NATIONAL SCIENCE FOUNDATION

THE PRESIDENT OF THE UNITED STATES
THE WHITE HOUSE
WASHINGTON, D.C.

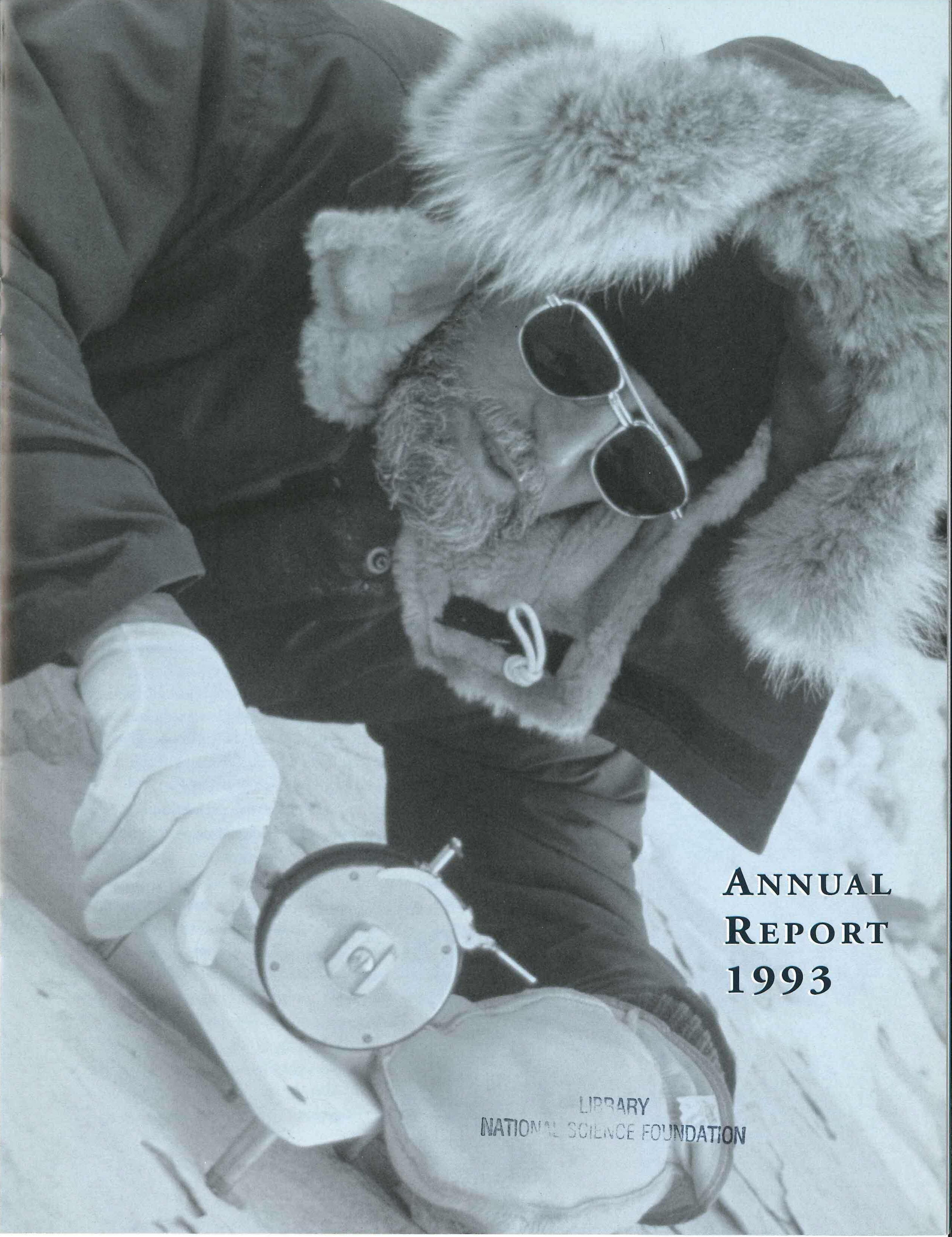
DEAR MR PRESIDENT:

I am pleased to transmit the Annual Report for Fiscal Year 1993 of the National Science Foundation, for submission to the Congress as required by the National Science Foundation Act of 1950.

