cell photographs that Safrit had taken through a light microscope.

Commented Safrit, "Complex scientific equipment combined with modern photographic and silkscreening processes have given artists the ability to capture nature's inherent beauty and creatively display the 'art of science.'" The exhibition of winning artwork, co-sponsored by NSF and the New York Academy of Sciences, has travelled throughout the United States.

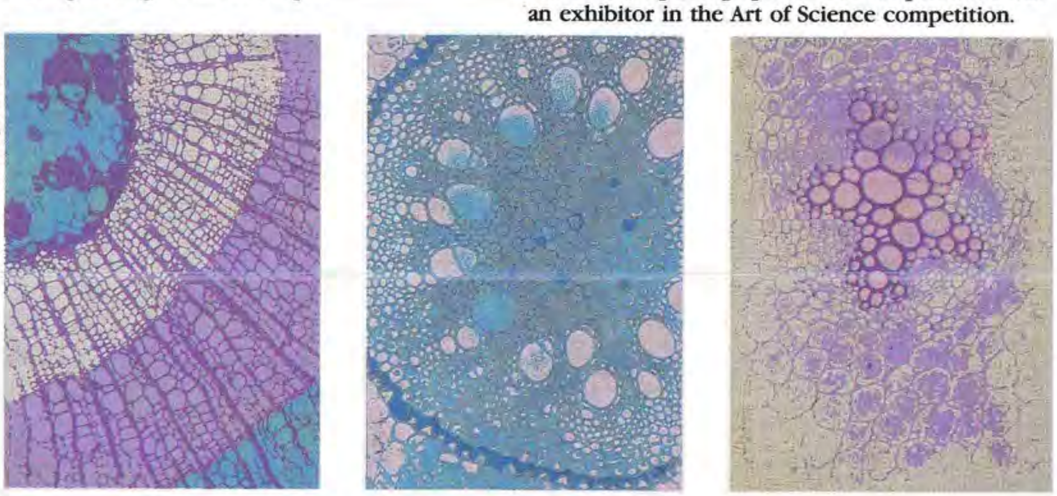
Art exhibitor. Seong Kim at the Bronx High School of Science in New York turned the bone structure of the human hand into a work of art with "Hand: The Ultimate Tool."



New York Academy of Sciences

Art of science. Ellen Dare Safrit at the North Carolina School of Science and Mathematics used microscope photographs of plant stems to create "Botanist's Cathedral," a photographic silkscreen print. She was an exhibitor in the Art of Science competition.

New York Academy of Sciences



First Volume of Einstein Papers Published

More than 30 years after his death, Princeton University Press has published the first volume of Albert Einstein's papers. The papers track the thoughts of Einstein as a young man through 1902, and include letters detailing his early views about physics and the beginnings of his thoughts about relativity theory. Other letters are an account of Einstein's fruitless search for a university position—a search that finally led him to accept a job at the Swiss patent office, where in his spare time he was to develop his Special Theory of Relativity.

The documents, commented science historian Gerald Holton, portray "a mind sharpening its tools, a young man of 22 beginning to ask fundamental questions, an intellectual giant." Publication of the volume was made possible in part by a $750,000 grant from NSF. A projected 40 volumes of Einstein's papers will be published over the next few decades.

Please forgive a father who is so bold as to turn to you, esteemed Herr Professor, in the interest of his son.

I shall start by telling you that my son Albert is 22 years old, that he studied at the Zurich Polytechnikum for 4 years, and that he passed his diploma examinations in mathematics and physics with flying colors last summer. Since then, he has been trying unsuccessfully to obtain a position as Assistant, which would enable him to continue his education in theoretical and experimental physics . . .

My son therefore feels profoundly unhappy with his present lack of position, and his idea that he has gone off the tracks with his career and is now out of touch gets more and more entrenched each day . . . it is you to whom I have taken the liberty of turning with the humble request to read his paper . . . and to write him, if possible, a few words of encouragement, so that he might recover his joy in living and working.

If, in addition, you could secure him an Assistant's position for now or the next autumn, my gratitude would know no bounds.

Hermann Einstein to
Prof. Wilhelm Ostwald,
1901

Joyce Latham

Einstein statue at the National Academy of Sciences, Washington, DC

"3-2-1 Contact" Goes to Antarctica

In the fall of 1987, crew members from a major science show on television visited the coldest continent and filmed major program segments. The show was "3-2-1 Contact," seen on public TV and produced by the Children's Television Workshop in New York City. "Contact" is aimed at young people (ages 8 to 12) and partially funded by NSF. During the show's visit to Antarctica, the four crew members stayed at NSF's McMurdo Station, with a further trip to the geographic South Pole. They filmed segments on such topics as the antifreeze properties of antarctic fish; ongoing studies of the local seal population; the geology and glaciology of the extraordinary antarctic landscape; and the monitoring of ozone levels in the upper atmosphere. The visit will result in a week's worth of antarctic stories scheduled to air on PBS in the fall of 1988.

In addition to the "3-2-1" visit, Cable Network News (CNN) also filmed major program segments in Antarctica in late 1987.

3-2-1 Contact in Antarctica. The TV crew poses in front of Shackleton's Hut, where explorers rested during their investigations of Antarctica in the early 1900's. _3-2-1_ is supported in part by NSF.

Penguin research. Debra Shapiro, cast member of _3-2-1 Contact_, feeds penguins in preparation for a diving study. At right is Scripps Institution zoologist Gerald Kooyman.

Life Saver

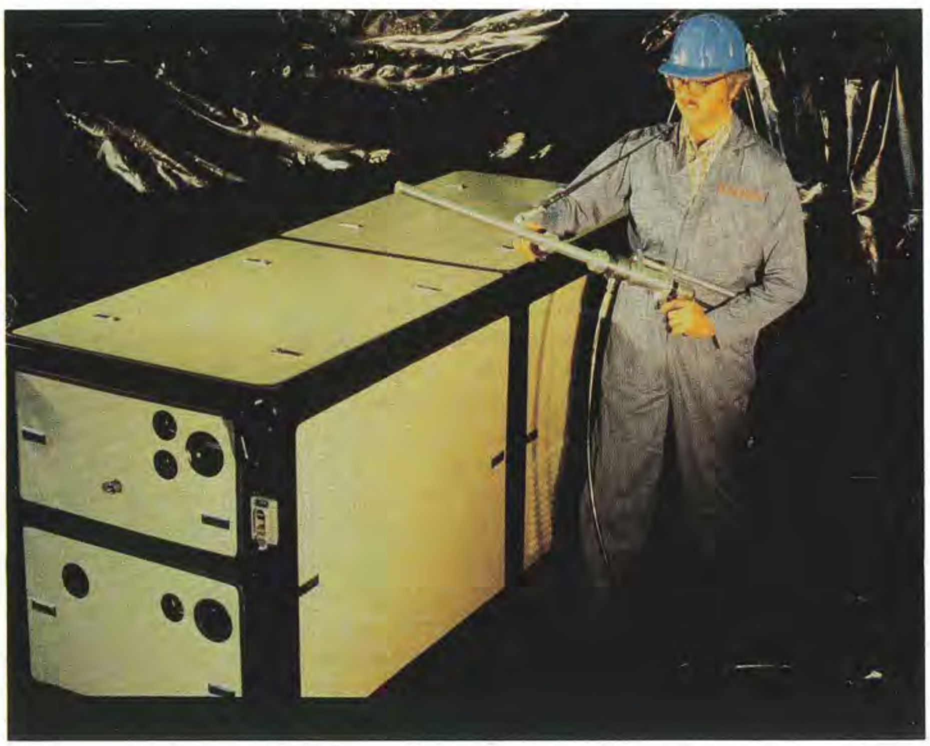
An NSF Small Business Innovation Research (SBIR) grant was instrumental in developing a high-pressure water drill that helped save a life in October 1987.

World attention was focused on 18-month-old Jessica McClure, trapped inside a well in Midland, Texas. When other oil-drilling equipment—including a diamond drill—failed to rescue her, a special water-powered drill was rushed to the scene. The drill, which sprays a fine, high-pressure jet of water at 2,900 feet per second (two to three times the speed of a bullet), slices through rock quickly by eroding the surface. In just two hours, the drill had cut a hole two feet in diameter through three feet of extremely hard caliche limestone rock, where the baby was trapped in the well shaft. An hour later, the child was free.

The special drill was supplied by ADMAC, a spinoff of Flow Technology Company of Kent, Washington. Flow Technology, a minority-owned firm, received an NSF grant in 1980 for research on the high-pressure water drill, a tool with a novel design that had at first been greeted with skepticism. While further development and financing were required to commercialize the drill, the NSF-funded research initiated the innovative technology and encouraged the company to continue its efforts.

Flow Technology has received other SBIR grants in the field of abrasive metal cutting, surface materials, and robotics. The company has leveraged this research support to market commercial products.

For more on SBIR grants, see chapter 3.



Life-saving equipment. An ultrahigh-pressure pump and jet lance, similar to what is shown here, powered the waterjet rock-cutting system used to free Jessica McClure from a well in Midland, Texas. NSF was instrumental in early funding of the research that produced the ultrahigh-pressure nozzles and related technology used in the rescue. Second photo shows pump that is inside large box.

CHAPTER 1

INTO THE 1990's

Natural curiosity—the unwavering instinct to know how and why—is often the driving force behind basic research in science and engineering. But from Isaac Newton's discovery of the universal law of gravitation to the wonder of the Wright brothers' triumphant liftoff at Kitty Hawk, the study of science and engineering has done more than merely satisfy the intellect. Efforts in science and engineering improve our economic competitiveness with other countries, provide better health care for the nation, and form the basis of our national defense.

Against this backdrop, the mission of the National Science Foundation is indeed a challenge. For among all federal agencies, it is the Foundation's charge to promote science and engineering in general and support basic research across all fields and disciplines.

In 1987, NSF focused on several new issues and continuing concerns:

• **Economic Competitiveness.** In 1987, the need for the United States to compete in the world marketplace received new recognition. Revolutionary findings in superconductivity research highlighted the vital link between science and technology in creating new and competitive products. Moreover, mounting trade deficits with foreign nations, concern over inroads made by Japan and other countries in producing new technologies, and a shrinking supply of American college students pursuing science careers spurred action by the President, private groups, and Congress.

In the U.S. Congress, the Senate and the House of Representatives established a joint, bi-partisan Caucus on Competitiveness to formulate new legislation. Among two new private groups, the Council on Competitiveness examined issues ranging from ways to decrease the trade deficit to increased support for NSF; the Council on Research and Technology, a group whose members include universities and private research firms, began to study national R&D policy.

For its part, NSF embarked on a joint effort with the National Governors' Association and the Conference Board, a national organization of business groups. Together they examined the way economic competitiveness is perceived at the state level by industry, universities, and state officials. This activity had two components: a national survey, followed by regional discussion forums.

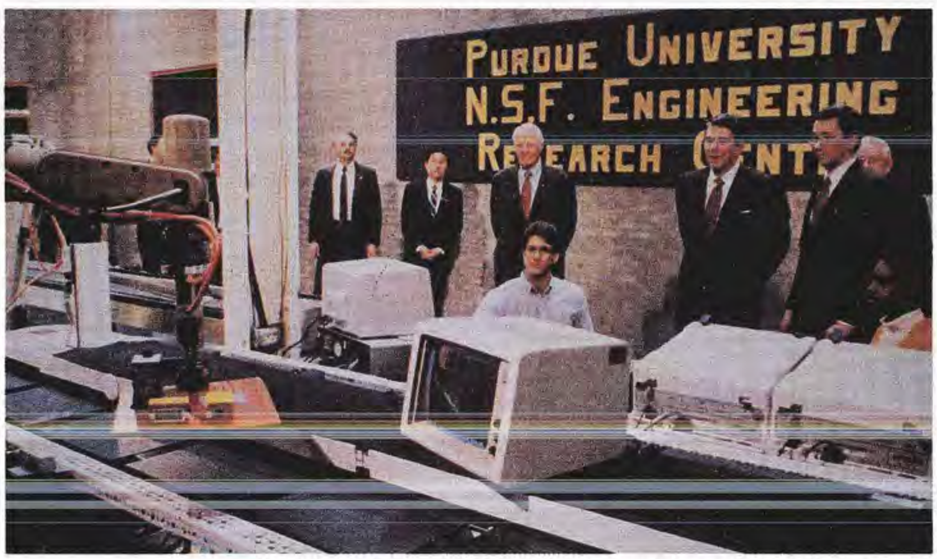
The survey identified several areas in which the United States must increase its investment in order to remain competitive. These include science and mathematics education, university/industry cooperative ventures, and greater commercialization of research findings. Moreover, these investments should be long-term, the survey report said.

Present and future tools. Supercomputers will continue to be valuable scientific tools. This Cray supercomputer is at the University of Illinois.


CRAY
CRAY

Star Ledger

State partner. In April 1987 New Jersey Governor Thomas H. Kean spoke at a regional conference at the AT&T Bell Laboratory in Holmdel, N.J., on the role of science and technology in economic competitiveness.



Presidential visit. President Reagan watches robotics demonstration at the NSF-supported Engineering Research Center at Purdue University.

Purdue welcome. At Purdue University's Engineering Research Center, the President shakes hands with Henry Yang, Dean of Engineering.

Along with these efforts, NSF also launched a pilot project to strengthen communication links with states. Initial efforts focused on four states in particular: Michigan, New Jersey, Arkansas, and Utah.

Focusing on the state level has provided better understanding of state policies and activities supportive of science and engineering research and education, and identified points of common interest with NSF. The states initiative also gave NSF a first-hand look at how the states are working with universities and industry to link research and education with their plans for economic development. This initiative is described further in chapter 2.

Also at the state level, NSF continued its Experimental Program to Stimulate Competitive Research (EPSCoR), begun in 1979 to aid states that lack large resource bases for research. A recent EPSCoR grant to the University of Alabama at Huntsville supported breakthrough research in superconductivity (see "Highlights" section).

• **Growing Emphasis on Interdisciplinary Research.** Some of the most significant problems in basic research are at the boundary between established disciplines. For example, advances in biotechnology, materials research, and information science depend on scientists and engineers with a variety of disciplinary skills, and research environments that encourage new types of collaborations. Recognizing this, NSF extended the number of its Engineering Research Centers, which stress an interdisciplinary approach, to 14 as of late 1987 (See chapter on centers and groups). In addition, NSF initiated a new centers program in biology; awards totalling $10 million for laboratory equipment resulted in "mini-centers" for biology at 20 campuses. And the Foundation began a program called Opportunities for Research in Computational Science and Engineering. This effort encourages the use of advanced computing techniques in collaborative research among mathematicians, engineers, physicists, chemists, and other scientists.

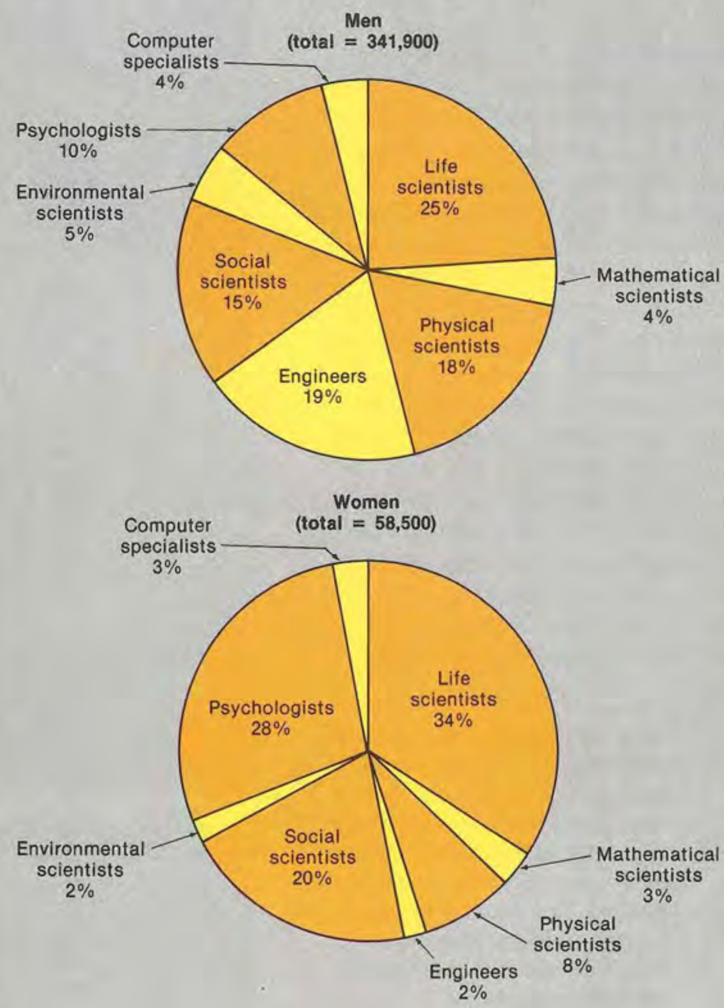
• **Expanding Human Resources.** Important parts of NSF's mission are to encourage young people in science education and to help ensure that talented women and members of minority groups are exposed to science and engineering careers and attain positions commensurate with their abilities. Faced with current faculty retirement rates* and the continuing decline of 22-year-olds — the main group from which future scientists emerge — increased participation by women and minorities may be a key way to avoid a future shortfall of scientists and engineers.

To assess the current status of women, minorities, and disabled persons in the sciences and develop long-range plans to advance their opportunities, the federal Office of Science and Technology Policy** appointed a new interagency task force in FY 1987. Members of the Task Force on Women, Minorities, and the Handicapped in Science and Technology are from NSF and other federal agencies concerned with R&D issues, private business, academia, professional associations, and nonprofit groups. They will report on their findings on or before December 31, 1989.

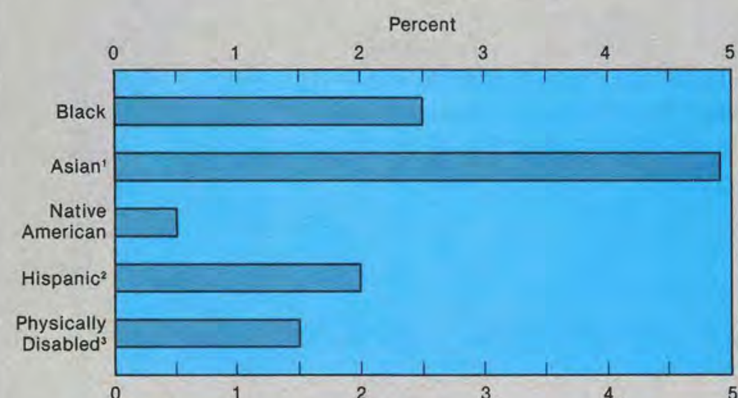
*A large segment of faculty will reach retirement age during the next five years, especially in civil and electrical engineering, physics, mathematics, and economics. See NSF Highlights No. 87-310, *Recent Doctorate Faculty Increase in Engineering and Some Science Fields* available from NSF, Division of Science Resources Studies, 1800 G St. NW, Washington, DC 20550.

**OSTP is headed by the President's Science Adviser.

Employed doctoral scientists and engineers by field and sex: 1985



Minorities as a percent of employed scientists and engineers: 1986



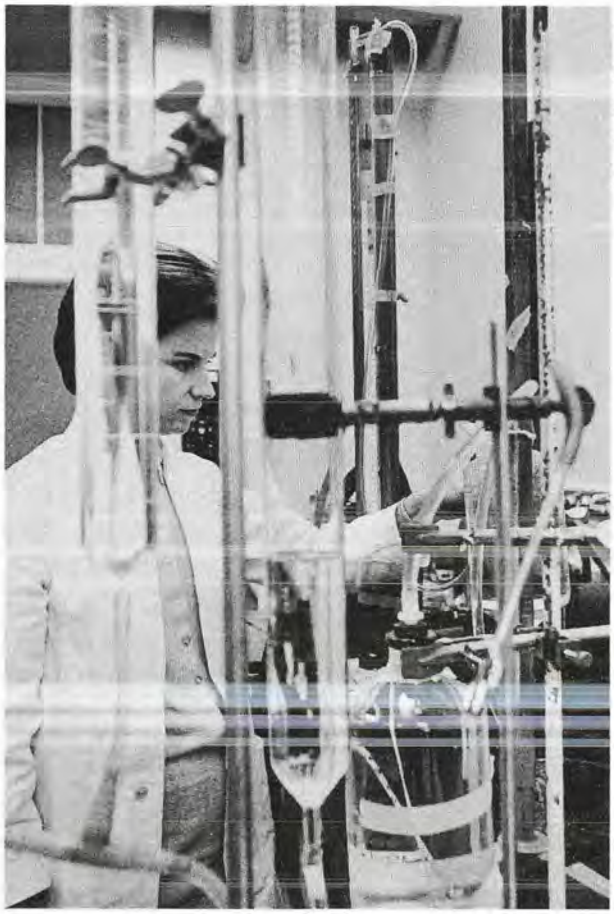
[1]In 1986, about 27 percent of all Asian scientists and engineers were not U.S. citizens.
[2]Includes members of all racial groups.
[3]Includes members of all racial/ethnic groups.

Source: *Women and Minorities in Science and Engineering*, Jan. 1988, NSF 88-301

Another group, the Congressionally appointed Committee on Equal Opportunities in Science and Engineering (CEOSE), currently advises NSF on ways to boost the participation of minorities, women, and disabled people in scientific and technical careers. In a 1986 report, CEOSE praised many ongoing and new NSF efforts to promote equal opportunity, including awards in engineering for disabled, minority, and women researchers; Visiting Professorships for Women; and grants for minority researchers and minority institutions. At the same time, CEOSE recommended that Congress reevaluate the need for a number of programs that NSF discontinued in the early 1980's, including Student Science Training programs.

We must significantly increase minority participation in science and engineering. And we must do so not just for reasons of equity, although equity is clearly a fundamental concern. The reasons are just as much related to national need and the challenge to our economic competitiveness.
—John H. Moore, NSF Deputy Director (speech to White House Conference on Historically Black Colleges and Universities, Sept. 1987)

During 1987, NSF also bolstered its long-term commitment to science education. For example, the Foundation launched a major new effort to upgrade the science curriculum from kindergarten through grade 12. At the college level, NSF began a program to



Johns Hopkins Magazine

Working woman. Increased participation by women and minorities in basic research may be crucial to avoiding a future shortfall of scientists and engineers.

Future scientist at work

give students, while still undergraduates, the opportunity to conduct research in science and engineering. Projects involving women, minority students or persons with disabilities are given high priority for support. And another NSF initiative in 1987, "Awards for Creative Engineering," gives research grants to engineering undergraduates and recent graduates based on creative ideas submitted in a research plan, rather than judging them solely on their academic record. See chapter 2 for more on these and other human resources efforts.

• **Continuing Issues.** Boosting support for basic research remains the Foundation's key priority. In the 1970's basic research gave us a rapidly developing biotechnology industry and taught us how to design high-speed supercomputers. And research dating back to 1911 paved the way for the recent technological breakthrough in superconductivity.

The challenge for NSF is twofold. At a time when the need for basic research is greater than ever, funding for academic R&D may have to double over the next decade just to maintain activities at current levels. Increased funding, ongoing NSF support of collaborations between universities and industry, continuing international cooperation and exchange of ideas, and the sharing of expensive equipment at universities may help smooth the road ahead for campus research.

Biotechnology—another face of science in the 1990's. Here a tobacco plant's genetic makeup was altered by introducing a firefly gene into the plant's DNA.

Children's TV Workshop

Science as fun—early exposure in the classroom

CHAPTER 2

HUMAN RESOURCES AND EDUCATION

Education is the great American adventure, the largest public enterprise in the United States, the country's most important business.

—Mary McLeod Bethune

Boosting the scientific and technical education of our nation's young people is one of the National Science Foundation's major responsibilities. Although NSF funds graduate-level education, supporting students who will become Ph.D. scientists and engineers, the Foundation also has programs at the elementary, secondary, and undergraduate levels. These efforts help to strengthen the quality of instruction in the sciences and mathematics.

In addition, NSF is committed to increasing the number of women and minorities in science and engineering careers, a goal that may be crucial to bolstering our economic competitiveness with other countries. NSF data show that employment of scientists and engineers grew three times as fast as total U.S. employment over the past decade, yet the proportion of college seniors who majored in the sciences is smaller today than it was in the 1970's. Efforts to attract a larger share of women and minorities in science classes and careers may help to compensate for a projected shortfall of scientists and engineers.

As part of a federal interagency task force set up in 1987, NSF has studied the role in science of women, minorities, and people with disabilities, considering new ways to advance their opportunities. NSF efforts in this area may never have been more urgent: the American Council on Education has termed declining college enrollments among Blacks a "national crisis," and the gains of women in science and engineering over the past 15 years now appear to be slowing, according to a special issue of NSF's *Mosaic* magazine, "Education and the Professional Workforce."*

Some NSF responses to the nation's human resource and educational needs include these activities:

PRECOLLEGE EDUCATION

There once was a time when the absence of a high school diploma and basic skills was not an obstacle to employment in certain occupations. Now those occupations are disappearing. Employment in the modern world increasingly demands basic literacy in science and mathematics. Yet nearly 30 percent of the nation's high schools offer no courses in physics, 17 percent none in chemistry, and 70 percent none in earth or space science.

The vast numbers of high school students take few mathematics or science courses. In comparative tests in subjects such as geometry, U.S. students were outscored by those of other

**Mosaic*, Spring 1987, Vol. 18, No. 1 (See article on "Women's Progress," by Betty M. Vetter, p. 2)

Early Learning Co.

Early learning about science

nations and often placed last. One recent international study* found that U.S. elementary and high school students, especially girls, know less about science than their counterparts did in 1970. Moreover, they lag behind British and Japanese pupils in physics, chemistry, and biology.

In short, too much of the population is unprepared to function productively in our increasingly complex and technological world. A survey conducted for the NSF in 1986** found that large numbers of Americans do not understand basic scientific terms such as "molecule" and "radiation." As NSF Director Erich Bloch has commented, "What is at issue here is not lack of interest; it's lack of opportunity. More explicitly, it is a lack of quality in the institutions on which we depend."

