NATIONAL SCIENCE FOUNDATION

FY 1996-1997 ANNUAL REPORT

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LETTER OF TRANSMITTAL

The President of the United States
The White House
Washington, D.C. 20500

Dear Mr. President:

I am pleased to transmit the Annual Report for Fiscal Years 1996-1997 of the National Science Foundation, for submission to the Congress as required by the National Science Foundation Act of 1950.

Sincerely,

Rita R. Colwell
Director

DIRECTOR'S MESSAGE

The Promise of Science and Engineering: An Investment in the Future

A Message From NSF Director Rita Colwell

At the close of the 20th century, America stands on the threshold of a new era of discovery--an era in which we will expand our understanding of the origins of the universe, discover new states of matter, command crops to grow and medicines to heal, and produce significant progress in efforts to protect our environment and make it safer for ourselves and future generations. The scientific inquiry that paves the way for these advances receives support from many sectors, including agencies of the federal government. Prominent among government supporters is the National Science Foundation (NSF), a major sponsor of much of today's fundamental research in science, mathematics, engineering, technology, and education.

The research funded by NSF ultimately improves the lives of the citizens who provide financial support through their tax dollars. The Foundation ensures societal benefits as part of its role as a steward of the nation's science and engineering enterprise. In this, my first annual report message, I would like to describe some of the investments in science and engineering that we are making now to assure that the United States maintains its pre-eminent position into the 21st century. It seems a fitting thing to do. The year 2000 will mark the 50th anniversary of NSF. Since it was created in 1950, the Foundation has had as its mission the promotion and advancement of progress in science and engineering research and education. Our strategic plan, *NSF in a Changing World,* published in 1995, sets forth three fundamental goals underlying this mission:

- **Enable the United States to uphold a position of world leadership in all aspects of science, engineering, and mathematics.** World leadership affords our nation the broadest possible range of options in determining the course of our economic future and national security.

- **Promote the discovery, integration, dissemination, and employment of new knowledge in service to society.** This goal emphasizes the connection between world leadership in science and engineering and the contributions that these fields make to the country's well-being.

- **Achieve excellence in U.S. education at all levels in science, mathematics, engineering, and technology.** A scientifically literate society is essential if the nation is to gain the maximum benefit from the research it sponsors.

Dividends from Basic Research

The importance to our Nation's future of support for basic science and engineering research and education cannot be overemphasized. According to economists, up to half of all U.S. economic growth during the past 50 years has come from technology and the science that supports it. Several of the fastest growing sectors of today's U.S. economy have emerged directly from basic research supported by NSF. Areas of enterprise, such as biotechnology, advanced software, high-speed communications, and medical imaging, all have deep roots in NSF-funded projects. The pay-offs from our investments in these areas have led to: higher crop yields and more environmentally friendly production practices; a better understanding of how people make decisions and solve practical problems; an ongoing revolution in the way people communicate; and digital technologies that aid in treating patients with life-threatening illnesses.

As NSF invests in promising new research and education, we will continue to expand the possibilities for dramatic advances in all areas of science and engineering. Our approach to making investments is similar to that of a venture capitalist. NSF does not conduct research itself, nor does it operate labs. Rather, the Foundation awards grants and other financial assistance to support scientists and engineers in their quest to discover new knowledge, and to support educators and researchers in their efforts to train the workforce of the future and discover new truths about the very process of learning. We support the best ideas and the most capable people in their pursuit of new knowledge and innovation. To assist us in determining the best and the most capable, NSF uses merit review by thousands of experts from various fields who volunteer their time to evaluate competitive proposals.

The Foundation's investments in people and ideas have resulted in world-class, award-winning research. For example, NSF-supported researchers have collected approximately 100 Nobel Prizes over the years, receiving recognition for their contributions to the fields of physics, chemistry, physiology and medicine, and economics. The year 1996 was particularly gratifying for NSF. Six of the seven Americans who won Nobel prizes that year had received Foundation support:

- **Richard Smalley** and **Robert Curl** of Rice University, who shared the 1996 chemistry prize with Harry Kroto of the University of Sussex in England, were recognized for their joint 1985 discovery of a new molecular form of carbon, named the buckminsterfullerene in honor of Buckminster Fuller, the architect and designer of geodesic domes. This molecule, whose 60 carbon atoms configure themselves into a soccer ball-like shape, could prove to be the key to extremely strong building materials, solar cells, and superconductors.