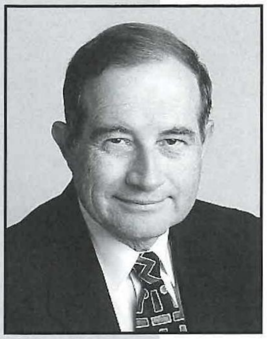
Sincerely,

Neal Lane

NEAL LANE
DIRECTOR



ANNUAL REPORT 1993



Message From NSF Director Neal Lane

"Potential and Promise Equal to Past Success"

As the National Science Foundation prepares to enter its 45th year, it looks with great pride over its past achievements while also working to position itself for the challenges and opportunities of the 21st Century. The Foundation's role as a key supporter of research and education is clearly established. Over the four-plus decades since NSF's inception, the United States has risen to an immensely valuable position of world leadership in fundamental science, mathematics, and engineering.

This Annual Report contains numerous examples of NSF's contribution to our society, our economy, and to securing our future as a nation. Just in the past few years, NSF-supported activities have provided new insights into the structure of the universe, helped to begin the building of the National Information Infrastructure, fostered innovative partnerships between academic and industrial researchers, and catalyzed the systemic reform of education in science, mathematics, engineering, and technology.

Looking ahead, it is clear that NSF's future contains potential and promise equal in every way to its past successes, as well as new demands and challenges that will test the agency's abilities. On the one hand, science, mathematics, and engineering remain replete with exciting opportunities for fundamental research and new approaches to teaching. On the other hand, our economy and society are continuing to adjust to the post-cold war era — an era that has brought tight budgetary constraints, increased concerns over the quality of the environment and the quality of life in general, and rising global

Previous Page:
Research at the top and the bottom of the world, conducted under NSF's Polar Programs, has yielded rich data for understanding such vital areas as global climate change and depletion of the ozone layer. Both Antarctica and the Arctic provide unique "laboratories" for studying certain phenomena in disciplines ranging from astrophysics to psychology of human survival in isolated environments.

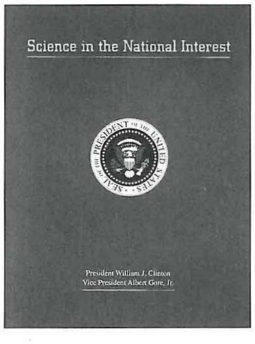
economic competition. These pressures are felt throughout society, and they are especially acute at the nation's colleges and universities, which are facing reduced growth in both resources and enrollments while both expectations and responsibilities continue to increase.

Therefore, to say that NSF faces a challenging future sounds almost cliché, but it is ever so true. In order for the agency to continue fulfilling its mission and help the nation tap the full potential of its science and engineering capabilities, NSF must provide increased leadership and stewardship. This requires setting clear priorities, rethinking and reinventing certain activities, and working in partnership wherever possible. It also requires preserving and enhancing the many strengths of the current system, notably our collective commitment to the highest standards of quality and excellence.

A key source of guidance for this challenging future is the recent White House statement on science policy, *Science in the National Interest,* which was issued in August by President Clinton and Vice President Gore. This is the first Presidential-level statement on science policy in over 15 years, and it provides the direction and vision needed to shape the Federal investment in science and technology both now and well into the future.

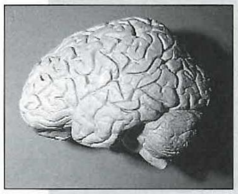
Science in the National Interest

Science in the National Interest provides a clear and compelling overview of the many ways that Federal investments in research and education have created a tremendously valuable asset for the nation. The report's thesis is that fundamental science, mathematics, and engineering are an endless resource that can help secure our continued economic and social progress. The report cites but a few of the numerous examples of how science has contributed to our health and well being — advanced medical devices, super-accurate naviga-



COMPUTING'S 3-D FUTURE

Imagine being able to visualize the complex movements of the heart or the firing of millions of neurons in the brain. With the high performance computing systems available at NSF's supercomputer centers, scientists can utilize complex three-dimensional images to study the functioning of internal organs.



NSF's four supercomputer centers are also playing a key role in the research underlying the new National Information Infrastructure or "information superhighway." A dramatic preview was provided by high performance computing's role in creating a "global observatory for the collision of the comet Shoemaker Levy-9 with the planet Jupiter. Even before the impact, NSF supercomputing systems helped predict accurately when and where the comet fragments would penetrate the Jovian atmosphere and what size fireball they would produce. When pieces of the comet arrived, astronomers on every continent were able to share their images of the planetary fireworks instantly through the NSF-initiated network. The network also served tens of thousands of citizens looking over the shoulders of the scientists as the impacts occurred.