Curriculum Grants

In its continuing effort to improve that quality, NSF's Directorate for Science and Engineering Education announced in 1987 a new program to greatly expand and upgrade science education in grades kindergarten to 12 over the next four years. The new NSF program, which began with three curricula grants totalling $6.6 million, emphasizes student participation in science experiments and seeks to relate lessons from other subjects — language, arts, and mathematics — to science.

For example, instead of demanding that young children memorize facts about acids, one of the NSF curricula grants encourages students to learn the concepts by studying acid rain, collecting rain in their backyards and measuring its acidity. In conjunction with the National Geographic Society, this grant supports children at 4000 schools nationwide as they collect and enter information on a central computer, which enables them to compare and compile within days data from across the country.

A novel feature of the program is that each of the four-year curricula grants is matched by publishers who work with the schools to develop and test new teaching materials, then train teachers to use them. The early involvement and commitment by publishers help to ensure that the course plan designed by researchers will actually be adapted for everyday use in the classroom. Publishers, which include the National Geographic Society and the Kendall/Hunt Publishing Company of Dubuque, Iowa, will devote 5 percent of their revenues from sales of the printed curriculum to teacher training and support.

Improving Middle School Teaching

NSF also awarded grants to nine universities and colleges to improve programs to prepare middle school teachers in science and mathematics. The goal of this NSF program is to foster a close collaboration among

*The International Association for the Evaluation of Educational Achievement, located at Columbia Teachers College in New York City, based these findings on research done in 1983 and 1986.

**See *Science and Engineering Indicators — 1987* (National Science Board, 1988).

On display. Seventh- and eighth-grade students from Lincoln Park Community School in Somerville, Massachusetts show off their science project at Lesley College. Lesley is one of several colleges and universities that have received NSF grants to improve middle school science and mathematics teaching.

The shape of things. Portland State University's Marjorie Enneking (center) discusses ways to teach geometry with prospective middle school math teachers Sandra Sump (left) and Anne Ryan (right).

Rose Nichols

Hands-on experience. Amy Barber, a middle school math and science teacher, discusses a science project with a student. They are attending a special evening program at Lesley College in Cambridge, Massachusetts.

science professionals, university faculty, and school personnel in developing model courses for training elementary, middle, and secondary school science and mathematics teachers.

Each of the nine projects includes special features. For example, the NSF grant to Lesley College, a college for women, focused on attracting women to teaching careers in mathematics and science. And a grant to Oregon's Portland State University developed a model to prepare math and science teachers in urban schools.

Private sector partnerships. A high school teacher and an industry scientist explore polymer chemistry at an NSF-sponsored summer workshop at the DuPont Company Experimental Station in Wilmington, Delaware.

Private Sector Partnerships

To improve science and mathematics education in grades kindergarten to 12, this program encourages partnerships between business/industry, school systems, and other educational institutions. The overall aim here is to demonstrate ways in which community concerns can be translated into positive action to improve the quality of science and math education in American elementary and secondary schools. This program seeks to generate novel approaches and models in such areas as teacher enhancement, teacher preparation, education networks, research in teaching and learning, instructional materials development, informal science education, and applications of advanced technologies.

Summer Programs for Chemistry Teachers

Updating the skills of experienced teachers and strengthening the science background of new faculty can spark new enthusiasm for science teaching. Through special summer programs at five sites,* the NSF-initiated and supported Institute for Chemical Education (ICE) seeks to improve chemistry teaching at the middle and high school levels.

The program has three main activities: a six-week course upgrades the skills of high school science teachers assigned to teach chemistry but lacking a strong background in the field. Another summer course prepares middle and senior high school teachers to use demonstrations and laboratory equipment in chemistry courses, helping to enliven and underscore the lessons students learn in lectures. A third course updates the knowledge of experienced high school chemistry teachers in selected topics.

Math teacher. New Hampshire's Timothy Howell won a Presidential Teaching Award in 1984.

* The University of Arizona at Tucson, the University of Northern Colorado at Greeley, the University of Wisconsin at Madison, the University of Maryland at College Park, and the University of California at Berkeley.

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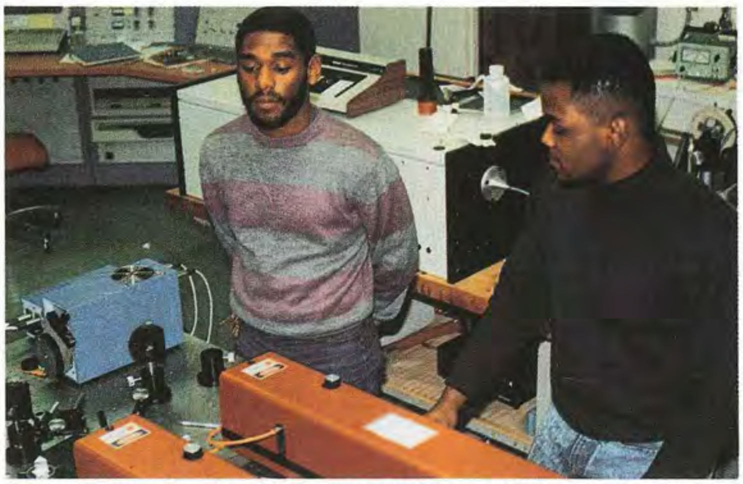
fold aim: helping women to further their science or engineering careers and encouraging other women to pursue such careers. Mathematician *Priscilla Greenwood*, the only woman in a department of 80 at the University of British Columbia, was one of the recent award winners; with her grant, she opted to spend 1987 at Johns Hopkins University. Greenwood, whose specialty is the study of random processes (a branch of probability and statistics) gave lectures and collaborated on research with Hopkins faculty.

Florida State meets Harvard. A special NSF grant for women scientists enabled Jill S. Quadagno, a sociology professor at Florida State University, to spend six months at Harvard University.

Minority Research Initiation. A graduate student in the solid-state electronics laboratory at Howard University holds a high-speed optical shutter made from silicon carbide.



Research opportunities. Student researchers conduct experiments in the laser spectroscopy laboratory at Howard University. They are funded under NSF's Minority Research Initiation program.

Research Improvement in Minority Institutions. At the University of Puerto Rico-Rio Piedras, NSF-supported mathematics staff and researchers work on the Alliant computer.

Visiting scientist. Juana V. Acrivos, a professor of chemistry at San Jose State University, was awarded an NSF Visiting Professorships for Women grant to spend a year in the chemical biodynamics laboratory at the University of California, Berkeley. Her disciplinary area is solid-state chemistry.

Astronomical visit. Alice L. Newman, a member of the technical staff of the Aerospace Corporation in Los Angeles, has broadened her research experience during a one-year stay at Cornell University's Department of Astronomy. The visit was made possible by an NSF Visiting Professorships for Women grant.

Sea change. An NSF grant gave Ellen R. Druffel, a marine chemist at the Woods Hole Oceanographic Institution in Massachusetts, the opportunity to spend a year at the University of California at Santa Cruz.

• In 1987 NSF announced the first two grants under its Minority Research Centers of Excellence (MRCE) program, a new initiative to address the continuing shortage of minority scientists and engineers in fundamental research. In addition to supporting qualified scientists, the MRCE's also seek to attract talented minority students to careers in science and engineering through scholarships and new research opportunities.

Researchers at Howard University's MRCE in Washington, D.C. will investigate materials important in telecommunications, defense, and industrial applications. At Meharry Medical College, the MRCE will establish a cellular and molecular biology research center focusing on three areas: studies of DNA reproduction critical to viral infection and mutations, enzyme studies that may provide a better understanding of fat metabolism, and upgrading of a neurobiology laboratory. The Meharry center will provide scholarships and research programs for high school students as well as undergraduates.

In an effort to boost research at schools that offer few advanced degrees, NSF funds several activities. For example, the Predominantly Undergraduate Institutions Program supports research at institutions that awarded no more than 20 science and engineering doctorates in fields supported by NSF during the past two years. The Research in Undergraduate Institutions initiative funds scientists at these institutions who work in departments that do not offer the doctoral degree. And Research Opportunity Awards enable science and engineering faculty to collaborate with NSF-funded investigators at better-equipped research universities.

Finally, there is an experimental program called University/Industry/Government Partnerships for Quality Engineering Personnel. The emphasis here is on incorporating major elements of engineering practice into engineering curricula, enabling students to be taught by adjunct faculty with a practical engineering orientation. In many cases, the partnership provides university students with industrial or other facilities and equipment used by the practicing engineer.

OUTREACH TO THE PUBLIC

National Science and Technology Week

In parallel with NSF's array of awards and fellowships to upgrade science education and research in schools and universities, the Foundation also supports activities that boost the public's awareness of science. Among these activities is National Science and Technology Week (NSTW).

The goals of NSTW are twofold: to raise public awareness of science, engineering, and mathematics, and to encourage young people to seek careers in these areas. A major component of NSTW 1987, held April 5-11, was the distribution of 130,000 education packets, one to every elementary and middle/junior high school in the country. The packets contained suggested teaching activities with hands-on experiments for students; science and mathematics teachers were trained to use the packets effectively at pilot workshops across the country.

Pam Shapiro

"Today" applauds tomorrow's scientists. NBC "Today" weather reporter Willard Scott congratulates winners of the New York science fair at the AT&T Infoquest Center in New York City. The contest was one of many events linked to National Science and Technology Week 1987.

Patrick Olmert

Spreading the word. Some 130,000 teaching kits—as well as posters and "how to participate" brochures—helped bring attention to National Science and Technology Week 1987.

Other NSTW activities: The New York Academy of Sciences coordinated a national "Art of Science" competition for high school seniors (see "Highlights"). In Texas, a science and technology festival highlighted the contributions of local research corporations and universities. And nationwide, children in more than 600 schools kicked off the week by releasing 250,000 balloons with attached weather cards. Data from the nationwide experiment indicated wind and weather patterns and were sent in a postlaunch packet to participating schools.

In addition, the beauty and variety of life on earth and the complex issues surrounding its survival were the focus of a travelling exhibit first made available during NSTW. The exhibit, entitled "Diversity Endangered," was produced by the Smithsonian Traveling Exhibition Service, with support from NSF.

National Science & Technology Week activities will increase awareness of the vital role science and science education play in improving our economic competitiveness, and our quality of life. Today science is not a part of the basic curriculum in many U.S. elementary schools. We're working to correct this.
— Erich Bloch, Director
National Science Foundation

States Initiative

In view of the increasing importance of cooperation and cost sharing — and recognizing the growing role of the states in supporting science/engineering research and education — the Foundation is working to strengthen communication with state governments. A recent effort — initiated by NSF's Office of Legislative and Public Affairs — began with a pilot project in four states: Arkansas, Michigan, New Jersey, and Utah. These states were chosen for their geographic representation, their diverse economies, the range of research and educational resources available to their leadership, and their strong commitment to pursuing excellence in research and education.

This project enabled NSF to establish contact with key people and organizations in each of these states, discuss mutual concerns, exchange information and ideas, and focus attention on national needs in research and education for science and engineering. The project also offered a first-hand look at how the states are working with universities and industry to link research and education with their plans for economic development. The effort is expanding to other states, and close ties have developed between NSF and the National Governors' Association.

Museum Programs

It was in 1970 that NSF made the first grant for a different kind of museum, one where people would learn by exploring, touching, experiencing, and trying to explain. Today, after years of NSF support, centers such as the San Francisco Exploratorium have become the standard for science museums throughout the world. NSF-funded museums have even entered the formal teaching business — for example, the Lawrence Hall of Science in Berkeley, California developed materials for Boy Scout and Girl Scout leaders to teach outdoor biology.

NSF provides seed money for a variety of new science museum programs. At the St. Louis Science Center, NSF funds have helped develop a science playground to teach children about motion, energy, light, sound, and the natural environment. The physics of motion can be explored through such devices as a friction slide, gravity hoop, and the familiar roller coaster ride. Children learn about energy by exploring watermills and the subject of water power; playing with kaleidoscopes teaches them about the nature of light.

St. Louis Science Center

The friction factor. In this exhibit, two balls race down a circular track; one is partially filled with sand and the other is solid. Because of internal friction, the sand-filled ball soon stops accelerating and the solid ball always wins the race.

St. Louis Science Center

Gears and gizmos. At the St. Louis Science Center, visitors learn how gears drive six different assemblies, including a clock, giant puppet, and laser-etched disk.

Strings attached. Teachers use wiffle balls and string to demonstrate the gravitational force between the earth and moon. They are participating in the Franklin Institute's Teacher Overnight Science Program in Philadelphia, PA.

Erwin Gebhard, courtesy of *Milwaukee Journal*

Setting up exhibit materials at the Milwaukee Public Museum

Richard Hoyt

A touching experience. Children pet a reptile at "Animals in Action," an activity at the Lawrence Hall of Science, University of California at Berkeley.

In addition to providing monetary support, NSF helped establish the first association of these science centers (the Association of Science-Technology Centers), so that informal educators could share their ideas and learn from one another. As a result, science museums today routinely collaborate on projects and ensure that travelling exhibits reach millions across the United States.

Television

NSF also provides key support for several television science series. During 1987, NSF gave the award-winning science program *NOVA* a special grant for an hour-long show on Supernova 1987A, the most important stellar explosion of its kind since the time of Galileo (see "Highlights" section).

NSF also supported the filming of "Stand and Deliver," a Public Broadcasting System (PBS) drama that chronicles the real-life success of Jaime Escalante and his nationally acclaimed mathematics program at Garfield High School in Los Angeles. Overcoming crime, poverty, and a 50 percent dropout rate, Mr. Escalante transformed his Hispanic students into some of the top calculus students in the country and helped turn Garfield High into a magnet school for science and math. The program stars Edward James Olmos, Emmy award-winning star of the *Miami Vice* television show. "Stand and Deliver" is being aired in both English and Spanish as part of PBS's *American Playhouse* series. (It was also released by Warner Brothers as a feature film in the spring of 1988.)

Mitzi Trumbo; © Warner Brothers Inc., 1988

Math teacher recognized. NSF supported the filming of "Stand and Deliver," a drama that chronicles the real-life success of teacher Jaime Escalante (right), from Los Angeles' Garfield High School. Escalante, played by *Miami Vice* actor Edward James Olmos (left), helped his students become some of the top calculus students in the country, turning Garfield into a magnet school for science and mathematics.

Tony Friedkin; © Warner Brothers Inc., 1988

Edward James Olmos, portraying mathematics teacher Jaime Escalante, holds an award as he is surrounded by students.

Children's Television Workshop

Dynamic duet. Mathwoman (Beverly Mickins) and Robert (Luisa Leschin) are two of the many characters who deliver messages about mathematics to children on *Square One TV.* The daily series for 8 to 12-year-olds began in 1987.

NSF continues to fund *Reading Rainbow*, the PBS series that introduces children to books through book reviews that combine reading aloud and displaying illustrations from the text. NSF support helped to produce five programs devoted to science books and science topics. NSF also funds one of PBS's latest educational efforts, *Square One TV*, designed to promote a greater enthusiasm for mathematics among the nation's third to sixth graders. This group may be crucial to reach: studies indicate that while most children enjoy arithmetic through grade three, their interest wanes starting in the fourth grade as they are exposed to long division, compound fractions, and other more complicated functions. By middle school, students may already be turned off on mathematics.

During a typical *Square One* episode, a rock group weaves square numbers into the lyrics of a zany song; a parody of a soft drink commercial delivers a lesson about subtraction; and the sign maker at Harry's Hamburger Haven teaches the viewer about decimals. Each half-hour show ends with an episode of "Mathnet," in which lead characters use math and problem-solving techniques to solve mysteries such as "The Problem of the Trojan Hamburger." Preliminary comments from more than 3500 children around the country helped shape the format and content of this program.

NSF also helped fund *The Ring of Truth*, a six-part series that gave a personal view of science through the eyes of noted physicist and science writer Phillip Morrison and his wife Phyllis Morrison, a distinguished science educator. The series first aired on PBS during the fall of 1987.

3-2-1 Contact. **Co-host Debra Shapiro visits New York's Cathedral of St. John the Divine to learn how a building arch is designed and constructed. This television show is supported in part by NSF and is aimed at 8 to 12-year-olds.**

Contact **visit. David Quinn and Kaori Tomita, from television's *3-2-1 Contact*, visit the Skiji Fish Market in Tokyo to learn about the different kinds of fish that make up a typical Japanese diet.**

Special Outreach Programs

In 1978, Joan Humphries, an Equal Opportunity Manager at NSF, and Oceola Hall of NASA established an interagency committee for women scientists and engineers, known as WISE. The purposes of WISE are to encourage women scientists and engineers to seek careers and advance in the Federal Government; to encourage young girls studying science and math to pursue scientific or engineering careers; and to ensure that excellence in female scientists and engineers is recognized.

Joan Humphries

As part of its annual national training conference, WISE sponsors a day-long program for talented 9th- and 10th-grade girls in the Washington, D.C. area. The group also presents three national awards recognizing the outstanding accomplishments of federally employed women scientists and engineers.

NSF staff members also participate in the Washington, D.C. chapter of Minority Women in Science (MWIS). The local chapter, part of a national network established in the 1970's, provides a communication and support system for minority women who are researchers, educators, or administrators in the fields of science and engineering. Since 1980, the D.C. chapter has sponsored "Science Discovery Day," in which junior high school students, their teachers, and parents meet and talk with MWIS members.

Other MWIS activities include:

- A workshop for precollege teachers, held annually since 1981;
- A speakers' bureau for local educational events and programs;
- A science fair and provisions for monetary awards and certificates for outstanding science projects.

Finally, there is outreach to university faculties. Foundation staff members make a special effort to reach out to their clientele by making presentations about NSF and its programs, and by conducting proposal development workshops. These may be visits to single institutions, often in conjunction with other official travel, or more formal colloquia/workshops, sponsored by a college or university acting as host for regional institutions. In 1987 formal regional colloquia were presented at institutions in 22 states, followed by informal one-to-one sessions as time permitted.

Vittoriano Rastelli

Ring of Truth. **MIT physicist Philip Morrison and his wife Phylis, a science educator, host this series on science. They are shown here at Thomas Jefferson's Monticello, during a segment on mapping.**

CHAPTER 3

DISCIPLINARY RESEARCH

While emphasis and attention in disciplinary research may shift from one area to another, the unpredictable nature of scientific investigation requires that support be maintained in all disciplines. Whether it be research conducted at the chalkboard by a small group of scientists or at a proton accelerator shared by large teams of investigators, NSF-supported efforts continue to respond to the challenge of searching for new knowledge. Hand-in-hand with the Foundation's commitment to research is increased emphasis on interdisciplinary studies and on new forms of collaborations between government, universities, and industry. These themes are evident in NSF-funded research during 1987, as described in this chapter.

PHYSICAL SCIENCES/ MATHEMATICS

Astronomy: Arcs and Black Holes

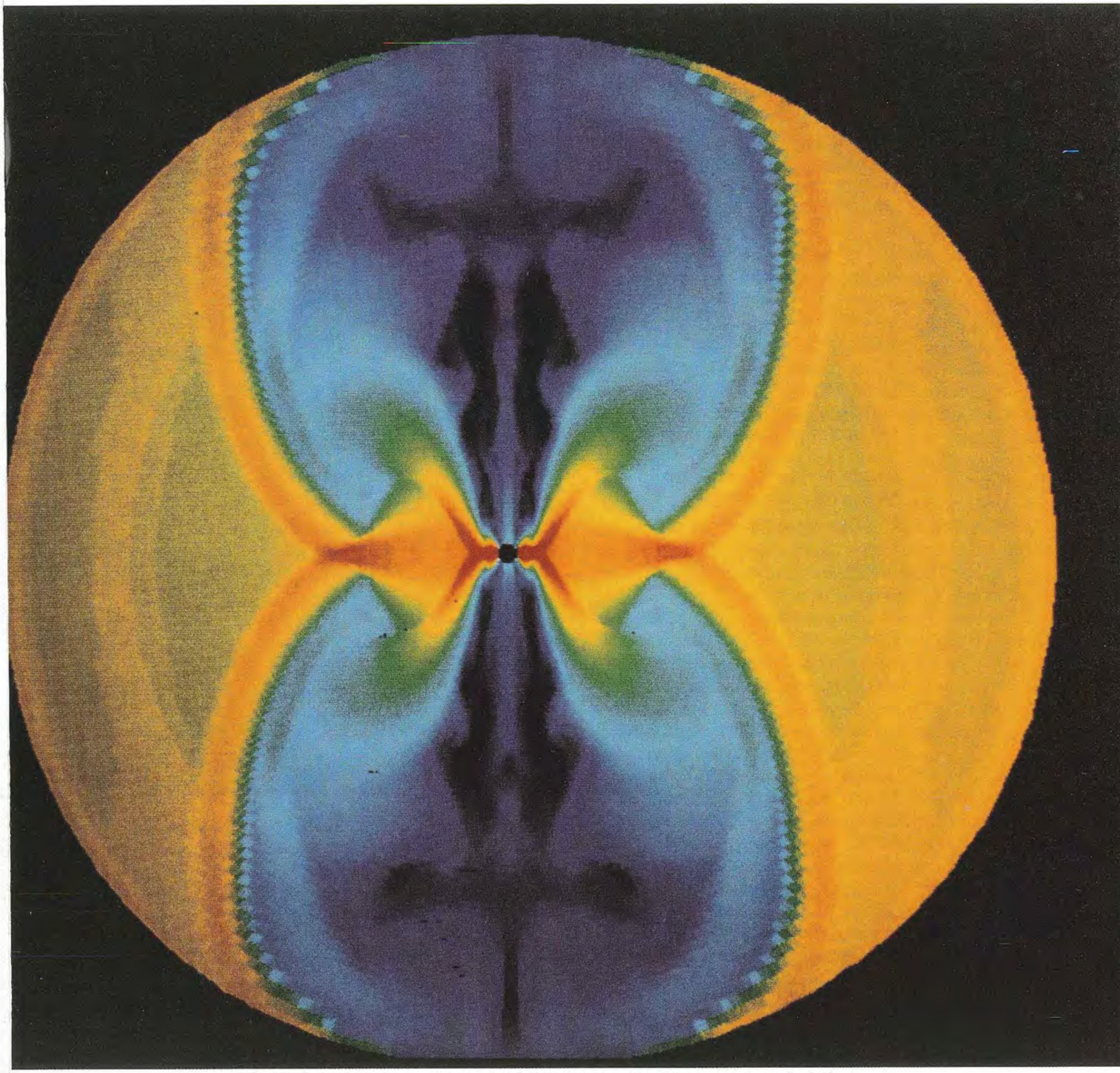
While the discovery of the most brilliant stellar explosion since the time of Galileo dominated the year in astronomy (see "Highlights"), the results of other NSF-supported research efforts also made headlines. For example, scientists using a telescope at Kitt Peak National Observatory in Arizona reported the sighting of giant blue arcs, trillions of miles long, that encircle at least two distant galaxies.

The arcs, some of which are three times as large as our own galaxy, the Milky Way, are the longest continuous features ever detected by telescope. Glimpses of the arcs were first sighted a decade ago, but their extraordinarily uniform structure was observed only recently with the help of the 157-inch (4-meter) reflector telescope at Kitt Peak and special electronic sensors. At first scientists thought that the arcs consisted of newly formed stars arranged along a curved shock front. However, at this writing they think that the arcs are images formed by a gravitational lens. In one case, the actual object is thought to be about twice as far away as the galaxies seen near the arc. The lens is probably a cluster of galaxies between us and the object.

In other research, an astronomer has found evidence that the Milky Way galaxy is part of a flat, oblong "supercluster complex" that encompasses millions of galaxies and stretches one-tenth the distance across the observable universe.

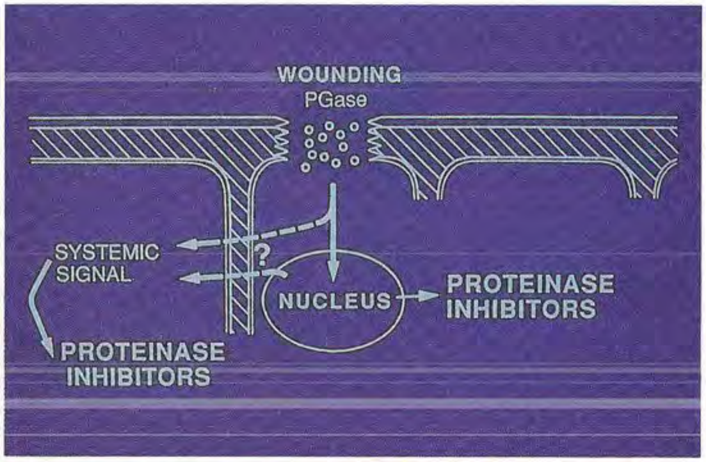
The supercluster complex is about 1 billion light years long and 150 million years across, according to its discoverer, *Brent Tully*, at the University of Hawaii's Institute for Astronomy in Honolulu. Tully has named the structure the Pisces-Cetus Supercluster Complex, after the constellations in whose direction it is found.

The evidence for the supercluster complex, 100 times more massive than any previously known structure, would suggest that, on this immense scale, galaxies are not randomly distributed throughout the cosmos, but are instead clustered in space in a way that is not anticipated by current conventional theories of galaxy formation.