- **David Lee**, **Robert Richardson**, and **Douglas Osheroff** won the 1996 physics prize. While at Cornell University in 1971, they conducted NSF-funded research that helped to characterize helium-3. In addition to detailing the nature of a different state of matter, their work opened the door to new studies in low-temperature physics.

- **William Vickrey** of Columbia University shared the 1996 economics prize with James Mirrlees of England's Cambridge University. Vickrey carried out NSF-supported research on incentives under asymmetric information. His contributions to the field included new ways of thinking about fair forms of taxation and practical approaches to pricing transportation and utilities.

In October 1996, Smalley, Curl, Richardson, Osheroff, and Lee accepted NSF's invitation to discuss their work at several public events in Washington, DC. Besides talking about the research that led to their Nobel prizes, they underscored the importance of public investments in science and engineering to their work and to society. As David Lee said during a National Press Club Newsmaker program, "The Government has a very large program to fund interstate highway systems, and this is a facility which is used by everyone. Now, the basic research enterprise can be thought of in the same way. It provides a facility of new discoveries, and those discoveries are accessible to all industry." Lee went on to point out two major challenges to public support for research, noting that "the time horizons are rather long. It also turns out that the basic research enterprise is a rather broad enterprise and only certain small parts of it--and very unpredictably--are going to lead to extremely important technological breakthroughs. But when those breakthroughs do come, they can have vast implications for our society--for example, the laser, magnetic resonance imaging, and many other things."

The following year produced four more Nobel Laureates who had received NSF support. **Steven Chu** of Stanford University and **William D. Phillips** of the National Institute of Standards and Technology (NIST) shared the 1997 physics prize with Claude Cohen-Tannoudji of France "for development of methods to cool and trap atoms using laser light," according to the Royal Swedish Academy of Sciences. **Paul D. Boyer** of the University of California at Los Angeles shared the 1997 chemistry prize with John E. Walker of the United Kingdom "for their elucidation of the enzymatic mechanism underlying the synthesis of adenosine triphosphate (ATP)." ATP functions as a carrier of energy in all living organisms from bacteria and fungi to plants and animals including humans. **Robert C. Merton** of Harvard University won the prize for economic sciences jointly with Myron S. Scholes of Stanford "for a new method to determine the value of derivatives." The contributions of these and other NSF-supported researchers and educators have been of tremendous value to the advancement of science and engineering knowledge.

In addition to providing support to the most promising people and ideas, NSF uses partnerships with various institutions and organizations to maximize the return on the public's investment. NSF funds nearly 25 percent of the basic research undertaken at academic institutions. This partnership between NSF and academic institutions has provided the United States with a continuous supply of both new knowledge and new generations of world-class scientists, engineers, educators, and other technically trained professionals.

Explorers in Search of New Knowledge

Science is not a tidy pursuit operating only within disciplinary boundaries. Frequently, the pursuit of knowledge will lead scientists and engineers into unexplored territories that cross the traditional boundaries between disciplines. Many of the societal benefits arising from research funded by NSF have rested on contributions from several scientific fields. As an illustration, take magnetic resonance imaging (MRI). This vital medical procedure to image bone and tissue--counted among the breakthroughs of great importance to society by Nobelist Lee--originated in early studies of nuclear physics. Those studies led to the use of nuclear magnetic resonance (NMR) as a fundamental analytic tool in chemistry. Only when NMR was well established did the technology become an essential tool for the diagnosis of disease. NSF invested in fundamental research that, at the time, promised only to advance knowledge in a limited scientific discipline. Yet the investment has saved chemists countless hours in characterizing new compounds, and it has produced a medical technology with profound benefits to patients' health. The progression from fundamental research in physics to a medical technology that benefits millions of people exemplifies NSF's goal of "promoting the discovery, integration, dissemination, and employment of new knowledge in service to society."