"THE HISTORY OF SCIENCE HAS TAUGHT US TO EXPECT THE UNEXPECTED."

IDEAS TO MARKET

Industry has long utilized promising ideas from academic laboratories in developing new processes and products. But many ideas remain untapped too long before they are commercialized. NSF's approximately 50 Industry/University Cooperative Research Centers have over the past two decades led to a new era of closer interaction between academics and industry—with minimal investment of federal dollars. Overall industry and other outside support has been at a ratio of roughly 15 to 1 to NSF's investment. And in a period of contraction in industry spending on research and development, industrial members of centers put more than $100 million into new R&D in fiscal year 1990 alone.

Some of the new products and processes resulting from the centers include an industry-wide statistical process control program in the glass-making industry, a process for recycling plastic bottles, an advanced driving simulator that supports improved automotive safety research, and a computer-generated scheme for parts delivery that has already saved one major electronics manufacturer more than $100 million.

tion systems, new materials, insights into major diseases, environmental monitoring, and new understandings of human decision-making processes.

Even the most casual reading of *Science in the National Interest* makes clear that the social compact for government support of basic research — originally outlined 50 years ago by Vannevar Bush in Science: The Endless Frontier — has served the nation extremely well. In fact, a primary purpose of *Science in the National Interest* is to update the Bush compact and bring it into better alignment with society's current needs and expectations for investments in research and education.

Toward this end, the report proposes a series of actions around five broad goals:

1. Maintain effective leadership across the frontiers of scientific knowledge.
2. Enhance connections between fundamental research and national goals.
3. Stimulate partnerships that promote investments in fundamental science and engineering and the effective use of physical, human, and financial resources.
4. Produce the finest scientists and engineers for the 21st century.
5. Raise the scientific and technological literacy of all Americans.

The starting point for reaching these goals is building on the many strengths and core values of the current system. *Science in the National Interest* states that "our system rests on a strong commitment to investigator-initiated research and merit review based on evaluation by scientific peers." This commitment to quality and excellence is the cornerstone for the Foundation's future, and it has proven itself time and again as the best possible quality control mechanism for investments in research and education.

Another and perhaps the most important of these core values is captured by the first goal listed above: maintain effective leadership across the frontiers of scientific knowledge. This points to one of NSF's most unique and crucial responsibilities — providing support for all disciplines of science, mathematics, and engineering. The history of science has taught us to expect the unexpected, as key discoveries and advances often emerge from the unlikely areas. For example, over two decades ago NSF supported a number of fundamental research projects that examined the basic properties of molecular motion and light scattering in liquids. Today, we can look back on this research and see that it has helped make possible fiber optic communication, an industry with revenues of over $2 billion annually. This is just one of a long list of examples that attest to the unforeseeable payoffs that can emerge from investments in fundamental research, and it demonstrates the wisdom of NSF's commitment to maintaining a strong capability at all points on the frontiers of knowledge.

Beyond Business as Usual

With these strengths and core values as our cornerstone, the next step is to move beyond business as usual and address the major structural changes in society's rationale for investments in science and engineering. Each of these changes was recognized and underscored in *Science in the National Interest*, and they are also reflected in the new directions pursued by the Foundation in recent years.

The first of these changes is encapsulated in the second goal listed on previous page: enhance connections between fundamental research and national goals. This goal challenges the research community to demonstrate and articulate how its work is connected to the nation's priorities. *Science in the National Interest* specifically identifies five priority areas for investments in research and education: health, economic prosperity, national security, environmental responsibility, and improved quality of life.

To address these national priorities, NSF now supports focused sets of research and education activities in seven interdisciplinary areas: Manufacturing Science and Engineering, High Performance Computing and Communications, Advanced Materials and Processing, Biotechnology, Global Change and

MANAGING THE ECOSYSTEM

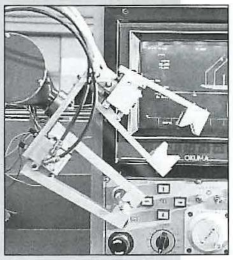
NSF-supported research is generating knowledge that can lead to better environmental policymaking. Two examples:

In one of NSF's 18 Long-Term Ecological Research projects, a University of Minnesota scientist found after an 11-year study of controlled grasslands plots that overall vegetation in plots with more diverse species is more resistant to droughts and recovers more fully after droughts. In addition, he and collaborators found an ecological "time-bomb" effect: extinctions of the dominant plant species generations after even moderate destruction of other species in the plots. These findings have wide applicability for land management, including how intensively cattle and other range animals are allowed to graze on particular species of grass.