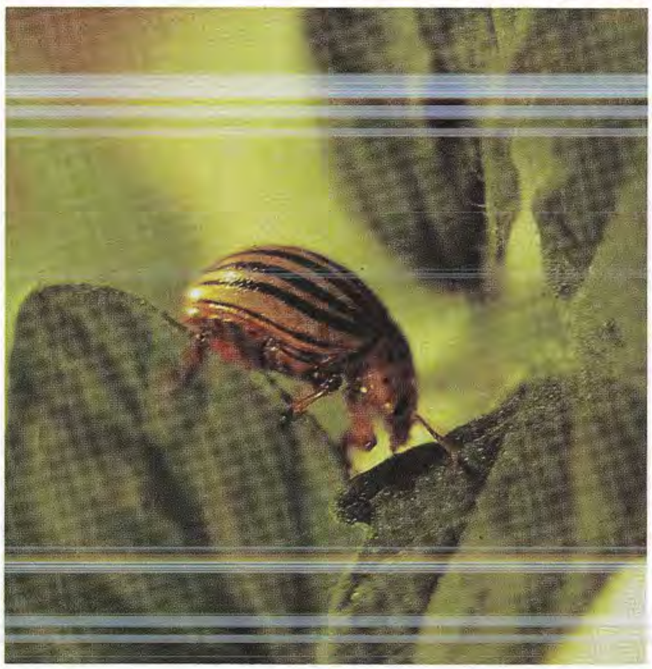


Black hole. In this supercomputer simulation, the round image represents a calculation of the accretion of rotating gas onto a black hole in space. (This supercomputer work was done at the National Center for Supercomputing Applications at Champaign, IL.)

Self-protection in plants. When wounded by insects, some plants protect themselves from further damage by triggering a series of chemical events, as shown in this hypothetical model.

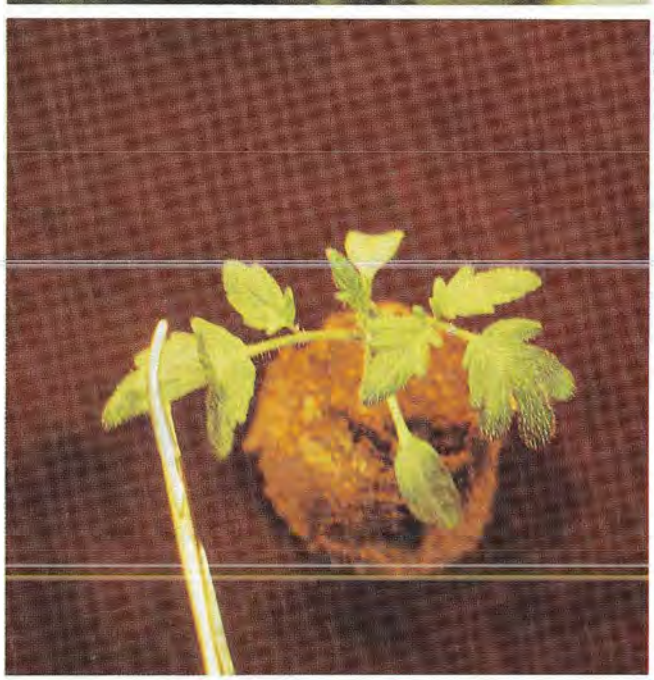


Protective mechanism. A Colorado potato bettle triggers the tomato plant it is feeding upon to release proteins that inhibit the insect's digestive enzymes. As a result, insects are discouraged from eating more of the plant.



Clarence Ryan

Laboratory predator. Crushing leaves with a hemostat in the lab simulates the damage caused by insect attacks.



C Ryan

Genetics of the Mustard Plant

A distant cousin to the common mustard plant, *Arabidopsis thaliana* is creating excitement in the community of scientists who want to understand how genes are regulated in plants and how, in turn, the genes regulate the life processes necessary to the plant. It has been difficult to study the molecular genetics of most plants because of the large amount of genetic material, the large number of DNA sequences which are repeated many times, and the long period of time needed to grow plants. *Arabidopsis* is changing that. First studied at the molecular level by *Elliot Meyerowitz* and his associates at the California Institute of Technology, *Arabidopsis* has been shown to have the smallest amount of genetic material of any plant known. (For example, the genome size for wheat is 5,900,000 kilobases, compared to 70,000 kilobases for *Arabidopsis*.) Furthermore, it has very few repeated DNA sequences, and, best of all, takes only five weeks to grow from a seed to an adult plant. All of these facts, plus 40 years of genetic information gathered in the past, make it possible for scientists to ask very specific questions and, they hope, get very specific answers.

Meyerowitz is continuing the molecular characterization of this plant by making a complete restriction map of the genome. The genome is the genetic material, and a map can be made by the use of enzymes (restriction enzymes) that cut only in very specific areas of the DNA. If enough different restriction enzymes are used, one has specific sign posts which can serve as markers to localize a gene within the genome. Such localizing is often a first step to cloning a gene, and cloning is often a first step to identifying both what it does and how it does it.

As a larger project, Meyerowitz and his associates are also studying flower development in this plant. His associate on the initial molecular characterization was a graduate student, *Robert Pruitt*. After obtaining his degree, Pruitt became an NSF Plant Postdoctoral Fellow. At this writing, he is at the University of Minnesota and plans to study male sterility in *Arabidopsis*.

Other scientists have begun to identify and clone genes in *Arabidopsis*. *Joseph Ecker* at the University of Pennsylvania (also previously an NSF Plant Postdoctoral Fellow) is interested in how plant hormones are synthesized and is using this weed to find out. *C. Sommerville* of Michigan State has cloned a gene and shown that a one base change in the gene causes *Arabidopsis* to become herbicide resistant. *David Meinke* of the University of Oklahoma has created a mutant that can no longer make biotin, a vitamin; he will undoubtedly clone the mutated gene in the near future.

One of the most exciting and potentially productive pieces of work being done with this organism is that of *Gerald Fink*, at M.I.T.'s Whitehead Institute. An NSF Plant Postdoctoral Fellow in his laboratory, *Robert Last*, has succeeded in creating an *Arabidopsis* plant—an auxotrophic or nutrient-requiring mutant—that will not grow unless a specific amino acid, tryptophan, is added to the medium in which it is growing. This is exciting because it has been extremely difficult to produce auxotrophic plants. The reasons for this are not known, but many scientists have tried to surmount the difficulties because of the immense body of knowledge accumulated by studying bacterial auxotrophs.

Moreover, in this experiment, the specific amino acid required, tryptophan, is thought to be a precursor for auxin, a plant hormone essential for normal plant growth. The mutant plant shows all the expected characteristics of a plant that lacks auxin, and it can be essentially rescued by the addition of tryptophan to the medium.

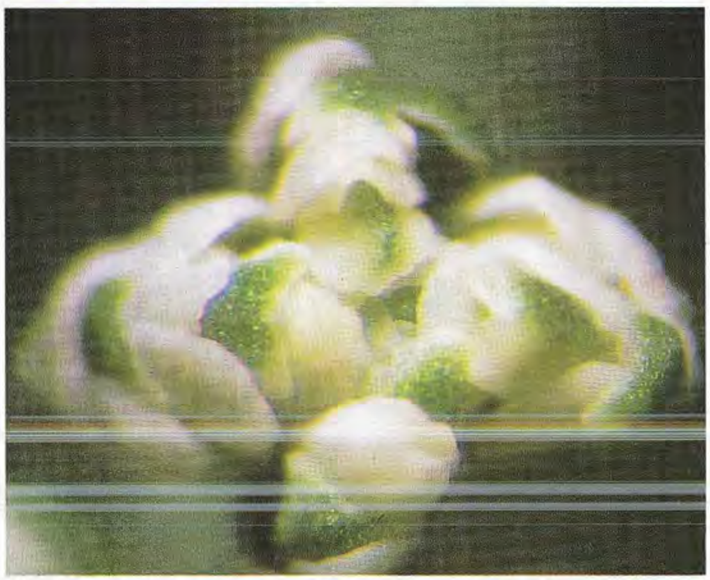
An interesting by-product of this mutation is the accumulation of a compound which cannot be converted into tryptophan because of the mutation and which causes the whole plant to fluoresce in ultra-violet light.

In a parallel study in the same laboratory, *Mary Berlyn*, an NSF Visiting Professor, has cloned the gene-encoding tryptophan synthesis, perhaps the same gene mutated in the fluorescing plant. The way is open for studying a biosynthetic amino acid pathway in plants; understanding how the gene encoding the mutated enzyme is regulated and how hormones act in plants; and perhaps gaining insight into the isolation of other kinds of nutritionally deficient plant mutants.

Arabidopsis is a weed. No matter what we learn or how we engineer it, we will probably never use *Arabidopsis* as a crop plant or eat it. However, what we do learn about the basic genetics and biology of this weed will have a great impact on the potential for bioengineering food plants.


Robert Paz, Caltech

Genetics team. At the California Institute of Technology, Elliot Meyerowitz (far right) and his research team study plant genetics.



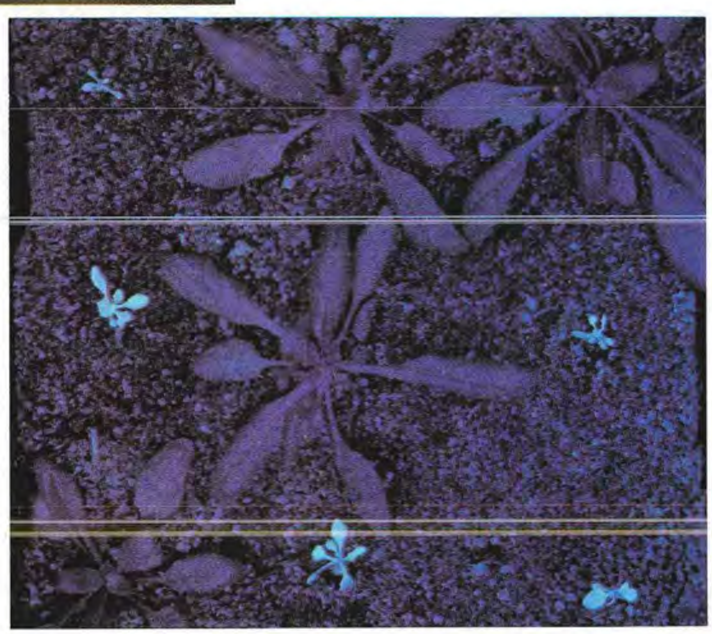
Plant watch. Researchers examine the *Arabidopsis* flower to understand genetic behavior. First photo shows normal growth; the four white petals, six anthers, and central stigma are visible. Second photo is a mutant flower of *Arabidopsis.* Genetic manipulations in the laboratory caused the flowers of this plant to consist of many whorls of petals and sepals, without the usual stamens or ovary.

Communication Between Cells

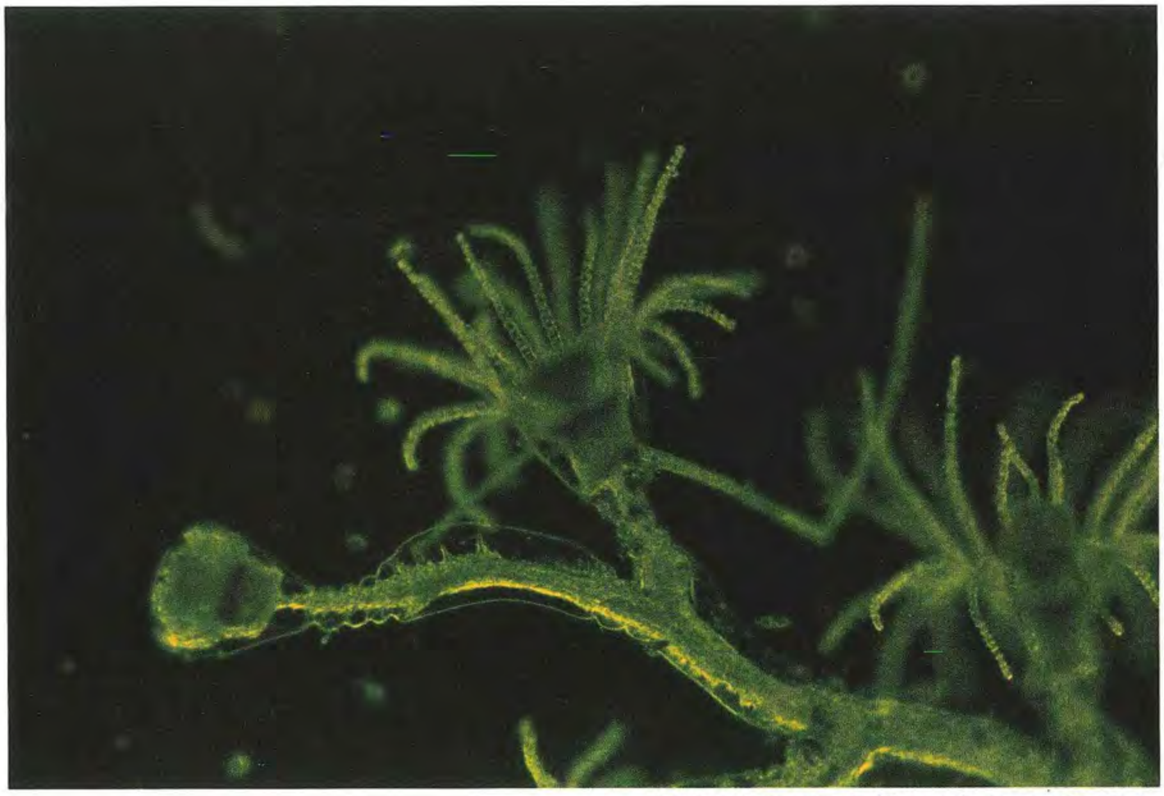
For years, scientists have studied the flashes of light emitted by a variety of biological species. Some marine organisms may emit light to ward off fish; other animals may use light to attract a mate or in response to chemical stimulation. But the details of how bioluminescence is triggered have remained a mystery.

Researchers *Kathleen Dunlap* and *Paul Brehm* at the Tufts University School of Medicine in Massachusetts have found new clues to understanding bioluminescence in studying a simple marine organism only two cell layers thick — the coelenterate. Certain cells of this organism emit short bursts of green light in response to increases in calcium intake.

Using a video camera connected to a microscope to record the exact location of the tiny light bursts, the scientists found that the first regions of the cells to light up were those in direct contact with nonluminescent cells that produce a small electrical signal when stimulated. When direct contact between the nonluminescent cells and the light-emitting cells was blocked, no light was emitted. According to the researchers, their work is supporting evidence that the connecting structure between the two types of



Mutation in plants. *Arabidopsis thaliana,* which are mutant for tryptophan biosynthesis, fluoresce under ultraviolet light because of the accumulation of an intermediate compound. The nonmutant plant in the background (large dark blue objects) does not fluoresce. The mutant plants (small, light blue objects) were isolated by Robert Last, an NSF Plant Postdoctoral Fellow working in the laboratory of Gerald Fink, at MIT's Whitehead Institute.



Luminescent animals. The coelenterate *Obelia* is the organism in which Kathleen Dunlap and Paul Brehm have been studying the control of bioluminescence.

cells, known as a gap junction, plays a crucial role in triggering the flashes of light.

Because no electrical voltage change has been detected in the light-emitting cells, scientists believe that it is a chemical signal rather than an electrical one that flows through the gap junction to trigger the light flashes.

This research, which provides the first evidence that a chemical passes through gap junctions to stimulate bioluminescence, highlights the importance of chemical signals in communication between cells.

GEOSCIENCES

Polar Programs

NSF-supported basic research in the antarctic and arctic regions explores polar ecology and biology, meteorological processes, climate history, glacial dynamics, regional geology and its global significance, the influence of polar oceans in global weather and climate, and sun-earth interactions. NSF funds and manages the United States Antarctic Program, which stresses science as the principal expression of U.S. interest in Antarctica, under an international treaty. The Foundation is also the lead U.S. agency on the Interagency Arctic Research Policy Committee, discussed later in this section.

A 1985 report by British scientists that the stratospheric ozone over Antarctica is depleted by as much as 50 percent during the austral spring has generated intense research interest, including two National Ozone Expeditions to McMurdo Station on the antarctic coast (see "Highlights").

In another NSF-backed antarctic project, atmospheric physicists have been investigating the earth's magnetosphere. From a special transmitter at Siple Station, they send very-low-frequency electromagnetic waves into the earth's upper atmosphere. These waves follow the geomagnetic field lines that thread the magnetosphere and intercept the earth's surface and ionosphere in polar regions. By analyzing the changes in the waves, detected in the northern hemisphere at Lake Mistissini, Canada, scientists have learned much about the composition of the magnetosphere, as well as the way electromagnetic disturbances may affect communications.

In 1987 geologists and paleontologists from four U.S. universities discovered the fossil remains of a 6-foot-tall, flightless bird, the jaw of a large crocodile, and 50 fossil lobsters.

Elizabeth Tait

Shadow on ice. An Emperor penguin casts a shadow on the ice edge of the Ross Sea in Antarctica.

Elizabeth Tait

Expected company. A seal pops up in a hole drilled through 12-foot-thick ice covering McMurdo Sound near Antarctica.

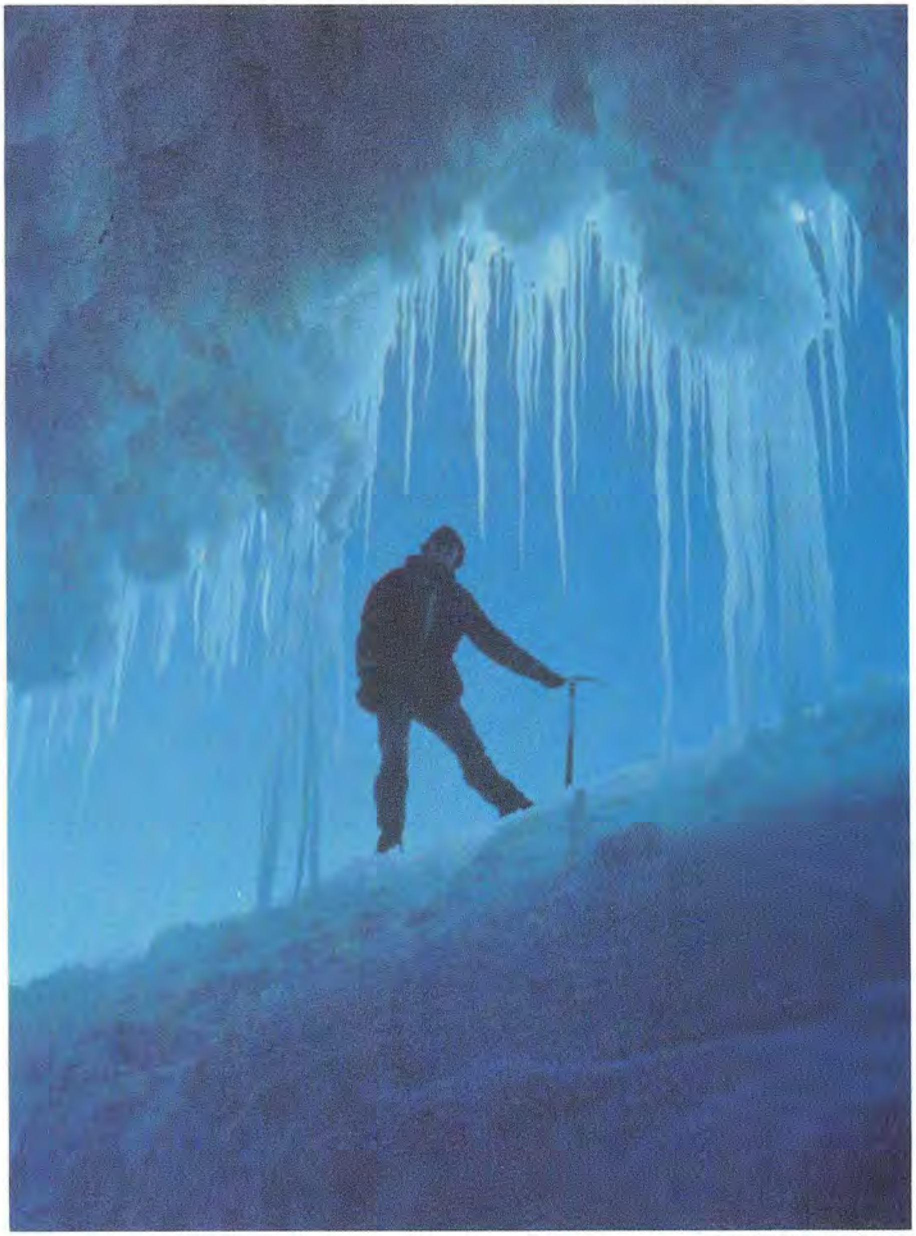
UNITED STATES OF AMERICA ANTARCTIC PROGRAM

The discoveries, made at Seymour Island (a rugged, barren area near the top of the Antarctic Peninsula), support theories that a land bridge connected Antarctica and South America between 40 and 140 million years ago and that contemporary marine organisms, now living in temperate waters, originated in the high latitudes.

Overall, field work in Antarctica consisted of 74 research projects at numerous summer-season camps, three year-round stations, and work on board research ships.

In arctic research, a team of scientists travelled to Greenland in July 1987 to make some of the most sensitive geophysical measurements ever done of the Newtonian gravitational constant and to test a new hypothesis that a fifth, yet undiscovered, force may exist in the universe. The experiment was designed to verify earlier measurements that indicate a variation of the gravitational constant with distance. Laboratory measurements of gravity are generally limited to lengths of a few inches.

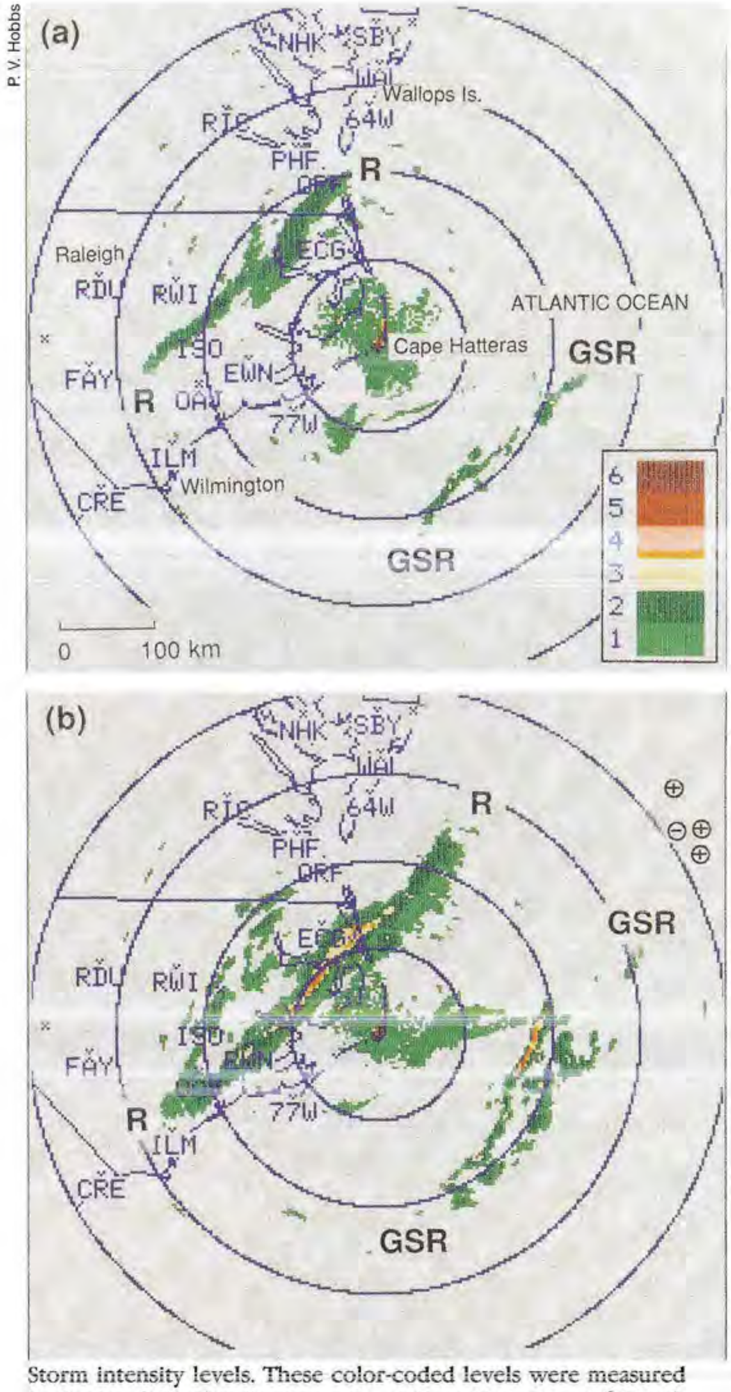
The scientists used a gravity meter, which was lowered into an existing 6700-foot hole bored into the Greenland ice sheet to measure the gravitational constant, commonly called the "big G" by physicists. After lowering the meter to 5000 feet, the researchers measured, in 300-foot intervals, changes in the force of gravity at different depths. The discovery of gravitational variations would have a significant impact on several branches of modern physics and would require the recalculation of the masses of planets and stars.



Arctic research site

Finally, two major reports issued by NSF in 1987 underscored the importance of polar research:

- *The Role of the National Science Foundation in Polar Regions* was prepared by a National Science Board committee chaired by Rita R. Colwell, Director of the Maryland Biotechnology Institute and Professor of Microbiology at the University of Maryland, College Park. The report includes contributions from 47 experts in science, research policy, and logistics. The 15 recommendations highlighted in the report are intended to aid the Foundation in fulfilling its responsibilities as lead agency for basic research in the polar regions.



Storm intensity levels. These color-coded levels were measured by National Weather Service radar at Cape Hatteras on 6 March 1986, at 10:21 E.S.T. (see "a") and at 12:31 E.S.T. (see "b"). Color codes 1 and 6 indicate the lightest and the heaviest precipitation, respectively. The prefrontal and the Gulf Stream rainbands are labelled R and GSR, respectively. The circles centered on Hatteras are range markers at intervals at 50 nautical miles from the cape.

- The Interagency Arctic Research Policy Committee, composed of representatives from the National Science Foundation and 11 other federal agencies, has laid out a plan (required by the Arctic Research and Policy Act of 1984) for federal support in arctic research over the next five years. Implementation of the plan will provide scientific and engineering knowledge required for national security, rational resource development with minimal adverse impacts, and improved understanding of regional and global climate change. The Committee's recommendations are outlined in the *United States Arctic Research Plan* published by NSF.