In the future, we expect multidisciplinary science to yield a growing number of opportunities for realizing new knowledge that serves society. NSF is adding programs to our investment portfolio that extend what we have learned about integrated research methods into critical areas, areas the science and engineering community expects will furnish large pay-offs for the nation in the 21st century. Our investment in biological systems research, for example, is designed to increase our understanding of how the earth's microorganisms, plants, and animals interact in an intricate web of interdependencies with the physical environment of planet Earth. These multidisciplinary efforts build on an expansive range of NSF-supported research, from determining the functions of the 20,000 to 25,000 genes of the *Arabidopsis thaliana*, a small plant in the mustard family, to developing a better understanding of the role the Arctic Ocean plays in global climate dynamics.

Information technology is another area that promises tremendous future pay-offs. As the lead agency of a multi-agency initiative called Information Technology Research, NSF is investing in research to establish new directions for computer and information sciences, push the frontiers of high-end computing, and improve both the reliability and performance of emerging technologies. Our information technology investments build on numerous NSF-supported, information-based activities, including the development of high-performance networks (such as the Internet and the very-high performance Backbone Network Service) and advancing high-end computational capabilities (our Partnerships for Advanced Computational Infrastructure program, for example). A third area of tremendous opportunity is educating the workforce so they have an understanding in mathematics, science, and technology that makes them competitive in a technological society.

Excellence in Education At All Levels

Improving science, mathematics, engineering, and technology education at all levels, from pre-kindergarten through post-doctorate, is nothing less than a national imperative. Knowledge, especially knowledge from science and engineering, drives economic growth and ensures prosperity. In the next century, more and more Americans will need to be "knowledge workers." But the 21st century workforce will only be as productive, innovative, and successful as the quality and accessibility of education has prepared it to be. For these reasons, ensuring excellence in education is critical to developing the nation's future intellectual capital.

NSF emphasizes increased opportunities for all students and workers to acquire the skills they will need to succeed in the future. In particular, our educational programming aims to prepare people for a workplace in which technical problem-solving and science literacy will be crucial to their success. The Foundation also supports activities to ensure that the United States continues to produce world-class scientists, engineers, and educators. In addition, NSF seeks to engage everyone in the excitement of discovery and to make people of all ages more aware of how science and engineering enrich their lives.

At the K-12 level, one of the Foundation's priorities is reform of whole education systems. Through systemic reform activities, we partner with parents, teachers, principals, state and local education officials, political leaders, the science and engineering community, academic institutions, business and civic leaders, the media, and other government agencies--everyone who holds a stake in America's education enterprise--to bring about improvements across entire jurisdictions such as cities, rural regions, and states. NSF-supported activities combine experimentation with rigorous assessment to determine which strategies work. To ensure broad-based, long-lasting impact, we emphasize improvements that are sustained through access to standards-based coursework and materials, along with first-class preparation of teachers.

In localities where NSF-supported systemic initiatives have taken place, science and math assessment scores have improved, enrollments in challenging classes have increased, and disparities in attainment have been reduced. Preliminary data suggest improvements in student performance in all districts participating in NSF’s Urban Systemic Initiatives (USIs) program. More than 75% of the USIs showed a direct correlation between student achievement and the length of time cohorts of schools participated in the program. Nearly all sites reported increased student enrollment and completion rate in higher level courses. In addition, participating school systems in Chicago, Cincinnati, Dallas, El Paso, and Dade County (Miami), have increased graduation requirements in science and mathematics.

While these results are good news, there is still more work to be done. Just how much more work was made clear by a set of studies known as TIMSS--the Third International Mathematics and Science Study. The largest and most comprehensive study undertaken to compare academic performance in science and mathematics across more than 41 countries, TIMSS was designed, managed and funded jointly by NSF and the National Center for Education Statistics in the Department of Education. Data released in 1996, 1997, and 1998 covered eighth, fourth, and twelfth graders, respectively. U.S. fourth graders scored above the international average in mathematics and science. Eighth graders tested above average in science but below average in math in comparison to their counterparts in other countries. Even more troubling, the nation's twelfth graders ranked near the bottom in math and science.