Atmospheric Research

Since the early days of sailing, when it was called the "graveyard of ships," the area off Cape Hatteras has been recognized as a region where winter storms often intensify very rapidly. A large field experiment called the Genesis of Atlantic Lows Experiment (GALE) was centered on the Atlantic Coast of North Carolina; one of its goals was to investigate the reasons why rapid storm intensification occurs at this location. During the experiment a recurrent region of banded clouds and precipitation was identified and found to be almost stationary over the Gulf Stream.

This phenomenon is attributed to large heat and moisture fluxes from the warm water of the Gulf Stream to the colder, overlying air. Indeed, the magnitude of these fluxes is comparable to what would be received from the sun on a cloudless day in summer. The full implication of this redistribution of heat and moisture is the subject of ongoing research. It is clear, however, that the intensity of this persistent rainband, as revealed by radar, indicates rainbands could play an important role in the intensification of winter storms on the East Coast.

In other atmospheric research, three complete ice cores from a subtropical region, the Dunde Ice Cap in the northeastern section of the Quinghai-Tibetan Plateau, were retrieved by a joint US-Peoples Republic of China expedition during the summer of 1987. Water samples and frozen ice cores in pristine condition were returned to the Byrd Polar Research Center at the Ohio State University and to China's Lanzhou Institute of Glaciology and Geocryology. Preliminary micropartical, oxygen isotope, and conductivity analyses of the samples indicated a strong likelihood that each ice core contains the first glacial-stage ice to be recovered from a nonpolar location. The detailed high-resolution paleoclimate record contained in these cores could be significant in calibrating the rich and diverse written record of historical climate in the Chinese region.

Finally, in the summer of 1987, scientists from the University of Illinois, using modern Lidar equipment, were working near Spitsbergen, in the Arctic Ocean. There they discovered a "hole" in the sodium layer near an altitude of 145 miles. The hole could be caused by adsorption on the ice crystals of noctilucent clouds (those that shine at night). Similar reactions of chemicals with winter ice crystals in Antarctic stratospheric clouds are thought to be responsible for the ozone "hole" over that continent (see "Highlights"). Research on the arctic phenomenon continues at this writing.

Earthquake Research

Scientists from 11 U.S. universities have been conducting scientific experiments in a hole being drilled at Cajon Pass near the San Andreas fault in California. There they have been

Earthquake research. At Cajon Pass, in the earthquake-prone region of the San Andreas fault in California, scientists have drilled a hole deep enough to sample the earth's crust and monitor the forces that may give early warnings of an earthquake.

creating a deep-earth observatory to monitor the earthquake-prone area over the next several decades. The drilling project, funded principally by NSF through an effort called Deep Observation and Sampling of the Earth's Continental Crust (DOSEC), enables researchers to sample the earth's crust near zones where forces crush and stretch rock. Deformation of that crust may be one early warning sign of an earthquake, and the drilling project could help to improve predictions of these natural disasters.

The State University of New York at Buffalo is headquarters for a national center on earthquake engineering research. This center was established by Cornell, Princeton, Columbia, and Lehigh Universities; the Rensselaer Polytechnic Institute; the City College of New York; and SUNY/Buffalo. Center researchers look into ways to minimize the loss of lives and property caused by earthquakes. Among the problems they address are seismic risk levels in the eastern United States and potential hazards caused by the fact that many U.S. structures were not built with earthquake risks in mind.

As part of its prevention studies, NSF also learns from earthquakes when they occur — including the one that hit Whittier, California, in the fall of 1987. Although this earthquake was relatively small, it claimed six lives and caused property damage estimated at $125 to $250 million. And researchers detected aftershocks for several days after the quake.

By studying such events, NSF hopes to learn more about the problems caused by larger quakes and better understand the vulnerability of communities in future situations of this kind.

As part of NSF-funded research, teams of scientists were quickly dispatched to the California site. There they assessed such influences as the quake's effect on power and water lines, the occurrence of (and the ability to extinguish) earthquake-related fires, and the stability of buildings. In addition, public briefings on earthquake issues were co-sponsored by NSF and held in San Francisco, Washington DC, and Pasadena.

NSF-supported research is also underway to learn from recent earthquakes in Chile and New Mexico. More than 30 research projects seek new knowledge and a basis for further mitigating the effects of earthquakes in the United States. And in a cooperative agreement with Japan, NSF is studying design methods that will help create masonry structures that are especially resistant to earthquakes and other seismic disturbances.

Ocean Drilling

The Ocean Drilling Program, an internationally supported effort to understand more about the earth's history through study of the ocean floor, has found surprising new details about the geography and climate of Antarctica. Sea floor sediment accumulated over a period of 50 million years at the bottom of the Weddell Sea near the South Pole revealed striking differences in ice formation between West and East Antarctica. Two months of drilling by the research vessel *Joides Resolution* also uncovered spores and pollen grains, providing new evidence that until about 39 million years ago beech trees and ferns flourished in Antarctica and the continent once had a much warmer climate.

The Weddell Sea drilling, made possible only after a companion ship towed away icebergs weighing millions of tons, extracted sediment hidden below three miles of icy ocean. Analysis of sediment layers off the shore of West Antarctica dated the formation of ice sheets there to 8 million years ago, and showed that contrary to some theories, the sheet has remained intact without melting for nearly 5 million years.

In contrast, drilling off Queen Maud Land in East Antarctica, separated by a mountain range from the west land mass, revealed that ice formation there began much earlier, about 37 million years ago. And the discovery of diatom fossils, microscopic algae that can live only in sunny waters, indicates that the eastern ice sheet did not cover the entire ocean for more than 20 million years.

Micropaleontologist *James R. Kennett*, then at the University of Rhode Island, led the expedition along with marine geologist and geophysicist *Peter Barker* of the University of Birmingham in the United Kingdom. They reported that climate changes in Antarctica can be inferred from detailed studies of the ocean floor. For example, melting ice sheets cause rivers to form; the rivers in turn deposit sand and gravel on the continental shelf. Periodically, these deposits fall to the ocean floor, leaving a permanent record of events that occurred millions of years ago.

The Ocean Drilling Program is funded by NSF and several international partners (Japan, France, United Kingdom, West Germany, Canada, and the European Science Foundation). Management is by contract to the Joint Oceanographic Institutions (JOI) Inc. and subcontracts to Texas A&M University and the Lamont-Doherty Geological Observatory.

Texas A&M University

Ice Work. *Maersk Master,* ice-support vessel for the ship *Joides Resolution,* tows an antarctic iceberg weighing nearly 12 metric tons.

COMPUTER SCIENCE

Cross-Disciplinary Research

The use of computers in research has become ubiquitous. Computers allow scientists to simulate experiments impossible to perform in the laboratory, and they serve as calculators for data that could not otherwise be analyzed.

Recognizing these and other applications, NSF has launched a new funding program that stretches across all disciplines in encouraging investigators to use computers in solving research problems. While many universities already have strong programs in computer research, most do not foster interdisciplinary studies. In addition to emphasizing collaborations among scientists, engineers, mathematicians, and computer specialists, the NSF program (called Opportunities for Research in Computer Science) also supports training of advanced students in state-of-the art computer techniques.

Robot Language

Robot programming languages—ways to describe and manipulate complex spatial and temporal relationships—present both a major intellectual challenge and an opening to new technical and economic frontiers. One of the most exciting pieces of research in this area is that of *John Hopcroft* of Cornell University. Through a simulation environment, Hopcroft has developed a new system that would allow a user to design, test, and evaluate a robotic system before it is built. By reducing the amount of prototyping time, a fully developed capability of this sort would significantly accelerate the transformation of a robot from an idea into a functioning production device.

Gripper. A simulated three-fingered robot hand holds an object in a Cornell University robotics research effort.

Hopcroft's research group has developed a modeling system that allows objects to be built and modified quickly and easily. The team has produced an electronic model of a three-fingered gripper developed by Stanford University and the Jet Propulsion Laboratory. The group also has developed electronic models of variations on the gripper.

Through NSF-funded projects such as this one, the field of robotics has evolved from a strictly mechanically-based endeavor to a science of representing, manipulating, and reasoning about physical objects with a computer. The mechanical aspects of kinematics and dynamics are still important, but other exciting areas of research are now open. Robotic systems can be seen as not just a replacement of labor, but as an intelligent interface between perception and action, and as a new form of human/machine partnership.

Experiment in Electronic Mail

The primary form of communication among scientists and engineers is still paper documents. Although the use of electronic mail — messages, reports, and graphics sent via computer — speeds communication and can enhance the work of researchers collaborating on written material, scientists have sometimes faced obstacles in adopting the new methods. One obstacle is that the incompatibility of different electronic word processing and desktop publishing systems makes communication between people with different machines or editing environments nearly impossible.

To help improve electronic communication among different computer systems, NSF launched EXPRES, Experimental Research in Electronic Submission. The project seeks to develop a system that would handle electronically all aspects of the NSF grant proposal process, including document submission and reviewer comments. Once such a model system is developed, researchers hope to extend its use to more general scientific communications. At this writing, NSF supports EXPRES projects at Carnegie Mellon University and the University of Michigan.

Internally, NSF has implemented a Foundation-wide electronic mail system known as NOTE. The NOTE system has direct connections to the major academic and research networks and thus provides enhanced communication not only between employees at headquarters but between them and grantees and reviewers in the research community. In addition to electronic mail, NOTE provides an electronic bulletin board and online access to NSF manuals and documentation. Some of the present and planned uses of the system include electronic dissemination of NSF policy and program announcements and electronic receipt of proposal information and reviews.

Technology Transfer: From Computer Lab to Industry

In recent years a number of computer programs developed through NSF-supported research have made their way from academia to the marketplace. In some cases researchers have set up companies that collaborate with universities to improve upon and market software that might otherwise never reach its intended audience.

At the University of Illinois, computer scientist *David Kuck* and his associates formed Paracomp, a company that tailors software developed on the campus supercomputer so that it can be easily used by businesses and research institutions. The computer programs have application to weather prediction; airplane design; structural mechanics, including the stability of bridges and the safety of automobiles; and analysis of field theories that underlie the fundamental forces of physics.

Another collaboration between university and industry involves the work of University of Utah computer scientist *Lee A. Hollaar*, who developed a computerized text-searching system. Hollaar's system improves upon search programs already on the market because it can electronically copy the text it locates into other documents. This feature is particularly useful for lawyers, who often need to cite the wording of a precedent-setting case in court documents. In addition, the system has a special processor, tailored to the search task, that significantly reduces search time. It is also easily expandable, so that extra computing power is available as the size of the text to be searched increases.

University of Utah

Technology transfer. NSF supported Lee Hollaar, a computer scientist who developed the computerized text-searching system pictured here.

In 1983, Hollaar set up Contexture Inc., a company that handles the commercial development, manufacturing, and licensing of the search system, which was developed with NSF funds at both the University of Illinois and the University of Utah. According to Hollaar, the company immediately developed packaging and completed tests required by the Federal Communications Commission to take the system from the university workbench to a prototype that could attract potential users. In addition, based on the preliminary research funded by NSF, another government agency (the Central Intelligence Agency) sponsored additional research to expand the search system for its own use.

ENGINEERING

For the 20 years ending in 1985, NSF provided funding for 31 of 46 engineering advances considered the most significant by representatives of six professional engineering societies. NSF was also cited more often than any other funding source in research papers associated with 10 specific advances. These advances were in such fields as robotics, ceramics, composite materials, and solid-state circuits.* Engineering research supported by the Foundation in 1987 continued this distinguished trend, as shown in the examples that follow.

Engineering and Biotechnology

Monoclonal antibodies, the molecules that destroy specific types of cancer cells and other disease-causing agents, are just one of the vital biological substances made possible by advances in molecular biology, genetics, biochemistry, and related fields. In order to address problems encountered in mass producing these substances and to bolster university training of people involved in large-scale production, NSF's engineering directorate has a program in biotechnology that ties together research from several disciplines. Topics include, but are not limited to, improved methods of culturing normal, exotic, and genetically altered cells; development of new uses of proteins and other biological materials in the design of large biological reactors; techniques to separate or purify large quantities of dilute and impure solutions of complex substances; and methods to monitor the metabolism of cells immersed in culture.

*Source: *National Science Foundation Support for Significant Advances in Fundamental Engineering Research, as Shown in Publication Acknowledgments 1965-1985,* NSF Program Evaluation Staff, Office of Budget and Control.

Engineering-Materials Research Link

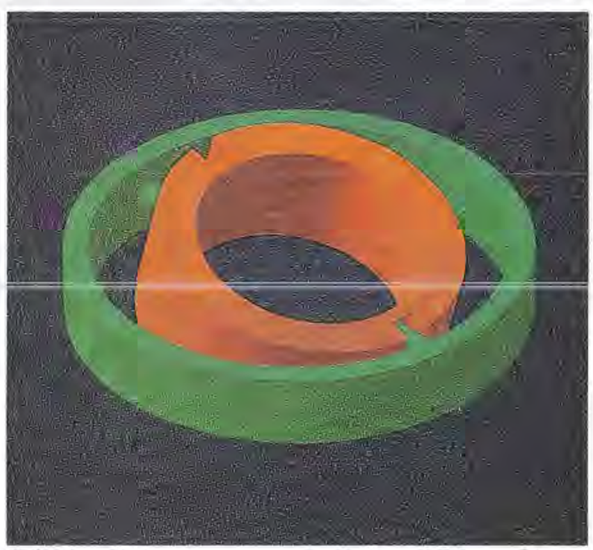
New demands for complex materials with precisely controlled chemistry, shapes, and properties have led to worldwide competition in manufacturing materials. To help meet this demand, NSF announced a joint effort by its Directorates for Engineering and for Mathematical and Physical Sciences; their goal is to strengthen U.S. research in materials processing and related activities.

Processing generally involves the transformation of raw materials into useful, finished objects. One example is the transformation of graphite compounds into composite, lightweight materials needed for aircraft such as the *Voyager* spacecraft, which has circled the globe. And the processing of high-temperature superconducting materials from ceramic compounds (see "Highlights") has become a major research endeavor.

The NSF initiative encourages collaborations with industry because of the concentration of expertise there, industry's economic stake in results, and its available facilities and research instruments. Collaborations among different disciplines are also important because materials research spans the full breadth of science and engineering, including solid-state physics, fluid mechanics, and mechanical engineering.

Tribology

Tribology is the study of surfaces that move or slide against each other. Ball bearings and gears in an automobile are examples of tribological components. Scientific research in the field of tribology is generally aimed at providing a mechanistic understand-



Tribology. This computer-generated model is used to study the contact dynamics and tribological performance of a mechanical face seal.

ing of the phenomena that occur at the moving contacts.

With new studies delving into the chemical interactions at surfaces, the development of models to predict the behavior of these materials, and related inquiries, NSF has increased support for its tribology program. Included in 1987 was a summer internship designed to draw faculty to such research. The program gave faculty members who had never investigated tribology but were experts in related areas the opportunity to learn about the field.

Neuroengineering

The brain is the oldest and most powerful computing machine we know, and its communication system is far more puzzling than that of the most advanced supercomputer. What fundamental processes underlie the complexities of information processing in the brain? Researchers look for biological analogues inside assemblages of transistors and diodes, electronic components that are the basis for computer circuitry. Conversely, networks of electronic circuits that mimic the pattern of nerve cells inside the brain are leading to experimental components that may revolutionize computer science. These studies offer potential advances in computers that recognize and respond to human speech, in creating more autonomous robots, and in computer vision systems. To help foster research in this relatively new branch of science, known as neuroengineering, NSF began a new funding program in FY 1987.

With the help of NSF funds, *Christof Koch* and his colleagues at the California Institute of Technology study the cat's eye to understand how nerve cells in the retina detect motion. Their research, in collaboration with *Tomaso Poggio* at the Massachusetts Institute of Technology, has uncovered an underlying biophysical mechanism for motion detection that may be involved in other types of nerve cell operations in the brain, including depth perception. In addition, their investigations, which suggest that each nerve cell acts like a computer chip containing hundreds of transistors, has application to robot vision systems and the development of automated television cameras.

Other neuroengineering research has focused on neural networks, the complex circuits that scientists design to mimic the sophisticated decision making of the human brain. Computer chips and electronic wire are the usual components of these networks, but now researchers have devised an alternative model: circuits that replace wire with lasers and mirrors and use light-sensitive crystals, rather than computer chips, to convey information and make decisions.

Dana Anderson at the University of Colorado at Boulder and *Jack Feinberg* at the University of Southern California in Los Angeles collaborated on an optical circuit that memorizes the shape and position of an object. A three-dimensional hologram of the object forms inside a crystal in the circuit, but the image quickly fades unless the object moves or changes position. For example, a Walt Disney animated film run through the circuit, known as a Novelty Filter, is visible only when the characters move or the scenery changes; if Mickey Mouse temporarily stands still, he disappears from the screen. Bacteria under a microscope connected to the Novelty Filter are seen only as they slither back and forth across the slide.

The filter instantly tracks the new position of objects as they move and may have potential applications to optical computing.

Another experimental circuit built by Anderson relies on laser light that travels through a loop containing mirrors and two crystals. One crystal uses the light to optically store a variety of simple images; the other crystal acts as an amplifier. When a light beam shines a fragment of any of the stored images into the circuit, this action triggers the circuit to search out and retrieve the entire stored image. For example, if the crystal stored the images of a cat and a dog, shining the image of the cat's tail would trigger the crystal to retrieve the full image of the cat. According to Anderson, this type of pattern recognition suggests some of the complex actions associated with the brain and human memory.

Novelty filter. Dana Anderson and Jack Feinberg collaborated on an ingenious new optical circuit that memorizes the shape and position of an object. A three-dimensional image of the object forms in the optical circuit—known as a "Novelty Filter"— but the image quickly fades unless the object moves or the background scenery changes, as seen in these two photos.

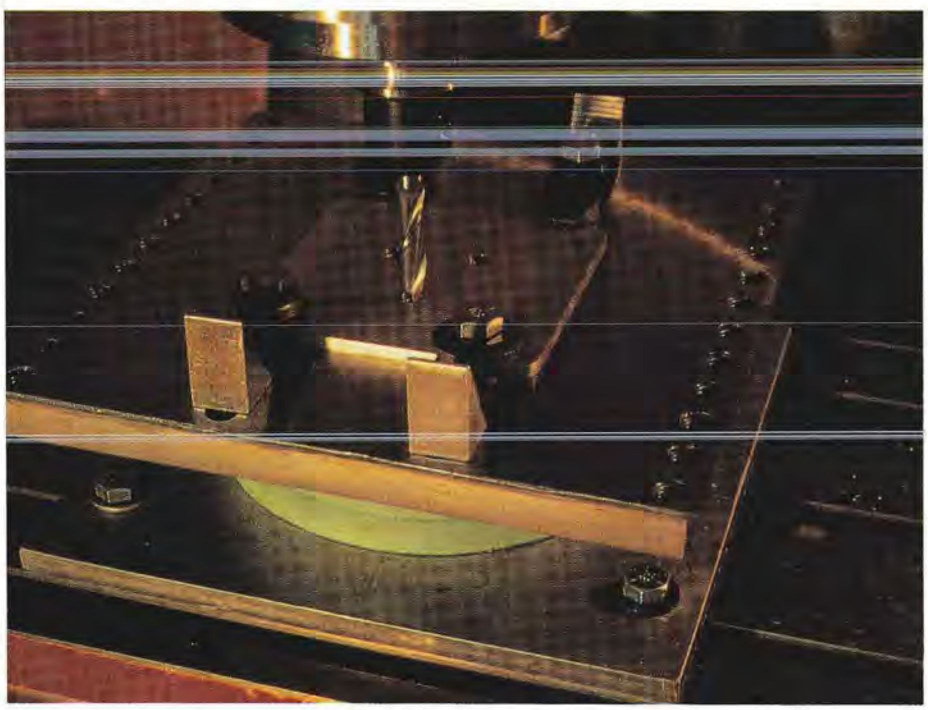
Research in Engineering Design

Thoughtful study of the design process can sometimes correct problems in a product before it is manufactured, suggest the most appropriate materials for its manufacture, and dramatically decrease production costs. In addition, computer programs based on expertise gleaned from successful design projects can aid the design of new products. NSF support focuses on developing scientific methods for engineering design and establishing a formal discipline in this relatively new area of study.

Beginning with a project for a design class taught at Stanford University, engineer *Mark Cutkosky* and his collaborators have developed the basics of an automated manufacturing system. The aim of their computerized system is to keep the designer in daily contact with staff involved in all parts of the manufacturing process, allowing the manufacturing resources of a specific company to be taken into account in planning a product. The model system also enables others in a company to suggest design changes — even if those employees work across the country. Engineering students have tested their original designs for manufactured metal parts on the system, honing the design skills learned in class. According to Cutkosky, students have found that their design style is creatively altered by interaction with the computer.

Myron Fiering at Harvard University has used computer techniques for another aspect of engineering design: the analysis of classic design failures to understand how errors can be anticipated and designs made sufficiently flexible to survive unexpected flaws or stresses.

Aided by a computer, Fiering and his graduate student, *Benito Villamarin*, grouped some 30 flawed designs, as well as designs that withstood unusual stresses, according to common themes. The researchers then began to develop a computer program, designed to run on an ordinary personal computer, that uses the analysis of flawed designs to indicate potential errors in new plans.



Mark Cutkosky, Stanford University

Myron Fiering

Computerized manufacturing. A machine part is drilled on a special platform that senses the forces and torques exerted on the part in all directions. The goal is to gather information from the manufacturing process as it occurs, in order to update or fine-tune the manufacturing knowledge base and to suggest changes in design. This work was done by Mark Cutkosky and his team at Stanford University.

Boyd C. Paulson, Stanford University

Construction automation: Computerized model of a machine that moves earth. The machine is connected to a microprocessor that allows it to adjust automatically for the weight of the load, type of material, and other day-to-day variations encountered at the construction site. This is an example of work done by Boyd C. Paulson and Raymond Levitt at Stanford University.

Automated Construction

Robots digging tunnels, computers that test design plans, artificial intelligence methods for tracking progress at the job site: such developments appear to signal the construction industry's future. If so, U.S. companies may be losing their competitive foothold. Although the industry is an important and lucrative business—American construction companies earn more than $380 billion a year and employ some 5.5 million workers—productivity of U.S. companies has remained flat and the industry spends less than 0.4 percent of sales on research and development. Japan and other countries are taking an increasing share of the business. A new program begun by NSF's engineering directorate seeks to boost the competitive position of U.S. firms through research in automated or computer-integrated construction.

In recent years, NSF has awarded eight grants to investigate use of the computer in planning, organizing, and building skyscrapers and other large structures. Some examples:

- At the University of Texas at Austin, engineers led by *Alfred E. Traver* collaborated with Bechtel, Inc. to explore the way pipes could be selected and fit together at a construction site with the aid of computers and a specially designed robot.
- Researchers at the University of Maryland, Virginia Polytechnic Institute, and Pennsylvania State University have studied various ways to (1) automate activities on construction sites and (2) provide an open, interactive data environment for engineering design of buildings, construction processes, and facilities management after construction has been completed.
- Engineers under the direction of *Irving J. Oppenheim* at Carnegie Mellon University have explored methods to automate digging at construction sites.
- At Stanford University, research teams directed by *Boyd C. Paulson* and *Raymond Levitt* considered instrumentation for monitoring equipment safety and production. One of the Stanford projects, known as "Sight Plan," sought artificial intelligence methods to design the layout of a model work site, coordinate workers or robots on the job, keep track of supplies, and record and make adjustments for the continually changing nature of the construction project.

INTERNATIONAL ACTIVITIES

China

In an effort to boost international cooperation, NSF sponsors a number of research activities and agreements with other countries. In 1987, for example, NSF sponsored a joint seminar with China on the subject of advanced ceramic materials, anticipating continued cooperative research in this area. Such joint research allows U.S. scientists to forge ties with their Chinese counterparts in areas of mutual scientific interest.

Yugoslavia

An NSF-sponsored cooperative project in theoretical physics between the University of Zagreb and Purdue University has spurred development of a new theory about nature. The theory postulates a fifth force — the hypercharged force — that acts at short distances against the tug of gravity. The theory, with implications that would greatly alter our view of the universe and its origins, has stimulated widespread interest and experimentation in the United States and abroad.

India

Scientists from Purdue University and the Indian Institute of Science, Bangalore, have joined forces to develop and study high-temperature superconductors (see "Highlights") made of metal oxides. The researchers designed new methods for synthesizing the oxides; some 30 technical papers on their work have appeared in major international journals.

Japan

Through a new collaborative research program with Japan, NSF is helping to advance computer research and spur development of the next generation of computers in the international community. The Foundation and the Japanese Institute for New Generation Computer Technology (ICOT) jointly developed a program that allows U.S. scientists and engineers to conduct research at ICOT. Under the joint agreement, which began in 1987, ICOT opens its doors each year to up to three U.S. scientists selected and supported by NSF.

Example of international work: Researcher measures nutrient flow in a study of nutrient cycles in a tropical rain forest system. This project took place near the joint border between Brazil, Colombia, and Venezuela.

New International Information Office

In March 1987, NSF established a new information and analysis office to monitor technical developments in major areas of the world and to analyze their impact. Eventually this office plans to distribute — both in print and electronically — its information products to U.S. scientists and engineers. Examples include some 120 studies on technical advances and policy trends in Japan.

Also underway is a pilot program (developed with the U.S. Departments of State and Commerce) that involves selected academic, government, and industrial users nationwide. The aim of this study is to determine the most effective format, content, and public distribution method, as well as appropriate user groups, for U.S. government reports on foreign science and technology developments.

The new office is part of NSF's Directorate for Scientific, Technological, and International Affairs.

SMALL BUSINESS GRANTS

Small businesses involved in scientific and technological innovations often cannot support the research needed to develop the next generation of state-of-the-art devices. NSF's Small Business Innovation Research (SBIR) Program funds high-quality research at these companies. In 1987, NSF awarded 151 "Phase I" grants that provide firms with up to $40,000 for six months to explore innovative research ideas. The most promising projects to emerge from Phase I are awarded up to $200,000 for two additional years of NSF-supported research. Private investors then take over during the third and final stage, which involves product development, manufacturing, and marketing efforts.

Products resulting from SBIR-funded research include:

- Plant-derived insecticides, as well as new plant gene-mapping techniques, by Native Plants Inc. (NPI) of Salt Lake City. NPI raised $64 million in private investment and increased employment from 40 to 450 since receiving its first SBIR award in 1980.
- Improved catalysts for continuous flow fermentors, which use microbes for rapid production of genetically engineered protein, by Verax Corporation of Lebanon, New Hampshire. Since receiving awards in 1982 from the Foundation's SBIR program and from the National Institutes of Health, the company has increased its size from 12 to 87 employees.

See also the "Highlights" section of this report for another example of SBIR support.

Small business innovation: an innoculation trial at Native Plants, Inc., Salt Lake City, Utah. In this trial of a mycorrhizal plant growth system a symbiotic association between a nitrogen-fixing fungus and the root system enhances growth.

Verax processor. Another small business effort supported by NSF resulted in equipment such as this processor, which is based upon the development of microporous beads that serve as the growth surface for cells.

CHAPTER 4

BASIC RESEARCH: CENTERS, GROUPS, ANI

Increasingly, research relies on expensive and complex equipment. Even mathematics, which once required only a pencil and paper, now depends on computers. One research institution alone often cannot afford to buy and maintain the facilities and tools used in modern research. And as studies in biotechnology, materials research, and other fields cross the boundaries between disciplines, the pooling of diverse resources and the sharing of equipment become inevitable.

In some instances, universities, industry, and the federal government have shared their scientific and engineering talents, as industry and the federal government have jointly funded campus-based research programs ranging from small collaborations to large facilities with scores of investigators.

In supporting major facilities for astronomy, atmospheric science, engineering, materials science, physics, and computing, NSF has led the way for many collaborative research efforts. Fiscal year 1987 saw new discoveries at some of these facilities, continuation of the new engineering research centers established in 1985, and a presidential plan to expand greatly the number and role of federally funded centers.

NEW EFFORTS

Reagan Plan

President Reagan's "Quest for Excellence" speech, delivered to the Congress in January 1987, outlined a national policy for science and technology. As part of that policy, the President announced an initiative for several new NSF-supported centers for research in science and technology. The President described these centers as "new university-based, interdisciplinary 'Science and Technology Centers' that will focus on fundamental science that directly contributes to the nation's economic competitiveness."

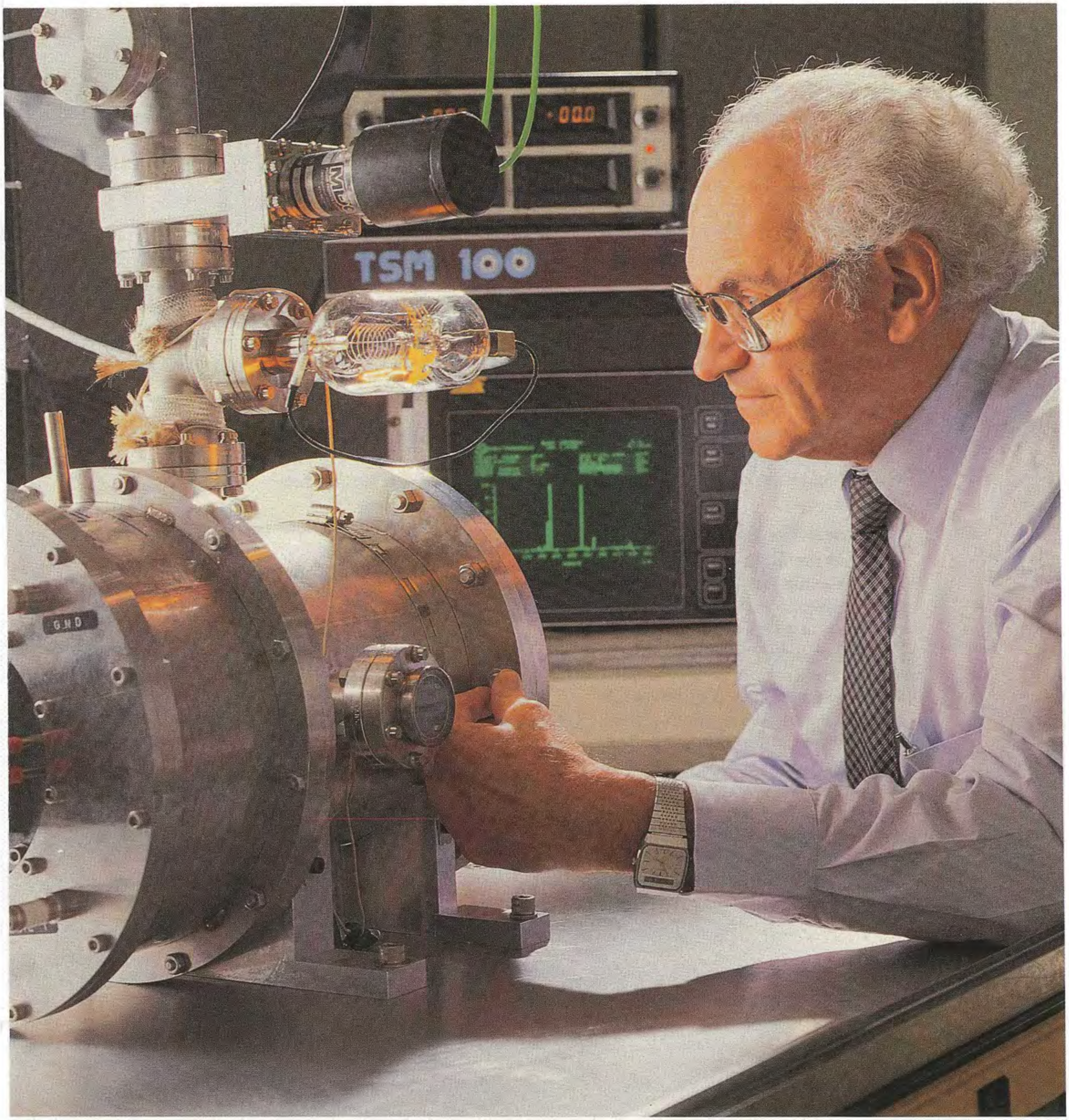
New Engineering Research Centers

This program supports cross-disciplinary centers focused on the research and education that are critical to U.S. industrial competitiveness. The program is a partnership between academia, industry, and government.

NSF announced in 1987 the initiation of three new centers at the University of Colorado, Boulder/Colorado State (a cooperative effort), the University of California at Los Angeles (UCLA), and Duke University. The universities will receive up to $46 million in NSF funds over the next five years to operate and maintain these campus-based efforts. This brings the complement of centers to 14. They are clustered in design and manufacturing, optoelectronics, biotechnology, and resource utilization.

New Engineering Research Center. Jacques Pankove, a program manager for Colorado's Optoelectronic Computing Systems Center, was the first to demonstrate high-luminescence efficiency in gallium arsenide. He also discovered and explained radiative tunneling in semiconductors.

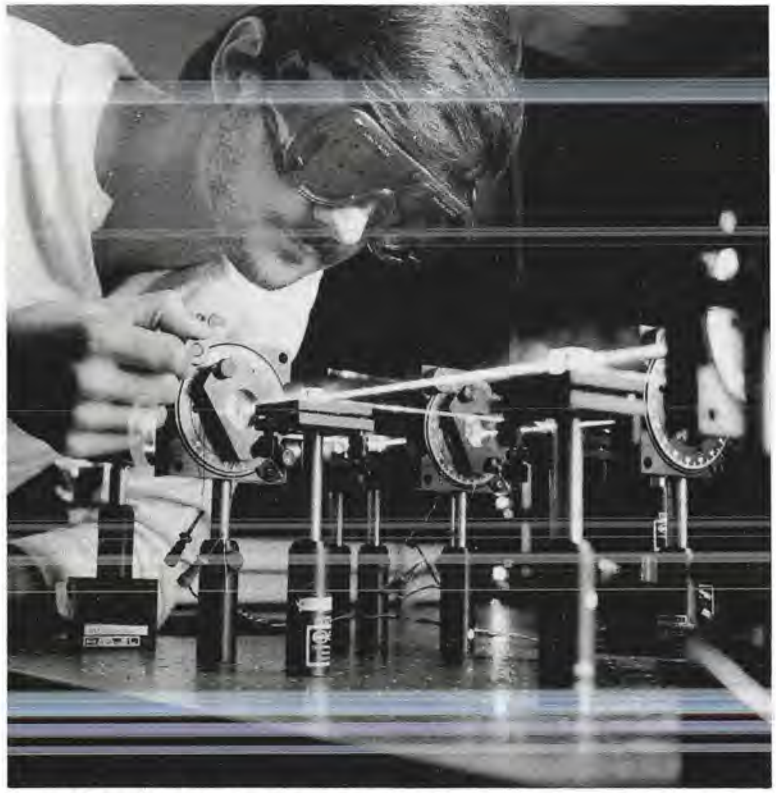
INSTRUMENTATION



The UCLA center focuses on hazardous substance control and will explore emerging technologies to minimize the production of hazardous wastes. Research at the UCLA facility examines the flow of hazardous materials from their origin to their eventual disposal, and considers the impact of releasing toxic materials into the environment.

The Colorado center focuses on optoelectronic computing systems to explore the use of light waves, rather than the flow of electric current, to carry information used in computing, signal processing, and artificial intelligence systems. The timely availability of optoelectronic computing and optical devices is expected to improve the nation's competitive position in the communication and information industries.

The Duke University ERC will explore fundamental engineering research critical to emerging cardiovascular technologies. This center will focus on research leading to advanced imaging methods and microelectronic technologies to aid in diagnosing and treating cardiovascular diseases.



More Colorado work. One group at Colorado's new Engineering Research Center is examining the usefulness of optical neural network systems. A key component under development is this central switch, which uses ferroelectric liquid crystals. These crystals, developed by an interdisciplinary team at the University of Colorado, easily exceed the switching speeds of commercially available crystals and have an inherent memory.

Biological Centers

In mid-September 1987, NSF announced support of $10 million for 20 campus centers conducting research in various aspects of biology. The purpose of the Biological Facilities Centers Program is to provide sophisticated instrumentation to biological reseach centers investigating challenging problems in biotechnology. This will encourage researchers from diverse biological disciplines to share state-of-the-art equipment and to work jointly to solve complex problems requiring insight from different scientific perspectives. Two of the 20 awards focus on the development of unique instrumentation that may help solve fundamental biological problems and eventually affect commercial biotechnology.

NSF is accepting proposals for additional Biological Facilities Centers to be awarded during 1988. Submitting institutions are expected to show a willingness to share center costs and to make a commitment to maintain a facility after the tenure of the NSF award.

Center on Energetic Materials

At the New Mexico Institute of Mining and Technology, NSF helped establish a center for the study of so-called energetic materials—explosives, propellants, and flammable chemicals—and the hazards associated with using them. Founded under NSF's Industry-University

Symbolizing the heart of biotechnology: double helix of DNA molecule

Cooperative Research Program, the Research Center for Energetic Materials is working closely with industry to answer questions about the manufacture of energetic materials, their performance in particular applications, and safe methods for transport and storage. The five-year, $500,000 NSF start-up grant for the center complements support from other federal agencies and from industry. After the first five years, the center will be supported solely by industry sponsors.

Materials Research Initiatives

• More Funds for Superconductivity

To help spur the further development of new high-temperature superconductors (see "Highlights"), NSF allocated an additional $1 million to three of the Materials Research Laboratories (MRL's) it funds—those at Northwestern, Stanford, and the University of Illinois at Urbana-Champaign. Superconductors, materials that lose all resistance to electric current below a certain temperature, have enormous potential applications in power transmission lines and as potent magnets used in medical imaging, particle accelerators, and transportation systems. The recent discovery of higher temperature superconductors offers promise that some of these materials may not require a costly cooldown to more than 400 degrees below zero Fahrenheit in order to operate. The MRL's have taken up the challenge of understanding the complex and subtle science underlying the synthesis, processing, and behavior of these new and intriguing compounds.

• High-Strength Steels, X-Rays for Micro Circuits

At Harvard University and the Massachusetts Institute of Technology, scientists have developed promising new high-strength steels that may have critical applications in aircraft landing gear and helicopter rotors. Existing steels normally have adequate tensile strength and toughness but are prone to corrosion from humidity, a problem that figured in several recent catastrophic helicopter crashes. Researchers at the MIT and Harvard MRL's analyzed changes in microstructure and chemistry that could improve the quality of commonly used steels. As a result, the investigators created steels that are less brittle and susceptible to corrosion. The second generation of these materials was produced by Carpenter Steel Company and is expected to show even greater promise.

At the University of Wisconsin, researchers have been looking at a technology that could shrink the smallest features of a computer chip down to one-quarter to one-tenth of their present size. The smaller size circuits would permit smaller and faster computer chips with more computing power, an especially valuable asset in building supercomputers. Known as X-ray lithography, the method uses intense beams of X-rays (from the Aladdin Synchrotron Source) to outline sharply the microscopic patterns on computer chips and to build up intricate integrated circuits—some as small as one ten-millionth of a meter. In contrast, beams of visible light that currently can make integrated circuits outline patterns not

John F. Cook

Material growth. Photograph shows pure lanthanum copper oxide grown on a platinum seed—a project of MIT's Materials Research Laboratory. The crystal has a layered structure that forms the basis for high-temperature superconducting materials such as lanthanum barium copper oxide.

much smaller than one-millionth of a meter.

The Wisconsin Center for X-Ray Lithography recently formed a consortium with businesses to pool resources and share profits in improving the X-ray method, which is already under intense investigation in Japan.

The Wisconsin Synchrotron Radiation Center is supported by NSF's Division of Materials Research, while the X-ray lithography research has been supported by the Division of Electrical, Communications, and Systems Engineering.

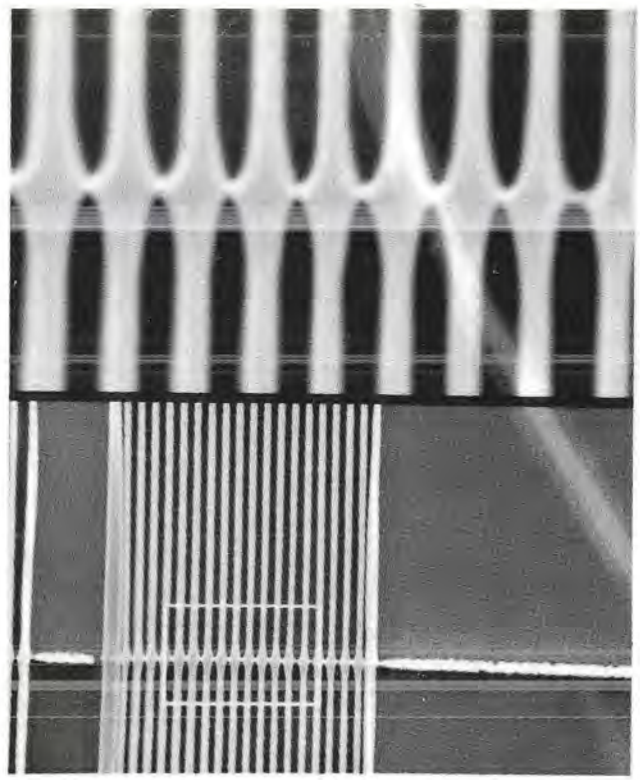
- **New Materials Research Groups**

In 1987, NSF established four new Materials Research Groups; research at the newest campus-based groups includes: at the University of California, San Diego, a study of the microscopic properties of magnetic materials; at Brown University, analysis of factors that make materials susceptible to deformation and fracture; at Montana State University, efforts to understand the basic properties of new types of semiconductors; and at the University of Michigan, development of a method to strengthen glassy polymers.

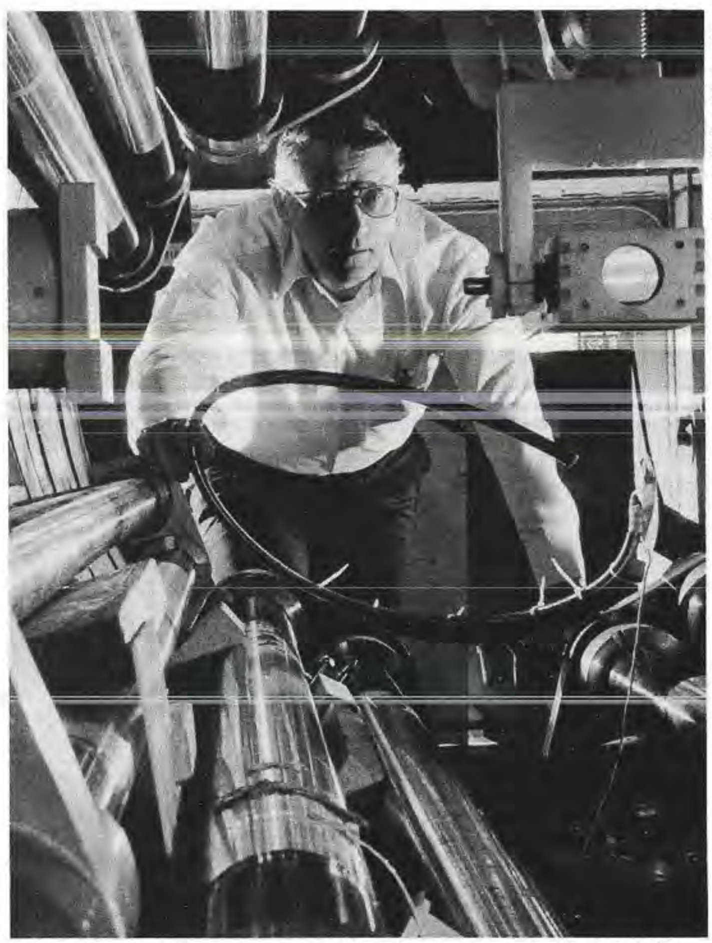
Advanced Scientific Computing

Recognizing that advanced computers are an integral resource for making new discoveries, NSF established five National Supercomputer Centers in 1985 and 1986. The following year, Cornell University received the International Business Machine's (IBM) most powerful supercomputer to date.

One feature of this machine is that it contains six processors, each of which can tackle a separate computing problem or operate in parallel on the same problem. The new supercomputer is being applied to research in medicine, physics, geology, biology, astrophysics, and other fields that require large amounts of computational calculations.



Materials research-engineering project. The lower part of this enlarged photograph shows a grating with vertical bars one micron apart and a cross line 0.2 micron wide. The cross line is etched by X-rays from the Aladdin light source at the University of Wisconsin. Upper part of photo shows a further enlargement of boxed area at bottom.

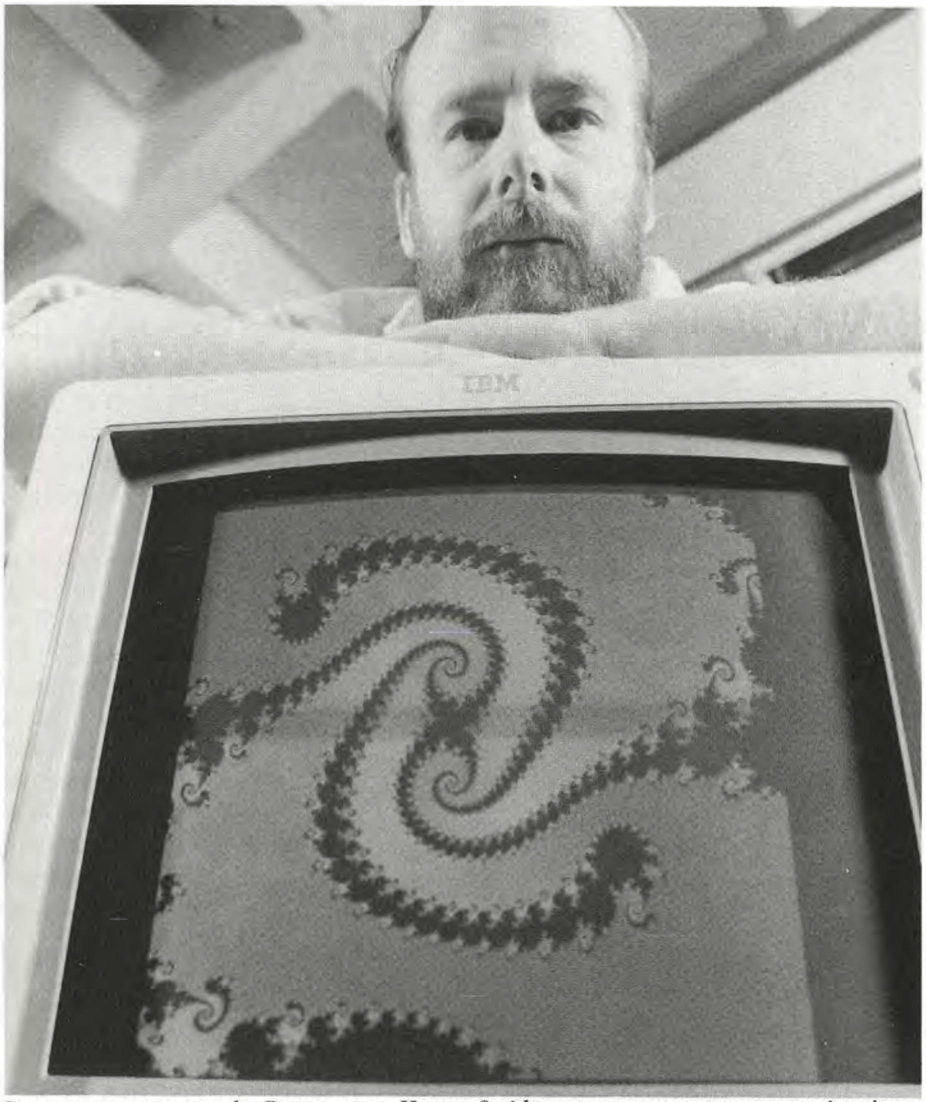


Argonne National Laboratory

Materials research: studying the effect of a magnetic field on metals of various shapes

Research advances are also being made at other NSF-supported supercomputer centers. At the University of Illinois, electrical and computer engineer *Karl Hess*, an NSF grantee, spent much of his time searching in the laboratory for new types of semiconductors, materials whose electrical properties make them ideal for computer chips. But when the university's supercomputer came online, Hess found that simulated experiments on the computer screen told him as much as costly and time-consuming laboratory experiments did, and they performed the work more accurately.

NSF grantee *Freeman Gilbert*, a geophysics professor at the Scripps Institute of Oceanography, University of California at San Diego, has used the campus supercomputer to compare his models of the deep structure of the earth with actual data. If the results of his simulated experiments match measurements obtained from drilling and earthquake activity, Gilbert and other geophysicists may have mapped the invisible—the center of the earth. (See also "Mapping the Earth's Interior," in the next section of this chapter.)



Supercomputer upgrade. Programmer Homer Smith rests on computer screen showing graphical representations of mathematical equations generated via the Cornell supercomputer, an IBM-based device. In 1987 the Cornell system was upgraded to a more advanced IBM supercomputer.

Most powerful mainframe. The IBM 3090 Model 600E supercomputer, recently installed at Cornell University, provides up to 60 percent more computing power than IBM's largest previous model.

At Carnegie Mellon University, *Gregory McCrea* and his colleagues relied on a supercomputer to model the effects of smog over Los Angeles and the effectiveness of different methods to reduce air pollution. Computer simulations by the research group showed that some suggested techniques to lower pollution in the city actually increased the problem in outlying areas.

Research Networking

In a parallel effort with supercomputer research, NSF created NSFNet, an umbrella group of computer networks designed to improve scientific communication and make advanced computing capabilities more accessible. In 1987, a new network joined the NSFNet group; NSF awarded a three-year, $1.8 million grant to begin NorthwestNet, which links major research institutions in the northwestern United States with the five NSF Supercomputer Centers. The link was needed because of the absence of academic supercomputers in that region.

Other members of NSFNet that came on board in 1987 include academic networks and regional networks in New York, Texas, Michigan, the San Francisco Bay area, and the Southeast. The Southeast network uses a computer-based routing system developed by Proteon, Inc., to connect 16 universities in 12 states and the District of Columbia to the major supercomputer centers. The Proteon system gives other universities in the 12 states access to the network, known as SURANet (for Southeastern Universities Research Association Network), through a combination of smaller state and local networks.

By the end of FY 1987, NSF had linked some 125 campuses to its research network.