Interestingly, many of the comprehensive reforms championed by NSF have taken hold in elementary science and mathematics education, and the TIMSS results for fourth graders provide evidence that we are on the right track. Now we seek to extend the reforms that work through all levels of education. NSF-supported activities are focused on developing high-quality, standards-based, instructional materials that stress experimentation and lead to a solid understanding of important concepts and themes. These activities target the development of well-trained and skilled teachers who are confident in both their knowledge of science, mathematics, engineering, and technology subjects and their understanding of how students learn, and also skilled in the use of the latest instructional materials and new technologies. Focus is also given to the creation of classrooms equipped with appropriate technology and stronger linkages between the science and engineering research enterprise and the educational system.

In recent years, NSF has seen success in using information technology to link students with researchers. Our support of WhaleNet-Interactive Education, an interdisciplinary, hands-on, collaborative telecomputing project sponsored by Wheelock College, is a shining example. Schools participating in WhaleNet use computers, the Internet, and related information technology to connect their students to research databases, to scientists and naturalists working in the field, and to other students, on a real-time basis. The program generates student involvement and interest in studies on marine mammals, pollution, and general environmental sciences while fostering an interdisciplinary approach to learning, research, critical thinking, and problem solving.

NSF is working to revitalize undergraduate education with support to colleges and universities to stimulate comprehensive, innovative reforms that promote student learning, prepare students for rewarding careers, and enhance awareness of and appreciation for science, mathematics, engineering, and technology. At the graduate level, NSF’s programs seek to educate researchers and faculty beyond the boundaries of a single discipline, giving them access to modern research instrumentation, and preparing them for the increasingly international venue of research. Besides our efforts to improve graduate science and engineering education, NSF provides financial support for a number of outstanding graduate students each year. Since 1952, NSF’s Graduate Research Fellowship Program has supported more than 34,000 students. (To learn more about the impact of the Foundation's fellowship support, I invite you to read "The National Science Foundation Class of 1952," an article on NSF's 50th anniversary website, http://www.nsf.gov/od/lpa/nsf50/classof52.htm.)

More recently, one of NSF's priorities at the graduate and undergraduate levels is the integration of research and education. The Foundation's Recognition Awards for the Integration of Research and Education (RAIRE) are designed to stimulate new thinking at colleges and universities about how to foster the natural connections between learning and discovery. The first RAIRE recipients, selected in 1997, demonstrated leadership, innovation, and achievement in developing programs at their institutions that integrate research and education.

Other NSF education activities seek to overcome the underrepresentation of minorities, women, and people with disabilities in science, mathematics, and engineering fields. All segments of society must take part if the United States is to succeed in the technology-driven, globally competitive world of the next century.

To strengthen America's system of education in the future, NSF is supporting continued experimentation and rigorous evaluation, better integration of the Foundation's research portfolio with the education we support, more and better uses of information technology to increase the resources available to K-12 students and others, and more research on learning. A better understanding of the science of learning could lead to entirely new ways of educating our children--and ourselves.

Conclusion

One of the most important principles the Foundation has proven over the course of nearly 50 years is that today's wise investments in science and engineering can yield stunning pay-offs in the years ahead. The American people have entrusted NSF with the task of building on past successes to create a brighter future, one that takes shape through the continuing integration of science and engineering into the details of our daily lives. As the 21st century dawns, the importance of every nation's scientific and technical capability is increasing. To keep our promise to today's taxpayers and to future generations of Americans, to keep America on the leading edge, NSF is committed to sponsoring fundamental research and education in science, mathematics, engineering, and technology in service to society.

At Work for America's Future

The returns on NSF's support of science and engineering research and education vary widely. Some projects produce fundamental knowledge that expands our understanding of our world. Others lead to observations that can have a more direct effect on our daily lives. The following examples of NSF funded projects for FY 96-97 exemplify NSF's philosophy of investing in the best ideas with the greatest potential for lasting impact.

- In 1997, astronomers using the Very Large Array (VLA) radio telescope in Socorro, New Mexico, first observed radio signals from gamma ray bursts. These bursts are remarkably energetic events of unknown origin that occur in the far reaches of space. The VLA observations may contribute to solving a major mystery of cosmology by helping to determine the nature of the bursts. Other groundbreaking work supported by NSF is taking place closer to home--in our solar system. Another astronomy project, the Global Oscillation Network Group (GONG), carried out a series of observations of the Sun, using sound waves rather than light. By understanding the inner workings of the Sun, researchers will learn more about how our star affects the planet on which we live.