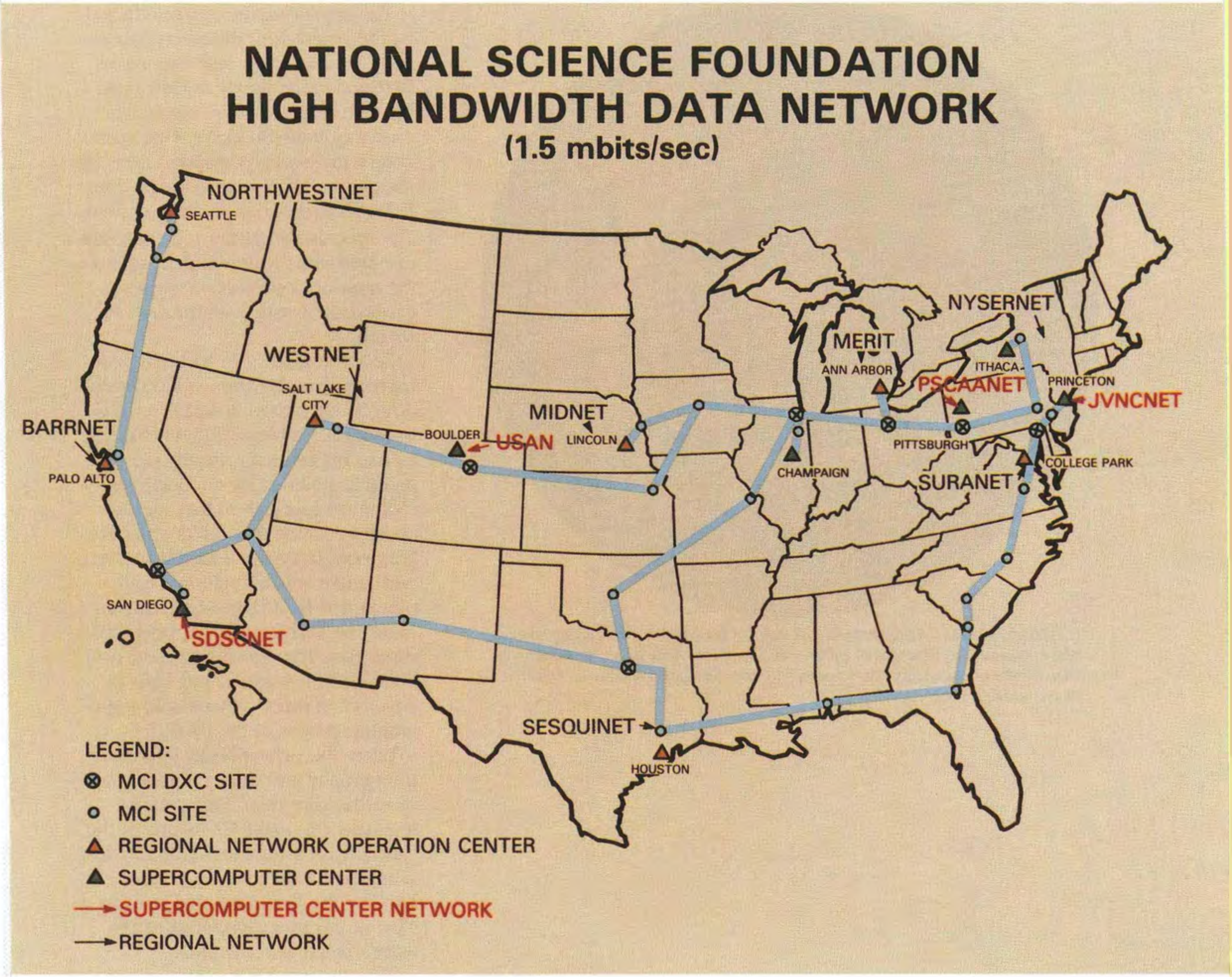
OTHER ACTIVITIES

Mapping the Earth's Interior

The ultimate goal of earth sciences is to understand the structure, composition, origin, and evolution of the earth. During the past two decades, the success of the plate tectonic theory has revolutionized earth sciences. We now have a coherent framework for understanding many of our planet's features: the global distribution of mountain chains, volcanos and earthquakes, major fault systems, the production of new crust at ocean ridges, and the building and migration of continents.

In recent years, great advances have occurred in various techniques for imaging the interior of the earth, using data from seismic arrays. One of the most exciting is seismic tomography. It combines measurements of earthquake waves from many seismic stations with sophisticated computer modeling to construct three-dimensional images of the earth's interior.

Seismic tomography is based on the same principles as the medical technique of Computerized Axial Tomography (better known as the CAT scan), which uses X-rays. Seismic tomography, however, measures the velocity of waves generated by earthquakes or explosions that travel through the earth. Seismic wave velocity is affected by the density of the material that the waves are travelling through. They travel faster in denser, colder material than in less dense, hot, or molten material.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HIGH BANDWIDTH DATA NETWORK
(1.5 mbits/sec)
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JVNCNET
PITTSBURGH
CHAMPAIGN
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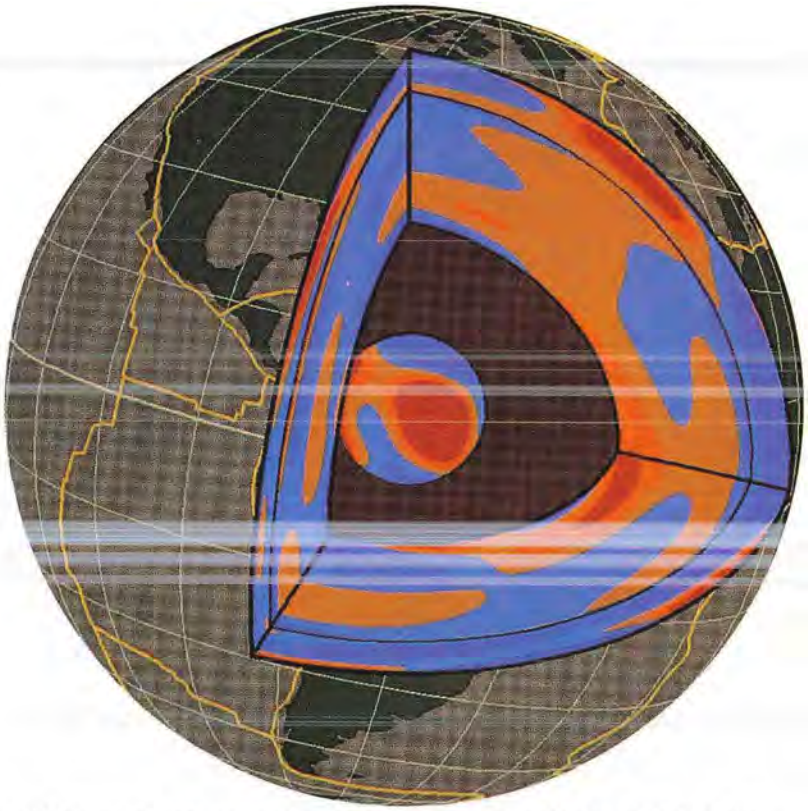


CAT scan. In this computerized 3-D map of the velocity of earthquake waves inside the earth, dark areas indicate waves that move more slowly than do those elsewhere. These waves are travelling through hotter regions of the earth's core.

The seismic waves are also affected by the orientation of the crystals that make up the earth, and they move faster or more slowly as they pass through regions where significant crystal orientation exists. One such zone is in the earth's mantle. There the rock is so hot that, over geologic time, it flows and deforms much like a fluid. The crystals within the rock become oriented with the flow and thus affect the measured seismic velocities as earthquake waves pass through the region.

Seismologists from 54 universities have now formed a nonprofit corporation, Incorporated Research Institutions for Seismology. IRIS is funded by NSF to implement critically needed national facilities for support of seismological research in the coming quarter-century. Among its objectives is a global array of at least 100 modern, permanent seismic stations, complemented by a large (1000-instrument) moveable array for finer-scale resolution. The signals recorded from these seismic stations will help in developing three-dimensional tomographic images of the earth.

Using the principles of seismic tomography and the new generation of earthquake recording stations, scientists can make CAT scans of the earth to map the composition and flow of material throughout its interior. And, for the first time, they can get a view of the inner workings of the earth's dynamic structure.

Astronomy Centers

Among the important facilities funded by NSF and shared by scores of researchers are astronomical observatories. Ranging from optical telescopes that peer out from dome-shaped covers on distant mountaintops to ground-level parabolic antennas, these instruments record the details of faint galaxies, comets, and other pieces of the heavenly puzzle.

● The National Optical Astronomy Observatories (NOAO), headquartered in Tucson, Arizona, include three facilities. Two of these, although serving different functions, are near neighbors. The National Solar Observatory has observing facilities for solar research in New Mexico and Arizona, while the Kitt Peak National Observatory provides access to optical telescopes and clear viewing on an Arizona mountaintop. The third facility, the Cerro Tololo Inter-American Observatory in Chile, is our country's only national astronomy center in the Southern Hemisphere. Cerro Tololo made headlines in 1987 when it captured some of the first pictures of Supernova 1987A, the brilliant stellar explosion (see "Highlights" section) visible only south of the equator. Observations at Cerro Tololo continue to track the remnants of the giant explosion, providing one of the first detailed comparisons between the evolution of a massive star and astronomical theory.

● More than a half-century ago, scientists discovered that certain stars and other sources in the sky emit radio waves in addition to the light visible to the human eye. The National Radio Astronomy Observatory (NRAO), headquartered in Charlottesville, Virginia, has facilities or observatories tuned to these radio frequencies in West Virginia, Arizona, and New Mexico. Radio wave observations at the New Mexico site — an array of 27 dish-shaped antennas that move on railroad tracks — aided astronomer

National Radio Astronomy Observatory's millimeter wave telescope (front and back views), located on Kitt Peak


National Radio Astronomy Observatory's 140-foot radio telescope at Greenbank, West Virginia

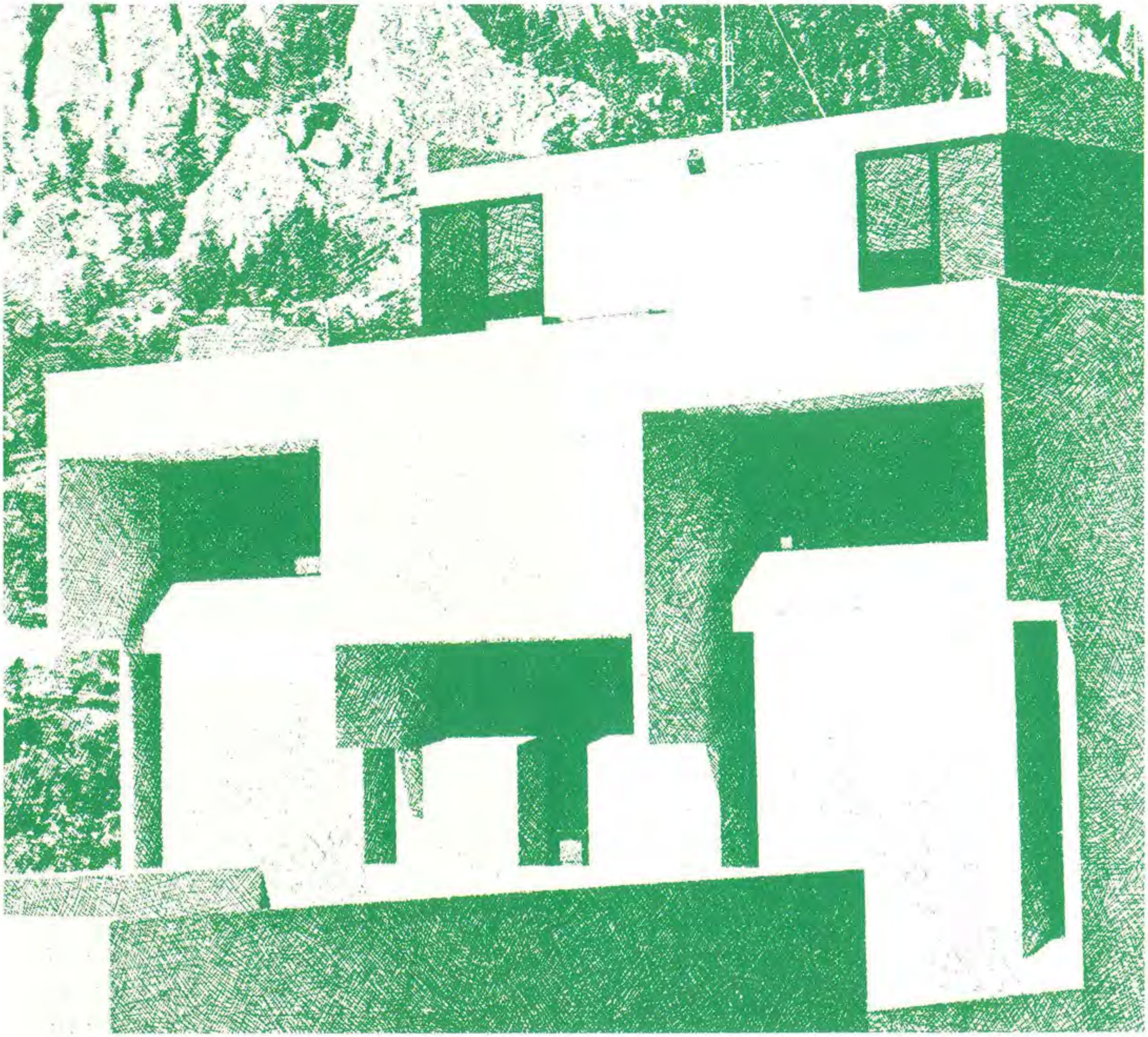
Susan Simkin and her colleagues in discovering the largest galaxy in the universe, Markarian 348, which measures 1.3 million light years across (see "Highlights" section).

- The National Astronomy and Ionosphere Center operates the world's single largest radio telescope — an antenna 1000 feet in diameter that has a radio signal collecting area of 18 and 1/2 acres — near Arecibo, Puerto Rico.

Atmospheric Research

The National Center for Atmospheric Research (NCAR), in Boulder, Colorado, engages in research on a variety of topics, including atmospheric chemistry, atmospheric dynamics, climate change, cloud physics, magnetospheric physics, mesoscale convective systems, numerical modeling of weather systems, and solar physics. Scientists at NCAR cooperate and collaborate frequently and enthusiastically with university scientists, for whom NCAR also provides major facilities, such as aircraft, supercomputers, Doppler radars, and atmospheric sounding systems.

A recent project involving an NCAR scientist has resulted in a breakthrough in the recognition of long-suspected relationships between sunspots and the weather. The breakthrough arose out of the quasi-biennial (27 months) oscillation, or QBO, of tropical stratospheric winds and the 11-year solar cycle. The effect has been isolated by a collaboration of *Harry Van Loon*, from NCAR, and *Karin Labitzke* from the Free University in Berlin. A consistent pattern of Solar Cycle-QBO changes in atmospheric circulation, North Atlantic storm tracks, and the mildness or severity of winters in the Eastern United States has become apparent. Following further research to understand the mechanism involved, it should be possible to improve long-range seasonal forecasts significantly.



Headquarters of the National Center for Atmospheric Research in Boulder, Colorado

INSTRUMENTATION NEWS

Ocean Sciences: Mass Spectrometer

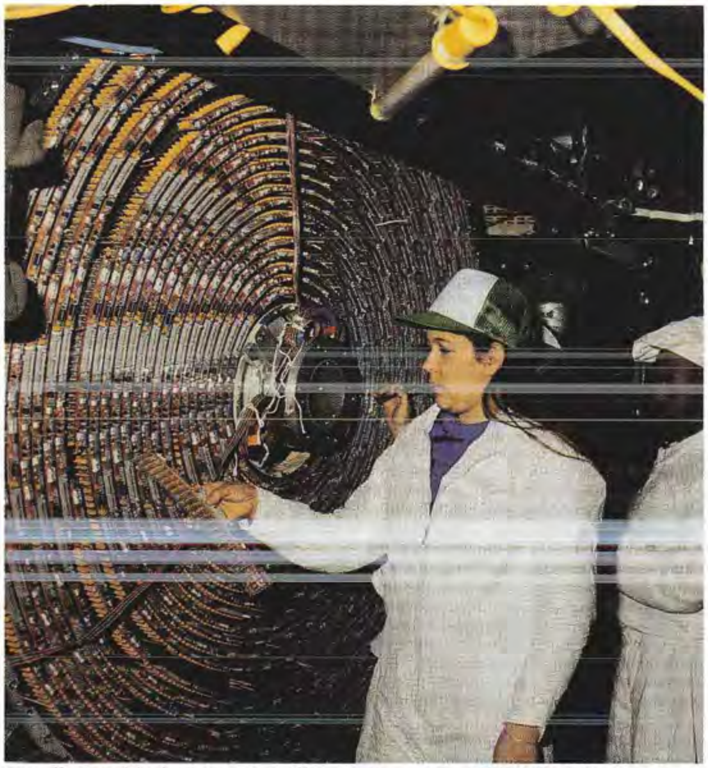
In order to analyze trace elements found in materials collected during upcoming geoscience projects, NSF's Ocean Sciences Division has announced plans for an Accelerator Mass Spectrometer. This ultrasensitive spectrometer, which uses magnetic fields to separate chemical compounds according to their mass, would reduce by a thousand the amount of seawater needed to detect trace materials.

Trace materials have become powerful tools for describing the history and dynamics of oceans. Analyzing the concentration of these materials in seawater provides information on long-term mixing and circulation in the deep ocean, on upwelling of currents, and on air-sea exchange of carbon dioxide.

Cornell Electron Storage Ring

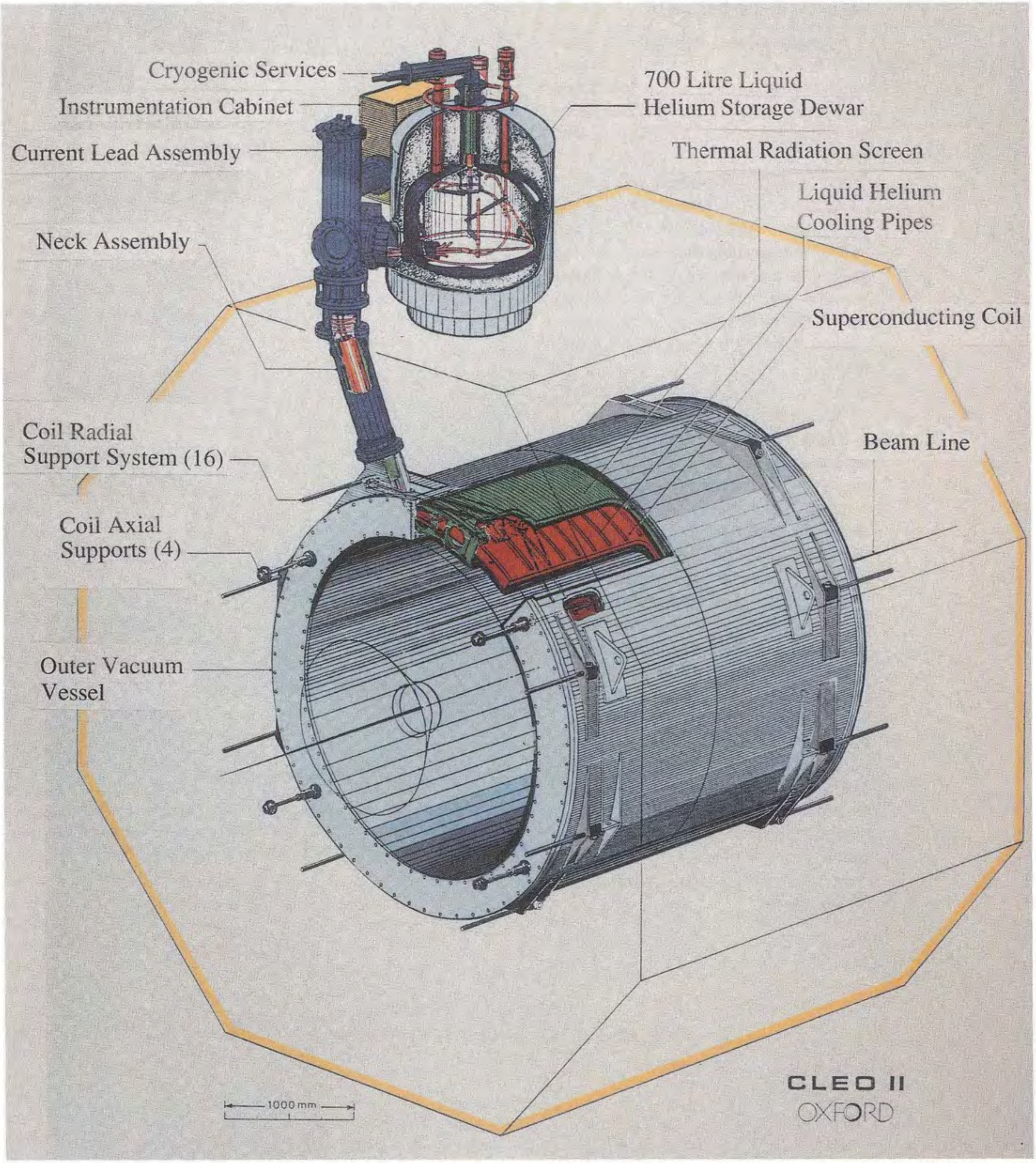
CESR, the only NSF-supported instrument for elementary particle physics research, has been undergoing a comprehensive upgrade of its storage ring and detectors. The upgrade will allow CESR to perform the most precise experiments possible within its energy range.

Research at CESR emphasizes the study of quarks, fundamental particles that bind together to form protons and neutrons. Several new combinations of quarks were discovered at the Cornell site, which draws research groups from 13 universities and colleges.



Installation. Technicians install preamps on the CLEO II drift chamber in Cornell's Electron Storage Ring (CESR).

CESR Work. Homer Neal, Jr., a Cornell undergraduate, installs photodiodes on cesium iodide scintillator crystals. Neal is the son of a former National Science Board member.



Cornell Electron Storage Ring. Diagram shows the superconducting coil and cryogenic system for CLEO II magnet.

Telescope Technology

Larger mirrors mean greater light-gathering abilities for optical telescopes and higher-resolution pictures of distant galaxies. But large mirrors are difficult to cast. *Roger Angel* at the University of Arizona is trying to develop large, lightweight, stiff mirrors that can be carefully controlled for temperature. Working under the university's football stadium, Angel and his collaborators are assembling a huge rotating oven in which they hope to cast mirrors that are up to 8 meters (308 inches) in diameter. By spinning the entire oven as the glass is melting and flowing into a special honeycomb mold, a rough parabolic curve is automatically cast into the mirror's top surface. This avoids months of tedious and wasteful grinding usually needed to achieve the shape. In addition, the thin honeycomb mold serves to stiffen the mirror, making it less likely to sag or warp under its own weight.

The innovations of Roger Angel and his research team do not end with casting. To cut down on polishing time and to make the final mirror surface more precise, Angel has experimented with computer-controlled polishing tools. Instead of using a succession of small tools to achieve the large curvature needed, Angel uses a single tool whose shape is adjusted by computer several hundred times a second. These methods are expected to garner enormous savings in the manufacture of telescopes.

Innovative design. Special rotating furnace designed by University of Arizona's Roger Angel creates the rough parabolic curve in telescope mirrors that ordinarily takes months of polishing to achieve.

Instrumentation Survey

In 1987, NSF released the results of its second national survey on the need for instruments and instrumentation in academic research.* Conducted in 1985, the survey was designed to gather national statistics on the number, age, cost, and condition of research equipment in the computer and physical sciences, and in engineering fields, and compare the data to findings from a similar NSF study in 1982.

NSF found that in 1985 more department chairs in computer science and the physical sciences said that available research equipment was "excellent" (increases from 2 to 13 percent and 4 to 12 percent, respectively). However, the proportion of engineering department heads reporting "excellent" equipment declined from 9 to 5 percent between 1982 and 1985. In both of those years, about half of the chairpersons in engineering categorized equipment as "insufficient" for investigators to conduct their research.

The report noted the increasing importance of federal funds in purchasing research equipment in computer science: government funds bought 43 percent of such equipment in 1982 and 52 percent in 1985. At the same time, departmental expenditures to maintain or repair computer science equipment soared by 114 percent from 1982 to 1985. Smaller increases were found in engineering (37 percent) and the physical sciences (9 percent).

**National Survey of Academic Research Instruments and Instrumentation Needs.* National Science Foundation, fall 1987

CHAPTER 5

AWARDS

• **Alan T. Waterman Award.** Named for NSF's first director, this award is presented each year by the Foundation to an outstanding science, mathematics, or engineering researcher who is 35 years of age or younger and has had a doctoral degree for not more than five years.

For the first time since it was established 12 years ago, the award in 1987 went to an economist, *Lawrence H. Summers* of Harvard University. A major portion of Summers' research has focused on the nature of unemployment and how it can persist in competitive labor markets. Summers has also analyzed the effects of taxation and the impact of alternative tax policies on the nation's present and future wealth. In commenting on Summers' work, a colleague noted: "In each field of research in which he worked, he combined important analytic insights with imaginative econometric research. Our profession is already much richer for the contribution he has made during the past . . . years, and we look forward to the contribution he will make in the years ahead."

A measure of the high regard that others in his field hold for Summers is his appointment as full professor at Harvard within a year of receiving his Ph.D. degree there. NSF selected Summers from among 110 highly qualified nominees to receive the Waterman Award, which includes a medal and NSF support for up to $500,000 for three years of research and advanced studies.


Harvard News Office

Lawrence H. Summers

• **Vannevar Bush Award.** The National Science Board, NSF's governing body, grants this prestigious award to individuals who have made outstanding lifetime 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 presidential report recommending establishment of the National Science Foundation.

In 1987, the Vannevar Bush award went to *David Packard*, co-founder of Hewlett-Packard, one of the nation's first science-based high technology companies. Packard established his pioneering company (along with his former classmate, William Hewlett) in 1939. Headquartered in Palo Alto, California, Hewlett-Packard achieved its reputation as an international manufacturer of measurement and computation products, clearing ground for other technology-based companies in the area now known as Silicon Valley. More recently, Packard has served as a member of the White House Science Council, as Deputy Secretary of Defense, and as chairman of the President's Blue Ribbon Commission on Defense Management.

David Packard

In 1985, Packard co-chaired a White House Science Council panel that examined the status of U.S. research universities with respect to social and economic policy. The panel's study,* known as the Packard-Bromley report, has been widely cited. One of its recommendations for encouraging government-university-industry cooperation was the creation of science and technology centers for basic research; this idea later became part of the Reagan Administration's FY 1988 budget proposal.

As NSB chairman Roland Schmitt noted in announcing the Bush Award, "David Packard realized, almost half a century ago, that the prosperity of this country and all its citizens depends on the imaginative uses of its science, engineering, and technology base. He is not only a builder of high-technology enterprise, he is also a prime exemplar of the conviction that the value of science and technology can best be measured by the extent that they serve the public good."