- The SHEBA (Surface Heat Budget of the Arctic Ocean) project is also expected to yield significant benefits for society. Started in September 1997, a drifting science station was established in the Arctic Ocean to gather data on the Arctic's canopy of pack ice. SHEBA researchers obtained new information on how the sun, clouds, air, ice, and ocean interact and affect the annual melting and refreezing of the Arctic ice cap. This data, much of it posted to the Internet, is improving our understanding of the role of the Arctic in the global climate system.

- NSF's Engineering Research Centers (ERCs) provide environments in which academic and industrial scientists and engineers can focus on next-generation advances in complex engineering systems. The ERCs aim to build effective partnerships with industry, develop shared infrastructure, and increase the ability of engineering and science graduates to contribute to the nation's competitive edge. An illustration of ERC program value to industry and society is the Emerging Cardiovascular Technologies Center at Duke University. It led to the world's first commercially available instruments that can acoustically image a living heart noninvasively. The first two instruments were shipped to the National Institutes of Health and the Cleveland Clinic in 1997. Another ERC project set a new standard in the aviation industry: an integrated analysis tool, developed by the Mississippi State University ERC in cooperation with NASA's Langley Research Center. The Boeing Company used this tool to redesign the wings of its 747 aircraft. Within the past year, such companies as AlliedSignal Inc., General Electric Company, and Pratt & Whitney have bought and used the simulation package.

- What we know today as the Internet grew from predecessors in the 1980s and earlier, notably ARPANET and NSFNet. The NSFNet was a research and education network linking universities to NSF supercomputer centers. In the same decade, scientists from NSF’s supercomputer center at the University of Illinois developed the first web browser. That browser moved the Internet from the realm of university research to public communication and commerce. Today the Internet links 37 million computers and over 150 million users. Individuals around the world who use the Internet do research, exchange information, and conduct business. However, as the number of commercial transactions, data transfers, and other activities that rely on the Internet increases, the medium has become noticeably slower. Anticipating the need for a faster and more efficient version of the Internet, NSF has supported research on the vBNS (very high performance Backbone Network Service). The vBNS is an experimental platform that enables scientists and engineers to bypass the bottlenecks in today’s information superhighway and push the boundaries of networking research in search of technology and applications that will benefit all Internet users. This new platform connected NSF's supercomputer sites when it went into operation in April 1995. It expanded in 1996 and 1997 to link more than 20 academic and research sites at speeds four times those available through commercial servers. The speed makes possible such computing-intensive applications as three-dimensional simulations of ecosystems and studies of the impact of rapid fluctuations on weather patterns.

- Another program supported by NSF has made impressive progress since it was launched in 1990. The Multinational Coordinated *Arabidopsis* Genome Project is moving steadily toward its goal of sequencing the entire genome of *Arabidopsis thaliana*, a small plant in the mustard family, by the year 2000. In September 1996, NSF and the Departments of Agriculture and Energy collaboratively funded three groups of researchers who, along with other international groups, are sequencing the *Arabidopsis* genome. The sequencing has already led to conceptual advances in several areas of plant biology. These advances include understanding the mechanisms of hormone action in plants, interactions of plants with environmental factors, plant pathology, developmental pathways, and complex metabolic pathways. When the project ends, scientists will have a complete catalogue of all the genes involved in the life cycle of a typical plant. The catalogue will help researchers develop new varieties of plants for agriculture, for novel industrial raw materials, and for purposes not yet imagined.

- NSF-funded research in the geosciences focuses on the Earth's geological record from the past; current studies of the earth, ocean, and atmosphere; and the development of predictive climate models. In 1996 and 1997, two teams of NSF-supported researchers unearthed new evidence that supports the theory that a meteorite struck the Earth in the Gulf of Mexico and the Yucatan Peninsula 65 million years ago and contributed to the extinction of the dinosaurs. A team from Rutgers University, Queens College, and the New Jersey Geological Survey drilled sediments that contained a layer 1,260 feet deep rich in glass beads that formed as a result of the heat generated by the impact. This layer is located precisely at a stratigraphic level that has been identified as the boundary between the Cretaceous and Tertiary periods. A second team, led by a scientist from the Woods Hole Oceanographic Institution, used the JOIDES Resolution (the drillship of the international Ocean Drilling Program) to retrieve sediment cores that revealed a continuous record not only of the cataclysmic upheaval of the impact but also the post-impact recovery of life in the ocean. These cores will allow scientists to conduct further research on geochemical and paleontological characteristics of the re-population of the oceans.

- On yet another frontier, social and behavioral research is revealing new information about how people think and how they handle the information they receive. One important area of activity is the exploration of the many factors that influence jurors' decisions in court cases. Research studies look at preconceptions that people bring to court and how the presentation of evidence and other information can influence perceptions and decisions. New knowledge of this type promises increased understanding of behaviors and institutions important to us all.

- Information technologies, such as the Internet, not only provide schools with access to scientific resources and information for the classroom, but also with opportunities for students to learn and understand complex material. The use of technology to expand and enrich educational opportunities for all students has the potential to revolutionize instruction and learning in classrooms, schools, and entire school systems. An NSF-sponsored project at the University of California, Berkeley, is using the Internet as a means to instill in middle school students a lifelong love of science and scientific research. The project, Knowledge Integration Environment (KIE), combines scientific content, pedagogical supports for teachers, and software to form a powerful instructional framework. Augmented with Internet resources, the project guides students in developing a cohesive, linked, and integrated understanding of scientific phenomena, from the nature of light to the evolution of dinosaurs. KIE learners develop scientific ideas from personal experience, school instruction, Internet exploration, and other activities. KIE software includes a World Wide Web database of science information; tools for organizing evidence and constructing arguments; and a variety of other management and help tools.

These are just a few examples of how NSF-funded scientists and engineers have gone exploring, in search of new knowledge that ultimately serves society. For more information on the broad range of activities we support, see our website (http://www.nsf.gov).

Financial Table for Fiscal Years 1996 and 1997

	FY 1996 Number of Awards	FY 1996 Amount in Millions	FY 1997 Number of Awards	FY 1997 Amount in Millions
Biological Sciences	2,963	$304.43	2,901	$324.27
Computer and Information Science and Engineering	1,434	$262.43	1,463	$272.96
Engineering	2,823	$322.70	2,738	$349.41
Geosciences	2,582	$424.49	2,592	$444.33
Mathematical and Physical Sciences	4,389	$660.51	4,382	$693.45
Social, Behavioral and Economic Sciences	1,663	$119.31	1,710	$122.61
U.S. Polar Programs	478	$231.28	520	$224.23
Critical Technologies Institute	1	$2.63	1	$2.67
Education and Human Resources	2,327	$601.16	2,193	$619.14
Academic Research Infrastructure	38	$70.89	76	$30.02
Major Research Equipment	1	$70.00	6	$76.13

National Science Foundation Executive Staff

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Dr. Rita R. Colwell, Director
Dr. Joseph Bordogna, Deputy Director

Office of Equal Opportunity Programs
Ms. Ana A. Ortiz, Equal Opportunity Coordinator

Office of the General Counsel
Mr. Lawrence Rudolph, General Counsel

Office of the Inspector General
Mr. Philip L. Sunshine, Inspector General

Office of Integrative Activities
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Office of Legislative and Public Affairs
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Dr. Robert A. Eisenstein, Assistant Director

Office of Budget, Finance and Award Management
Mr. Joseph L. Kull, Director

Office of Information and Resource Management
Ms. Linda P. Massaro, Director

Patents and Inventions Resulting from NSF Support

The National Science Foundation received 310 invention disclosures in fiscal year 1996 and 286 invention disclosures in fiscal year 1997. Rights to these inventions were allocated in accordance with Chapter 18 of Title 35 of the United States Code, commonly called the "Bayh-Dole Act."

National Science Board Members

Term Expires May 10, 2000

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Term Expires May 10, 2002

Term Expires May 10, 2004

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