- **Distinguished Public Service Award.** This award, for distinguished service to science and engineering, is one of the highest conferred by the Foundation. In January 1987, the honor went to astronomer *Martin A. Pomerantz* during a ceremony held at Amundsen-Scott Station, South Pole. He was recognized for his leadership in the design and conduct of multidisciplinary research at the U.S. South Pole Station, his understanding of the unique characteristics of the South Pole as an observation site, and his ability to attract qualified scientists to conduct research there.

*A *Renewed Partnership*, Report of the White House Science Council, Panel on the Health of U.S. Colleges and Universities (Feb. 1986)

Martin Pomerantz

Pomerantz is director of the Bartol Research Foundation in Newark, Delaware at this writing. His research at the South Pole focused on cosmic rays, solar-terrestrial interactions, astrophysics, and the physics of the sun.

Hugh F. Loweth, a major contributor to U.S. science policy since the 1950's, also received the NSF Distinguished Public Service Award. After serving three decades in the U.S. Bureau of the Budget and the Office of Management and Budget, Loweth was recognized for "extraordinary leadership, initiative, and outstanding contributions to the federal government and to the


Hugh Loweth

support and strengthening of U.S. science and engineering programs."

In particular, the award noted, Loweth saw as early as the 1950's Antarctica's significance as a natural research laboratory, and he helped to formulate what became the U.S. Antarctic Research Program. His early emphasis on the need for major research instruments for scientific progress led to the establishment of NSF's national research centers in astronomy and the atmospheric sciences, the Materials Research Laboratories, and the earthquake engineering program.

• **Meritorious Public Service Award.** During 1987, Erich Bloch gave this award to the staff of the Deep Sea Drilling Project at the Scripps Institution of Oceanography in San Diego. Specially cited was *M.N.A. Peterson,* "in recognition of his long and dedicated service as Chief Scientist, Program Director, and Principal Investigator of the Deep Sea Drilling Project at Scripps Institution of Oceanography."

The accomplishments of the staff members, who operated 96 drilling expeditions between 1968 and 1983, include new understanding of how the sea floor spreads and new information confirming the plate tectonics theory on the formation of continents. The Scripps drillship dug 1092 holes at 624 sites, penetrating the ocean's crust to a depth of more than 3240 feet. Studies of natural ocean trenches using the drillship provided new clues into the origin of large-scale earthquakes.

• **Bloch receives award.** In December 1986, NSF Director *Erich Bloch* received from the Council of Scientific Society Presidents its award for support of science. Mr. Bloch was cited for his contributions to the improvement of science and engineering education and to the exchange of scientific information within the United States and abroad. In addition, the Council noted that Mr. Bloch has given high priority to industrial competitiveness, working to increase the number and quality of graduates in science and engineering and encouraging fuller use of the talents of women and minorities.

• **Presidential Awards for Excellence in Science and Mathematics Teaching.** Each year two outstanding high school or middle school teachers from every state, the District of Columbia, Puerto Rico, and the U.S. territories receive this award, intended to encourage high-quality teachers to enter and remain in the field. NSF established the award, in cooperation with the White House and scientific and professional organizations, in 1983. Among the 1987 winners:

—*Panayiotis Pittas* is a teacher and chairman of the mathematics department at Heritage High School in Lynchburg, Virginia. He was cited for his innovative use of microcomputers in teaching calculus, a branch of advanced mathematics sometimes difficult for new students to grasp but a basic tool in the sciences and engineering. Pittas, who coaches a student team for math competitions, was selected by the Woodrow Wilson National Fellowship Foundation to attend its 1985 summer institute in mathematics.

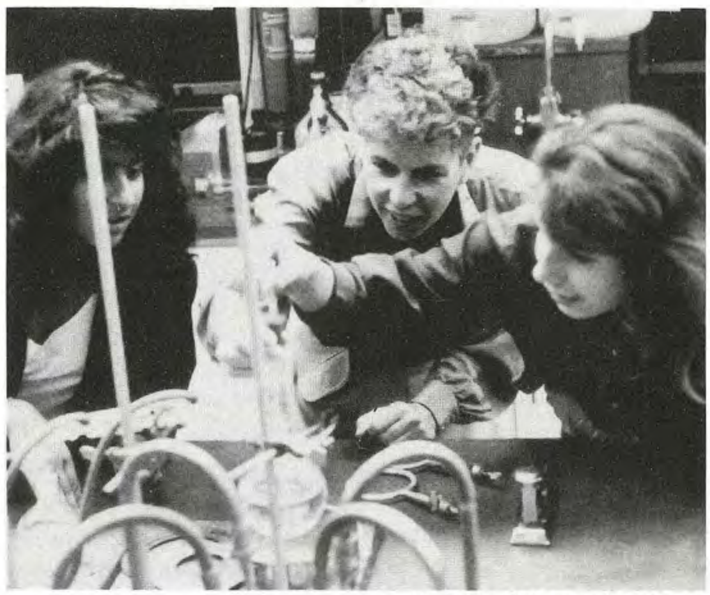
—*Adriano M. Gonzalez*, a 30-year-old high school science teacher in Austin, Texas, also received the 1987 award. Although Gonzalez has taught for only six years, he has already spent many hours in the classroom. By day he teaches chemistry, honors chemistry, and anatomy and physiology at Holmes High School; by night Gonzalez teaches biology and physics in an evening school. He also is a summer school teacher. Among his many activities, Gonzalez coaches students for the Texas academic decathalon, trains them for the Scholastic Aptitude Tests (SATs), and is a school adviser for the National Science League and the National Science Olympiad.

According to Gonzalez, his goal is to get students involved and deeply committed, thus making them more competitive for future science work in high school, college, and life. Said Gonzalez, who was voted outstanding high school science teacher in 1985 and chemistry teacher of the year in 1987: "I strongly believe that I do not succeed unless my students do, and they do!"

The schools where award winners teach benefit directly; NSF provides them with grants of $5000, to be used under the awardee's direction to improve science and education courses. Examples of innovation in use of the grant money abound. Among the creative projects from past presidential awardees are the following:

Karen S. Ward, math teacher, Lincoln Southeast High School, Nebraska

Murray P. Pendarvis (center), science teacher, Doyle High School, Livingston, Louisiana



Ruth Rand (center), science teacher, Latin School of Chicago

Guadalupe Sabino, math teacher, Hopwood Junior High School, Saipan, Marianas (U.S. territory)

—Installation of a videolaser disk player—with computer and satellite dish receiver—for science students all over Wyoming, where *Michael Pearson* of McCormack Junior High School in Cheyenne has established a satellite teleconference center.

—Introduction of a mathematics manipulatives program at Indian Trail Junior High School in Olathe, Kansas, where *Charlotte Keith* spices her math instruction with pattern blocks, color squares, geoboards, tangrams, and attribute logic blocks.

Other awardees have used their $5000 NSF grant to leverage generous matching donations from companies in the private sector:

—*Doris Johnson*, of St. Louis Park High School in Minnesota, interested Honeywell enough to invest $10,000 toward establishing and maintaining a science resource center at her school.

—At Rolling Hills High School in California, *John McGehee* raised matching funds from local aerospace and high-tech companies to develop and equip an electronics/instrumentation unit for the high school physics course.

• **Major Scientific Prizes: The NSF Link.** A study released by NSF in the fall of 1987 shows that 58 percent of the winners of prestigious national research prizes in the last 10 years received some form of financial support from NSF for their prize-winning work. Moreover, most of the winners consider the Foundation their major source of research funding.

Sources of Financial Support for Winners of Research Prizes (NSF 87-87) looks at the funding histories of 440 winners of 55 basic science and engineering prizes. Included were the Nobel Prize, MacArthur fellowships, NSF's own Waterman Award, 12 engineering honors, and prizes in 10 scientific disciplines.

The report, available from NSF's Office of Budget, Audit, and Control, also shows that 23 percent of the prize winners had received NSF funding for their graduate or postdoctoral studies.

AWARDS TO NSF STAFF

Director's Equal Opportunity Achievement Award

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

In late 1987 this award went to *Roosevelt Calbert*, for the dedication and commitment he has shown in (1)

M. Broffman

Roosevelt Calbert

developing the research capabilities of young minority investigators, and (2) enhancing the scientific research capabilities of minority institutions. Calbert is program director for three NSF programs that he helped launch: Minority Research Initiation, Research Improvement in Minority Institutions, and Minority Research Centers of Excellence.

Performance Management and Recognition System Award

To receive this Director's Award for Unusually Outstanding Service, NSF employees must have clearly distinguished themselves as top performers whose achievements could not have been attained without unusual planning, effort, and expertise.

The recipient of the 1987 PMRS Director's Award was *Jane T. Stutsman*, Head of the Program Analysis Section of the Office of Budget and Control (OBAC). The award was based on her exemplary effort in support of presentations to senior NSF staff, Congress, and the general public. This included all budget-related testimony before Congressional appropriations and authorization committees, and presentations to the National Science Board on planning and the budget. She has also served as Executive Secretary of the Director's Action Review Board (DARB) and the NSB Committee on Programs and Plans.

In addition to this honor, Stutsman also received a doctoral degree in 1987. Her doctorate in public administration is from the University of Southern California.

M. Broffman

Jane T. Stutsman with NSF Director Erich Bloch

CHAPTER 6

OPERATIONS, ORGANIZATION, NSF PEOPLE

OPERATIONAL NEWS

New Procedures to Investigate Charges of Misconduct in Research

At the request of NSF's Director, and in light of occasional reports of fraudulent research funded by both federal agencies and private groups, the Foundation has developed procedures to handle charges of misconduct in NSF-supported research. In brief, the agency will make careful inquiries into all allegations. If a problem is found, NSF may reprimand investigators or institutions, withhold grants for a set period of time, or terminate current awards. However, the new regulations emphasize that the primary responsibility for preventing, detecting, and investigating misconduct lies not with the Foundation but with the institutions that receive NSF grants.

Updating Animal Welfare Policy

Guidelines for using vertebrate animals in NSF-supported activities have been revised to clarify (1) the types of activities allowed in animal research, (2) procedures to obtain approval for those activities, and (3) recent amendments to the public law upon which NSF policy is based (the Animal Welfare Act of 1966). The recent changes aim to assure compliance with requirements for the humane use, care, and treatment of laboratory animals.

Electronic Bulletin Boards Set Up

NSF's Division of Science Resources Studies (SRS) established the Remote Bulletin Board System, a service offering up-to-date electronic information on financial and human resources for science and engineering activities. The service contains comprehensive statistical tabulations, briefs on current studies, and SRS publication announcements. The system is available to anyone with a personal computer and modem by calling (202) 634-1764. For assistance in accessing the system, call (202) 634-4250.

The Division of Grants and Contracts (DGC) has set up an electronic bulletin board to aid discussion on grants and general grants policy among grantees and NSF. The bulletin board will be used to post notices of interest and serve as a forum for sponsored research administration. For additional information, contact the DGC Policy Office at (202) 357-7880.

Grant Brochure Revised

Grants for Research and Education in Science and Engineering (GRESE) was issued in FY 1987. GRESE revises and replaces *Grants for Scientific and Engineering Research* as the principal brochure to be used for guidance in preparing unsolicited proposals to NSF. The publication number (NSF 83-57) is unchanged. For a copy of GRESE, contact NSF's Forms and Publications Unit at (202) 357-7861.

ORGANIZATIONAL NEWS

New Assistant Director for Geosciences

Robert W. Corell became Assistant Director for Geosciences on June 29, 1987. Dr. Corell came to NSF from the University of New Hampshire, where he served as director of the Marine and Sea Grants Programs. His research activities are associated with the Institute for the Study of Earth, Oceans, and Space. Corell succeeds William J. Merrell, who left to become president of Texas A&M University at Galveston.

Warolin of Georgetown

Robert Corell

New Engineering Division

The former Division of Fundamental Research in Emerging and Critical Engineering Systems is now two divisions: the Division of Fundamental Research in Critical Engineering Systems and the Division of Fundamental Research in Emerging Engineering Technologies. Both are in the Directorate for Engineering.

New Offices

In June 1987, NSF established the Office of Undergraduate Science, Engineering, and Mathematics Education. The new office serves to coordinate the diverse efforts of NSF directorates in encouraging undergraduate education in science, math, and technology—a key Foundation mission. NSF also appointed a steering committee to help oversee the planning and operation of undergraduate activities for the future.

An office to administer a new NSF program also started operations in FY 1987. The Science and Technology Research Centers program is a result of the Reagan Administration's proposal for several such centers. (See earlier chapter.) The program will make its first grants in FY 1989.

Reorganization in Computer Directorate

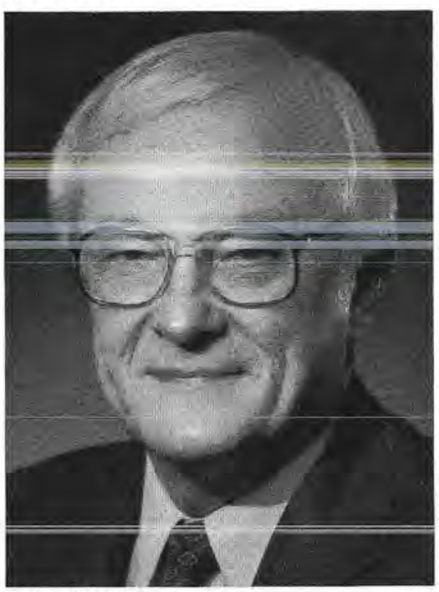
A number of reorganizations took place in the Computer and Information Science and Engineering directorate, in order to improve program balance and better represent current and new research directions. In March 1987, the networking and communications research activities of the Division of Advanced Scientific Computing moved into the newly established Division of Networking and Communications Research and Infrastructure (NCRI). Affected programs are NSFNet, EXPRES, and Networking and Communications Research.

SENIOR FOUNDATION AND BOARD OFFICIALS, FY 1987

Mort Broffman

Erich Bloch
NSF Director

John H. Moore
NSF Deputy Director



Roland W. Schmitt
Chairman
National Science Board

Charles E. Hess
Vice-Chairman
National Science Board

OTHER NSF PEOPLE

Following is a cross-section of Foundation jobs and the people who fill them in a noteworthy manner.

WILLIAM A. ANDERSON

Program Director

Earthquake Systems Integration Program

Division of Critical Engineering Systems

Directorate for Engineering

Tenure at NSF: 1976 to present

Special achievements:

William A. Anderson came to NSF from Arizona State University, where he was a professor in the Department of Sociology. He has had a long-term interest in the impacts of natural hazards and considerable experience in this area. From 1966 to 1969 he was Field Director for the Disaster Research Center at the Ohio State University. While there, Anderson conducted field studies after major disasters in locations such as Canada, Australia, El Salvador, Alaska, and other parts of the United States.

When he first came to the National Science Foundation, Anderson joined a directorate then called Research Applications for National Needs (RANN). At that time RANN staff handled research activities in earthquake engineering — one of the disaster areas in which Anderson had a strong interest. In his present position, Anderson is part of an interdisciplinary team concerned with earthquakes and other natural hazards.

The Earthquake Systems Integration Program is concerned with research and related activities (such as information dissemination) to improve the basis for actions taken to mitigate, prepare for, and recover from earthquakes. In addition to his regular program activities, Anderson has served on the federal Council on Environmental Quality and as a member of the Working Group on Earthquake Hazards Reduction, U.S. Office of Science and Technology Policy. In 1982 he spent four months on detail from NSF serving with the Office of

Contingencies and Crisis Management, Bureau of Refugee Programs, U.S. Department of State.

Background/other interests:

B.A. in Sociology, University of Akron
M.A. in Sociology, Kent State University
Ph.D. in Sociology, Ohio State University

Racquetball and guitar are but two of William Anderson's many outside interests.

ALICE C. HOGAN

Program Manager for the U.S.-China Cooperative Science Program

Division of International Programs

Directorate for Scientific, Technological and International Affairs

Tenure at NSF: 1986 to present

Special achievements:

Alice Hogan is the Foundation's key person for management of bilateral science activities with China under NSF's U.S.-China Cooperative Science Program. This program remains one of the largest and most complicated of U.S. intergovernmental agreements in science and technology. For Hogan, the job presents a management challenge with many complexities. These range from required use of the Chinese language to staying current on technical and policy matters touching upon the interests of most federal science mission agencies, several nonprofit entities, and NSF's disciplinary research programs.

All photos in this section are by Mort Broffman.

Alice Hogan maintains an "expert" network of researchers who have experience in working with the Chinese. She also visits active projects in China whenever possible. Her effectiveness in site monitoring and program negotiations is strengthened by proficiency in the Chinese language and a sound knowledge of the culture. With this background and her close coordination with other programs at NSF, Hogan ensures that quality science and mutual benefit come from research supported with our Chinese counterparts.

Hogan also manages a cooperative program involving scientists of the United States and Taiwan, which has a prosperous economy and a large cadre of U.S.-educated scientists. Hogan recognized this potential strength and, over the last year, successfully redirected the thrust of this program, which now benefits from higher visibility and has greater value to the United States from a scientific perspective.

Alice Hogan often represents NSF at seminars and symposia on China and she is increasingly recognized as a principal advisor to the Foundation's senior management on matters pertaining to China and Taiwan.

Background/other interests:

Alice Hogan's interest in Asian studies has been lifelong and marked by many travels, including an early high school exchange visit to Malaysia and a three-month visit to China in 1978. Her formal education at Cornell and Michigan focused on Asian studies.

Before joining NSF's international division, Hogan worked with the National Oceanographic and Atmospheric Administration for eight years. Highlights of this association include work with the satellite program and time at sea on the ship *Oceanographer* with U.S. and Chinese scientists. The latter was the first major U.S. government-sponsored oceanographic project with China.

Free time is devoted to long-distance cycling, gardening, scuba diving, and skiing. At NSF, Hogan also reserves time for involvement in activities designed to encourage the participation of women and minorities in science and engineering.

DEH-I HSIUNG

Program Analyst

Office of Budget and Control

Office of the Director

Tenure at NSF: 1984 to present

Special achievements:

In Deh-I Hsiung's four years at NSF, she has made significant contributions, both within and outside the Office of Budget and Control (OBAC). As OBAC's program analyst for the Mathematical and Physical Sciences Directorate (MPS), she helps plan and prepare budget justifications to the Office of Management and Budget and the Congress. When not crunching numbers, Hsiung arranges gourmet excursions to ethnic restaurants for an ever-widening group of MPS rotators and their guests.

Born outside of London, Hsiung was raised in Oxford, England, earning both B.A. and M.A. degrees in mathematics at Oxford University. In addition, she received an M.S. degree in management from the Massachusetts Institute of Technology.

Although raised outside of China, she is fluent in Mandarin Chinese, and maintains close ties with family in mainland China as well as in Taiwan, England, and the United States. She has also lectured at Chinese academic institutions on computer-aided management decision making.

As a charter volunteer to NSF's Equal Employment Opportunity Council, she helped develop strategies to correct underrepresentation of Asian Americans at the Foundation.

Other interests:

Deh-I Hsiung is active on the board of directors for the local MIT alumni organization. During tax season she may be found at a free tax clinic, where she volunteers to prepare tax forms for low-income individuals.

LARRY CLARK

Program Manager

Ocean Technology Program

Directorate for Geosciences

Tenure at NSF: 1981 to present

Special achievements:

Larry Clark joined NSF in 1981 from the Woods Hole Oceanographic Institution. He was the first program manager for the Ocean Technology program, established to accelerate the rate of adaptation

of new instruments and technology for ocean sciences.

Clark brings to his job a sound understanding of the multi-disciplinary ocean science community, combined with high performance standards. These are key qualities in a job where he must accept a high level of risk in the projects he chooses to fund.

An example will illustrate Larry's innovative approach to getting the most out of the program's dollar. One of his projects involves using outdated NASA communications satellites. The NSF-supported researcher on this effort operates out of central Florida in order to have a radio-free environment. He controls the operations of several satellites that were launched by NASA in the late 1960's. Although past their NASA use, these satellites provide data and voice communication for ships at sea and for antarctic operations. All this is done at a fraction of the cost for commercial services. The instruments have provided valuable learning opportunities for scientists to integrate their field operations with computers and laboratory activities ashore.

Other interests:

Larry is a licensed pilot. He once operated a seafood market on Cape Cod. He has three children and is active in school and church affairs.

CHARLES W. FROST, JR.

Contractor Property Officer

Division of Administrative Services

Directorate for Administration

Tenure at NSF: 1959 to present

Special achievements:

In December 1959, Charles Frost transferred from the Office of the International Geophysical Year (IGY) to the Office of National and International Affairs in NSF. For several years he was the Communications Officer for the U.S. Antarctic Research Program and later became the Logistics Officer, ensuring that supplies, equipment, and personnel arrived on time for the seasonal antarctic programs.

Frost travelled to McMurdo Station, Antarctica, in October 1963, to conduct a survey of field and support equipment and to establish an inventory system for this equipment. For his service, he received the Antarctic Medal and was honored by having a geographic feature named for him. "Frost Spur" is a mountain ridge located in the Dufek Massif of Antarctica.

In 1970 Frost transferred to Administrative Services to work on NSF's contractor and grantee property programs. In his position as NSF Contractor Property Officer, Frost has been responsible for oversight and inventory control of all government-owned real and personal property in the custody of NSF's contractors and grantees. Frost has management responsiblity for all land, buildings, and equipment associated with four National Centers, eight research vessels, the Michigan State University Cyclotron, and the antarctic program.

Charles Frost has saved the Foundation millions of dollars over the years by acquiring excess government equipment for use at the National Research Centers. His acquisitions include aircraft, ships, computers, tank trucks, fire trucks, ambulances, and even 130 miles of railroad track for the Very Large Array of telescopes located outside of Socorro, New Mexico. Frost has also negotiated numerous leases, use permits, and other agreements for land to be used by NSF contractors for a variety of ongoing scientific research projects—among

them the National Solar Observatory, the Very Large Array, and the Very Long Baseline Array.

Background/other interests:

Charles Frost grew up in Rhode Island and now lives in Arlington, VA. He is a sports enthusiast and fan of both the Boston Red Sox and the Boston Celtics. He serves on the board of his church and sings in its choir. He is also a "Big Band" buff who owns a complete collection of Glenn Miller records, including 75 "Original" Blue Bird 78 RPM recordings.

In June 1988, Charles Frost completes 39 years of government service, 29 of them at the National Science Foundation.

SANDRA HAIRSTON

Secretary (Stenographer)

Office of the General Counsel

Tenure at NSF: 1978 to present

Special achievements:

Office automation is changing the traditional job of secretary. Sandra Hairston has shown how a thoroughly competent person can take advantage of those changes, adding content to her job and value to her contribution.

Sandi Hairston began her career at NSF as a program secretary in the Division of Chemistry and served there for seven years in positions of increasing importance. In 1985 she joined the Office of the General Counsel, where she has again been promoted and taken on additional duties. Her formal title masks the complexity and variety of the tasks she now performs and reveals nothing of the calm and cheerful proficiency with which she does them.

In addition to what remains of traditional secretarial support for as many as five lawyers and one paralegal assistant, Hairston has important responsibilities in the Foundation's ethics and conflict-of-interests program. She manages the filing of public financial disclosure reports by senior NSF officials and participates in the review of filed reports.

Hairston also manages NSF's review and comment on proposed legislation and on other federal agencies' testimony or legislative reports — a function in which time pressures are often extreme.

Sandi Hairston handles with unruffled aplomb these disparate duties and pressures. She never loses her calm demeanor and quick, quiet smile. She is the kind of person colleagues and friends know they can depend upon.

Other interests:

When she's not sewing or reading (her favorite hobbies), Sandra Hairston likes to dabble in home improvement projects or tinker with her car. She has raised three children and is the Clerk in her church. She is a busy woman both inside and outside the office.

SIDNEY DRAGGAN

Polar Coordination Specialist, Antarctic

Division of Polar Programs

Directorate for Geosciences

Tenure at NSF: 1978 to present

Special achievements:

Dr. Sidney Draggan is an ecologist who joined the Foundation's Division of Policy Research and Analysis in 1978. He served there as analyst of environmental and human health policy issues of interest to the federal government. His special interests are in the control and testing of toxic substances. Before joining NSF, Draggan served as Ecological Effects Team Leader with the Office of Toxic Substances of the U.S. Environmental Protection Agency, as Senior Visiting Research Fellow at the Monitoring and Assessment Research Centre in London, and as Research Ecologist at Oak Ridge National Laboratory's Environmental Sciences Division. In 1987, he edited and published four volumes on long-term environmental research and development requested by the President's Council on Environmental Quality. Draggan is certified as a Senior Ecologist by the Ecological Society of America.

Draggan is with the Polar Coordination and Information Section of NSF's Division of Polar Programs. His work there focuses on implementing U.S. responsibilities under the Antarctic Treaty and enforcing and strengthening U.S. legislation on the protection and conservation of the antarctic environment. In 1987, Draggan became the first NSF staff member to winter in Antarctica, at McMurdo Station on Ross Island. During his 11 months there he drafted reports on safe performance of research at U.S. antarctic stations and on the behavioral aspects of human isolation.

Background/other interests:

Sidney Draggan enjoys photography, carpentry, and bicycling. He received his B.A. in biological sciences from City College of New York and his Ph.D. in ecology from Rutgers University.

CHARLOTTE AUGHENBAUGH

Administrative Officer
Directorate for Mathematical and Physical Sciences

Tenure at NSF: 1960 to present

Special achievements:

Charlotte Aughenbaugh joined the Foundation in 1960 in what was then the Directorate for Scientific Personnel and Education. Since 1968 she has been promoted through various positions in the research directorates to her present job, which she has held since 1975. Because of her long tenure in administrative positions and her outstanding abilities, program and support staff throughout the Foundation often seek her professional counsel and advice. She copes with this considerable drain on her time with customary diplomacy and good humor.

For almost two years during 1982 and 1983, Aughenbaugh served as Administrative Assistant to the National Science Board's Commission on Precollege Education in Mathematics, Science, and Technology, while simultaneously retaining her full-time position in the Directorate for Mathematical and Physical Sciences (MPS). For six months in 1987 she held the position of Administrative Officer for the new Office of Science and Technology Centers, again in addition to her full-time responsibilities within MPS. In both instances she handled her dual roles skillfully, efficiently, and cheerfully.

Among the many citations and awards that Aughenbaugh has received at NSF is the Meritorious Service Award—the second highest honor conferred on a Foundation employee.

Other interests:

Throughout her long career at NSF, Charlotte Aughenbaugh has been active in both the Credit Union and Employees' Association, serving in many positions, including president of the latter group. Whether in office or not, it is Charlotte to whom people turn for ideas and assistance. She is also an accomplished gardener as well as an avid traveler and collector of such items as antique quilts. Her frequent participation in auctions, bazaars, and garage sales has been curtailed somewhat in recent months as she has helped her husband build a home in the mountains of Pennsylvania. Aughenbaugh also has two married daughters, a son, and a dog to keep her occupied during her free time.

SHERRY SCOTT

Administrative Officer
Division of Cross-Disciplinary Research
Directorate for Engineering

Tenure at NSF: October 1970 to present

Special achievements:

Among Sherry Scott's significant contributions to NSF are the development and coordination of the Proposal Review and Management Tracking System (from proposal to award) for the Engineering Research Centers. The Centers program is an innovative and highly visible NSF effort, and Scott is responsible for day-to-day administrative duties—from budget administration to personnel actions—for the Centers.

Many of the NSF programs that Scott has served over the years have involved new operational procedures; her persistence and creativity have aided development of these initiatives.

As a federal employee for more than 20 years, Sherry Scott has been employed by the Department of Health, Education, and Welfare (now Department of Health and Human Services); Department of Justice; Federal Trade Commission; Department of Housing and Urban Development; and the Securities and Exchange Commission.

Scott has been an active member of the NSF Employees Association, serving in such offices as Secretary and Vice President for Cooperative Activities. She is one of the original members of NSF Local 3403, American Federation of Government Employees, and production manager for that union's NSF newsletter, the *Retort*.

Other interests:

Sherry Scott is married, has two children, and lives in Washington. She does volunteer work for the blind as a reader and as an escort; she is also a volunteer in the critical care unit of a local hospital. At NSF she takes the time to be sure that all birthdays of her fellow staff are celebrated with a cake—which she often makes herself.

DARLA J. CLARK

Administrative Officer

Resource Center Manager

Office of Legislative and Public Affairs

Tenure at NSF: 1960 to present

Special achievements:

Darla J. Clark came to the Foundation directly out of high school in 1960. In fact, part of her senior-year requirement for graduation was a part-time working assignment with NSF. That assignment has become a career spanning almost 30 years of dedicated federal service.

Clark started at NSF as a clerk-typist. At the time, the Foundation was under the leadership of Alan T. Waterman, NSF's first Director. Now, eight directors later, Clark has the dual role of Administrative Officer/Resource Center Manager for the Office of Legislative and Public Affairs.

When the development of resource centers began to take hold at NSF in 1986, Clark applied her skills to creating a center that could handle the critical and time-sensitive functions of legislative and public affairs. Her knowledge of both the internal and external workings of the Foundation is valuable in helping the office accomplish its mission. In addition, for well over 15 years Clark has balanced her administrative duties with service on many Credit Union and Employee Association committees.

Background/other interests:

Originally from Swarthmore, PA, Darla Clark moved to northern Virginia in 1956. Residing close to her two brothers and parents, she now lives in Burke, VA, where she enjoys animals, gardening, boating, and tennis. Her favorite vacation spot is Myrtle Beach, South Carolina.

JOHN YELLEN

Program Director for Anthropology

Division of Behavioral and Neural Sciences

Directorate for Biological, Behavioral, and Social Sciences

Tenure at NSF: 1977 to present

Special achievements:

The anthropology program has grown under John Yellen's direction into one of the largest and most complex in the Foundation. Yellen has overseen the development of two major initiatives: support for systematic (usually museum-based) anthropological collections and support for archaeometric laboratories. The laboratory program reflects archaeologists' need to maintain state-of-the-art expertise in their ability to measure the age of artifacts.

Archaeologists deal with sensitive materials in their research, since many of the artifacts are national treasures. Yellen has worked with Mexican and African authorities to maintain U.S. researchers' access to archaeological sites while assuring that the host governments' concerns are met.

John Yellen took a sabbatical from his Foundation duties in 1982 to conduct archaeological research in Botswana, where he excavated a Stone Age site and continued his studies of changes among the local Bushmen peoples. Some of his results were published in *Science* magazine in 1985.

While in Africa, Yellen worked with his wife Alison Brooks, also an anthropoligist, and they brought their two young children to share the experience.

Background/other interests:

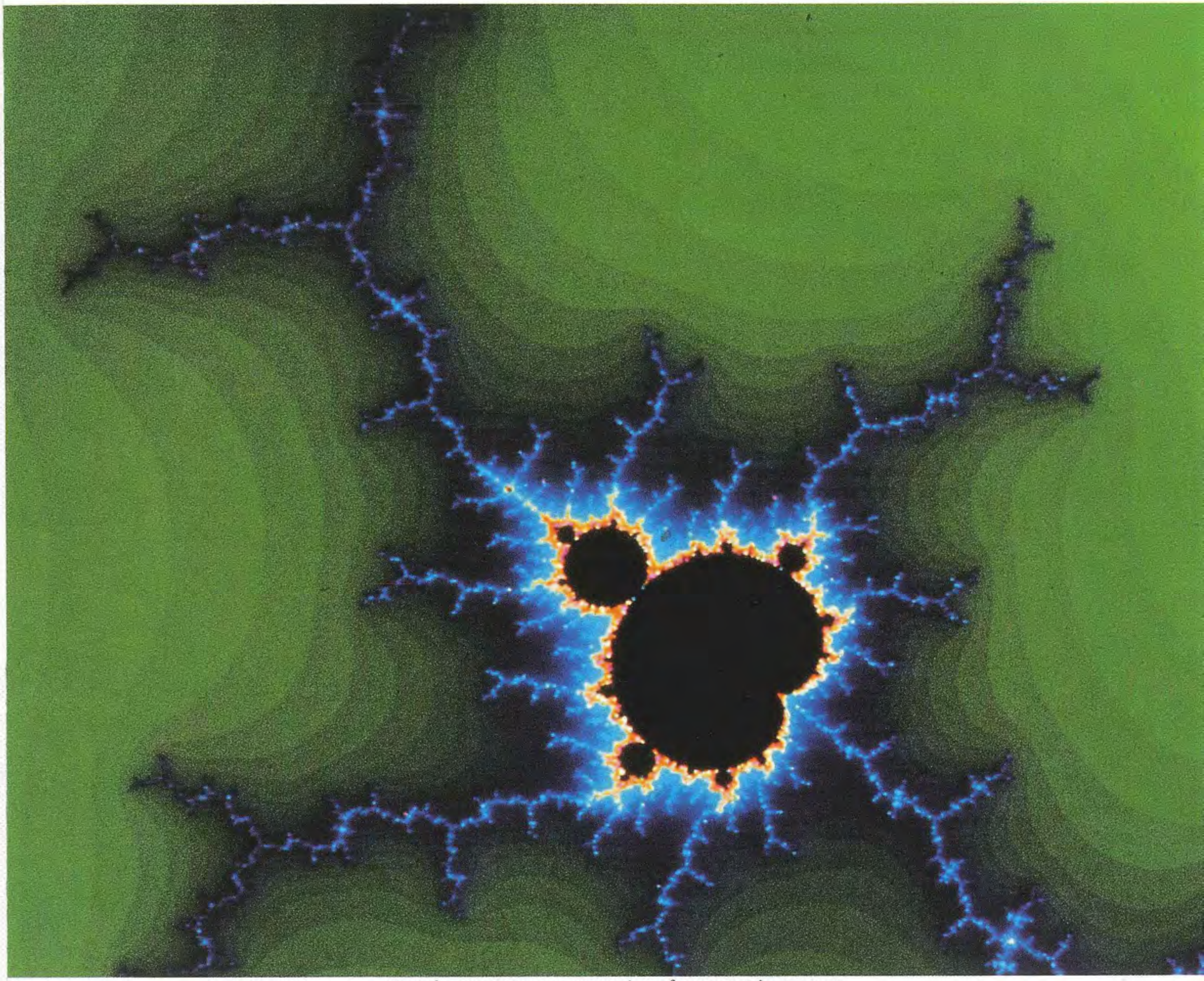
John Yellen received his B.A. in English from Hobart College (1964) and his Ph.D. in anthropology from Harvard (1974). He has done archaeological research in East Africa and has been a pioneer in the field of enthnoarchaeology (the study of how living peoples use artifacts that will later become archaeological material), focusing upon the !Kung Bushmen. He has published a book, *Archaeological Approaches to the Present,* and many professional articles. He is also an avid birdwatcher.

CHAPTER 7

CONCLUSION

The breakthroughs in superconductivity research cited earlier in this annual report symbolize the importance of basic research supported by the National Science Foundation. The potential economic and technological payoffs from the discovery of new high-temperature superconductors are great, but the findings came only after years of laboratory work steadily funded by NSF. Similarly, some of the clearest photographs and most important studies of the spectacular supernova explosion of 1987 were made possible by an NSF-supported observatory that opened with little fanfare on a Chilean mountaintop in the early 1960's.

In 1687, Isaac Newton published a landmark book that revolutionized science. Now, some 300 years later, NSF looks forward with new vigor to continued support of high-quality research that—like Newton's masterpiece—challenges the scientific community and may even change our world.



Fractals: computer representation of a geometric concept

APPENDIX A

NATIONAL SCIENCE FOUNDATION STAFF AND NATIONAL SCIENCE BOARD MEMBERS (FISCAL YEAR 1987)

NATIONAL SCIENCE FOUNDATION STAFF

(as of September 30, 1987)

Director,
Erich Bloch

Deputy Director,
John H. Moore

Senior Science Advisor,
James F. Hays (to August 31, 1987: Mary E. Clutter)

General Counsel,
Charles Herz

Deputy General Counsel,
Robert M. Andersen

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

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

Director, Office of Information Systems,
Constance K. McLindon

Director, Office of Science and Technology Centers Development,
Alan I. Leshner

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

Executive Officer,
W. Franklin Harris

Head, Office of Interdirectorate Research Coordination,
Thomas S. Quarles

Director, Division of Behavioral and Neural Sciences,
Richard T. Louttit

Director, Division of Biotic Systems and Resources,
John L. Brooks

Director, Division of Cellular Biosciences,
(Acting) Bruce Umminger

Director, Division of Molecular Biosciences,
James H. Brown

Director, Division of Social and Economic Science,
Roberta B. Miller

Assistant Director for Computer and Information Science and Engineering,
C. Gordon Bell

Executive Officer,
Charles N. Brownstein

Director, Division Advanced Scientific Computing, (Acting)
Melvyn Ciment

Director, Division of Computer and Computation Research,
Peter A. Freeman

Director, Division of Information, Robotics and Intelligent Systems,
Yi-Tzuu Chien

Director, Division of Microelectronic Information Processing Systems,
Bernard Chern

Director, Division of Networking and Communications Research and Infrastructure,
Stephen S. Wolff

Assistant Director for Engineering,
Nam P. Suh

Deputy Assistant Director for Engineering,
Carl W. Hall

Head, Office for Engineering Infrastructure Development,
William S. Butcher

Director, Division of Cross-Disciplinary Research,
Marshall M. Lih

Director, Division of Engineering Science in Chemical, Biochemical, and Thermal Engineering,
E. M. Sparrow

Director, Division of Engineering Science in Electrical, Communications, and Systems Engineering,
Allen R. Stubberud

Director, Division of Engineering Science in Mechanics, Structures, and Materials Engineering,
Win Aung

Director, Division of Fundamental Research in Critical Engineering Systems,
(Acting)
Michael P. Gaus

Director, Division of Fundamental Research in Emerging Engineering Technology,
Frank L. Huband

Director, Division for Science Base Development in Design, Manufacturing, and Computer-Integrated Engineering,
Michael J. Wozny

Computer graphics: simulations of everyday objects through a technique known as ray tracing

Assistant Director for Geosciences,
Robert W. Corell

Executive Officer,
Kurt W. Sandved

Director, Division of Atmospheric Sciences,
Eugene W. Bierly

Director, Division of Earth Sciences,
Ian D. MacGregor

Director, Division of Ocean Sciences,
M. Grant Gross

Director, Division of Polar Programs,
Peter E. Wilkniss

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

Executive Officer,
M. Kent Wilson

Director, Division of Astronomical Sciences,
Laura P. Bautz

Director, Division of Chemistry, (Acting)
Kenneth F. Hancock

Director, Division of Materials Research, (Acting)
Adriaan M. de Graaf

Director, Division of Mathematical Sciences,
Judith S. Sunley

Director, Division of Physics,
Gerard M. Crawley

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

Executive Officer,
Peter E. Yankwich

Head, Office of College Science Instrumentation,
Robert F. Watson

Head, Office of Undergraduate Science, Engineering, and Mathematics Education, (Acting)
Robert F. Watson

Head, Office of Studies and Program Assessment,
William H. Schmidt

Director, Division of Teacher Preparation and Enhancement,
Arnold L. Strassenburg

Director, Division of Materials Development, Research, and Informal Science Education,
George W. Tressel

Director, Division of Research Career Development,
Terence L. Porter

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

Executive Officer,
Richard R. Ries

Director, Office of Small Business Research and Development,
Donald Senich

Director, Office of Small and Disadvantaged Business Utilization,
Donald Senich

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

Director, Division of Research Initiation and Improvement, (Acting)
Joseph G. Danek

Director, Division of International Programs,
John P. Boright

Director, Division of Policy Research and Analysis,
Peter W. House

Director, Division of Science Resources Studies,
William L. Stewart

Assistant Director for Administration,
Geoffrey M. Fenstermacher

Director, Office of Equal Opportunity,
Brenda M. Brush

Director, Division of Financial Management,
Kenneth B. Foster

Director, Division of Grants and Contracts,
William B. Cole, Jr.

Director, Division of Personnel and Management,
Margaret L. Windus

Director, Division of Administrative Services,
Robert E. Schmitz

NATIONAL SCIENCE BOARD

(addresses as of Sept. 30, 1987)

Terms Expire May 10, 1988

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

ROBERT F. GILKESON, Chairman of the Executive Committee, Philadelphia Electric Co., Philadelphia, PA

CHARLES E. HESS (Vice Chairman, National Science Board), Dean, College of Agricultural and Environmental Sciences, University of California at Davis, Davis, CA

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

WILLIAM F. MILLER, President and Chief Executive Officer, SRI International, Menlo Park, CA

WILLIAM A. NIERENBERG, Director Emeritus, Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA

NORMAN C. RASMUSSEN, McAfee Professor of Engineering, Massachusetts Institute of Technology, Cambridge, MA

ROLAND W. SCHMITT (Chairman, National Science Board), Senior Vice President and Chief Scientist, General Electric Company, Schenectady, NY

Terms Expire May 10, 1990

PERRY L. ADKISSON, Chancellor, Texas A&M University System, College Station, TX

ANNELISE G. ANDERSON, Senior Research Fellow, The Hoover Institution, Stanford University, Stanford, CA

CRAIG C. BLACK, Director, Los Angeles County Museum of Natural History, Los Angeles, CA

RITA R. COLWELL, Director, Maryland Biotechnology Institute, and Professor of Microbiology, University of Maryland, Adelphi, MD

AT&T

Lightwave cable

Science Museum of London

First computer programmer. Augusta Ada Byron, Countess of Lovelace and daughter of the poet Lord Byron, devised computer programs for an early mechanical computer. Most scholars consider her to be the first computer programmer.

APPENDIX B

PATENTS AND FINANCIAL REPORT FOR FISCAL YEAR 1987

PATENTS AND INVENTIONS RESULTING FROM ACTIVITIES SUPPORTED BY NSF

During fiscal year 1987, the Foundation received 147 invention disclosures. Allocations of rights to 48 of those inventions were made by September 30, 1987. These resulted in dedication to the public through publication in 11 cases, retention of principal patent rights by the grantee or inventor in 37 instances, and transfer to other government agencies in 2 cases. Licenses were received by the Foundation in 54 patent applications filed by grantees and contractors who retained principal rights in their inventions.

FINANCIAL REPORT FOR FISCAL YEAR 1987 (DOLLARS IN MILLIONS)

Research and Related Activities Appropriation

Fund Availability		
Fiscal year 1987 Appropriation	$1,406.15	
Unobligated balance available, start of year	1.48	
Adjustments to prior year accounts	4.47	
Fiscal year 1987 availability		$1,412.10
Obligations		
Biological, Behavioral, and Social Sciences:		
Molecular Biosciences	44.17	
Cellular Biosciences	53.79	
Biotic Systems and Resources	58.30	
Behavioral and Neural Sciences	43.32	
Social and Economic Science	31.16	
Instrumentation and Resources	28.57	
Subtotal, Biological, Behavioral, and Social Sciences		$ 259.31
Computer and Information Science and Engineering:		
Computer and Computation Research	$ 19.04	
Information, Robotics, and Intelligent Systems	17.02	
Microelectronic Information Processing Systems	11.61	
Advanced Scientific Computing	43.05	
Networking and Communications Research and Infrastructure	9.82	
Cross-Disciplinary Activities	16.32	
Subtotal, Computer and Information Science and Engineering		$ 116.86
Engineering:		
Chemical, Biochemical, Thermal Eng.	$ 28.42	
Mechanics, Structures, Materials Eng.	25.09	
Electrical, Communications, Systems Eng.	22.58	
Design, Manufacturing, Computer-Integrated Eng.	14.28	
Emerging Engineering Technologies	15.74	
Critical Engineering Systems	24.68	
Cross-Disciplinary Research	32.29	
Subtotal, Engineering		$ 163.08
Geosciences:		
Atmospheric Sciences	$ 93.46	
Earth Sciences	49.92	
Ocean Sciences	133.74	
Arctic Research Program	8.09	
Subtotal, Geosciences		$ 285.21
Mathematical and Physical Sciences:		
Mathematical Sciences	$ 59.92	
Astronomical Sciences	85.05	
Physics	116.98	
Chemistry	93.84	
Materials Research	108.87	
Subtotal, Mathematical and Physical Sciences		$ 464.66
Scientific, Technological, and International Affairs:		
Industrial Science and Technological Innovation	$ 16.78	
International Cooperative Scientific Activities	10.45	
Policy Research and Analysis	1.85	
Science Resources Studies	3.76	
Research Initiation and Improvement	10.94	
Subtotal, Scientific, Technological, and International Affairs		$ 43.78

Program Development and Management		$ 77.77
Subtotal, obligations		$1,410.67
Unobligated balance available, end of year		$ 1.26
Unobligated balance lapsing		$ .17
Total, fiscal year 1987 availability for Research and Related Activities		$1,412.10

U.S. Antarctic Program Activities Appropriation

Fund Availability		
Fiscal year 1987 appropriation	$ 117.00	
Unobligated balance available, start of year	.08	
Adjustments to prior year accounts	.20	
Fiscal year 1987 availability		$ 117.28
Obligations		
U.S. Antarctic Research Program	$ 12.62	
Operations Support	76.96	
Major Construction and Procurement	27.70	
Total, fiscal year 1987 availability for U.S. Antarctic Program Activities		$ 117.28

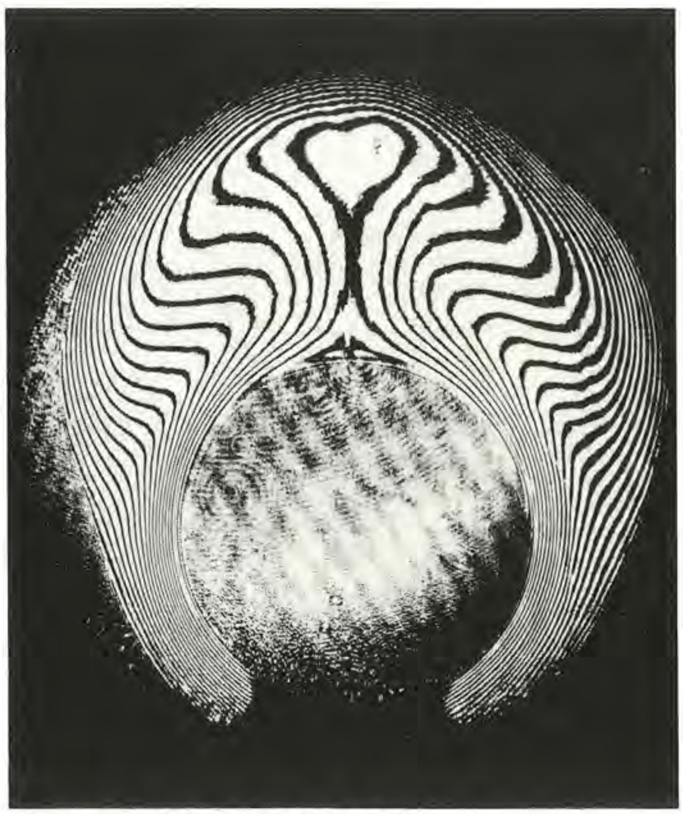
Special Foreign Currency Appropriation

Fund Availability		
Fiscal year 1987 appropriation	$ .70	
Unobligated balance available, start of year	.02	
Adjustments to prior year accounts	.04	
Fiscal year 1987 availability		$ .76
Obligations		
Special Foreign Currency	$ .72	
Unobligated balance lapsing	.04	
Total, fiscal year 1987 availability for Special Foreign Currency Program		$ .76

Science and Engineering Education Activities Appropriation

Fund Availablity		
Fiscal year 1987 appropriation	$ 99.00	
Unobligated balance available, start of year	.03	
Adjustments to prior year accounts	.02	
Fiscal year 1987 availability		$ 99.05
Obligations		
Research Career Development	$ 27.27	
Materials Development, Research, and Informal Science Education	29.48	
Teacher Preparation and Enhancement	30.49	
Studies and Program Assessment	2.20	
Undergraduate Science, Engineering, and Mathematics Education	9.50	
Subtotal, obligations		$ 98.94
Unobligated balance available, end of year		.06
Unobligated balance lapsing		.05
Total, fiscal year 1987 availability for Science and Engineering Education Activities		$ 99.05

SOURCE: Fiscal Year 1989 Budget to Congress—Justification of Estimates of Appropriations



Heat transfer patterns on a circular tube

Table 1. Biological, Behavioral, and Social Sciences, Sciences, Fiscal Year 1987 (Dollars in Millions)

	Number of Awards	Amount
Molecular Biosciences	673	$ 44.17
Cellular Biosciences	824	53.79
Biotic Systems and Resources	743	58.30
Behavioral and Neural Sciences	810	43.32
Social and Economic Science	491	31.16
Instrumentation and Resources	319	28.57
Total	3,860	$259.31

Table 2. Computer and Information Science and Engineering, Fiscal Year 1987 (Dollars in Millions)

	Number of Awards	Amount
Computer and Computation Research	272	$ 19.04
Information, Robotics and Intelligent Systems	237	17.02
Microelectronic Information Processing Systems	155	11.61
Advanced Scientific Computing	44	43.05
Networking and Communications Research and Infrastructure	80	9.82
Cross-Disciplinary Activities	62	16.32
Total	850	$116.86

Table 3. Engineering, Fiscal Year 1987 (Dollars in Millions)

	Number of Awards	Amount
Chemical, Biochemical, and Thermal Engineering	528	$ 28.42
Mechanics, Structures, and Materials Engineering	473	25.09
Electrical, Communications and Systems Engineering	369	22.58
Design, Manufacturing, and Computer-Integrated Engineering	195	14.28
Emerging Engineering Technologies	192	15.74
Critical Engineering Systems	335	24.68
Cross-Disciplinary Research	73	32.29
Total	2,165	$163.08

Table 4. Geosciences, Fiscal Year 1987 (Dollars in Millions)

	Number of Awards	Amount
Atmospheric Sciences	610	$ 93.46
Earth Sciences	773	49.92
Ocean Sciences	838	133.74
Arctic Research	97	8.09
Total	2,318	$285.21

Table 5. Mathematical and Physical Sciences, Fiscal Year 1987 (Dollars in Millions)

	Number of Awards	Amount
Mathematical Sciences	1,339	$ 59.92
Astronomical Sciences	287	85.05
Physics	563	116.98
Chemistry	1,118	93.84
Materials Research	873	108.87
Total	4,180	$464.66

Table 6. Science and Engineering Education, Fiscal Year 1987 (Dollars in Millions)

	Number of Awards	Amount
Research Career Development	155	$27.27
Materials Development, Research and Informal Science Education	152	29.48
Teacher Preparation and Enhancement	286	30.49
Studies and Program Assesment	23	2.20
Undergraduate Science, Engineering, and Mathematics Education	347	9.50
Total	963	$98.94

Table 7. Scientific, Technological, and International Affairs, Fiscal Year 1987 (Dollars in Millions)

	Number of Awards	Amount
Industrial S & T Innovation	227	$16.78
Internat'l. Coop. Sci. Activ.	461	10.45
Policy Research and Analysis	29	1.85
Science Resources Studies	41	3.76
Research Initiation and Improvement .	86	10.94
Total	844	$43.78

Table 8. U.S. Antarctic Program, Fiscal Year 1987 (Dollars in Millions)

	Number of Awards	Amount
U.S. Antarctic Research Program	146	$ 12.62
Operations Support	17	76.96
Major Construction and Procurement .	4	27.70
Total	167	$117.28

SOURCE: Fiscal Year 1989 Budget to Congress-Justification of Estimates of Appropriations (Quantitative Program Data Tables).

University of Alaska

Night sky

APPENDIX C

ADVISORY COMMITTEES AND CHAIRPERSONS FOR FISCAL YEAR 1987

(addresses effective as of September 30, 1987)

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Jonathan Darby

Instrumentation: At the University of Illinois at Chicago, a faculty member plots a graph in the animal laboratory.

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