NSF-funded research on the behavior of vapors and viscosity by a Johns Hopkins University physical chemist, in collaboration with Union Carbide scientists, led to development of supercritical carbon dioxide as a substitute vehicle for spray painting, thus reducing toxic emissions. The new spray-painting process not only causes less pollution and reduces labor cost but also provides better quality.

LAUNCHING HIGH-TECH

In global competition, American industry relies increasingly on sophisticated techniques such as robotics, computer-aided design, energy-saving and environment-friendly processes, and artificial intelligence. Much of the basic research was fostered by NSF.



Since the federal Advanced Manufacturing Technology Program was launched in 1992, NSF has played a key role.

Robots, for instance, could not find the precise position of parts to be worked on without the benefit of research on robotic vision systems. Once the parts are located, artificial intelligence techniques make it possible to determine how they are oriented so they can be fitted together.

The time required to design aircraft and high-speed trains for reduced air friction and turbulence can be drastically shortened by use of computer modeling based on advanced mathematical formulas and computational techniques.

Similarly, advances in materials research are making possible new job-creating products and sometimes new industries, such as semiconductors and fiber optics. NSF-supported research in high-temperature superconductors, for example, helped create devices for measuring tiny changes in magnetic field, a technology used in exploring for minerals and detecting human brain wave patterns.

Environmental Research, Civil Infrastructure Systems, and Science, Mathematics, Engineering, and Technology Education. The activities in these areas span all of NSF's directorates, because interdisciplinary approaches are often the key to progress in these areas. It is also important to note that the fundamental nature, quality, and educational impact of the work supported in these areas is entirely consistent with other activities supported by the Foundation and its traditional mission. NSF recently established the Strategic Areas Policy Group, chaired by the Deputy Director, Dr. Anne Petersen, to provide leadership for all activities in the strategic areas.

The second way that NSF is moving beyond business is by pursuing activities that embody a new understanding of the relationship between science and technology. For generations, U.S. science policy has reflected a linear model of the relationship between basic research and technological development. Basic research and its potential applications were treated as independent and isolated steps on an assembly line type of process running from discovery to development.

Over the years, it has become clear that science and technology are inherently interdependent. New technologies open new frontiers for research, just as advances in fundamental science and engineering contribute to technological progress. *Science in the National Interest* stresses this by noting "the intimate relationship among and interdependence of basic research, applied research, and technology...progress in any one depends on advances in the others..."

For over a decade, NSF's programming has evolved in keeping with this updated understanding. The agency's initiatives in interdisciplinary areas are one reflection of this. Other well known examples are the various types of centers NSF supports (such as Science and Technology Centers, Engineering Research Centers, and Industry-University Cooperative Research Centers). By supporting programs such as these, NSF is helping to form a new working relationship between academe and industry. These alliances speak directly to the third goal presented in the Administration's report, which calls for stimulating partnerships between government, universities, and industry that promote investments in fundamental research and education.

"...THE WATCHWORD FOR NSF'S LEADERSHIP IS FLEXIBILITY."

In the last two years, NSF has also begun to foster innovative collaborations at the level of the individual investigator. Innovative ideas and approaches to fundamental research often arise when investigators of different backgrounds and perspectives interact. NSF's Divisions of Chemistry and Chemical Engineering are working in cooperation with the Council for Chemical Research on a program in Environmentally Benign Synthesis and Processing. This program encourages academic researchers seeking NSF support to collaborate with their counterparts in the chemical industry. A similar program was established by NSF's Engineering Directorate: Grant Opportunities for Academic Liaison with Industry, which provides support for a number of different industry/university cooperative activities involving both faculty and students.

The third area where NSF's new directions are moving beyond business as usual is in education and human resources development. This directly addresses the fourth and fifth goals presented in *Science in the National Interest*: produce the finest scientists and engineers for the 21st century; and, raise the scientific and technological literacy of all Americans. As the report states, "the scientifically literate society that America will need to face the challenges of the 21st century will require orientation to science early in life and frequent reinforcement."

The activities supported by NSF aim to develop both a highly-trained cadre of professional scientists and engineers as well as a technologically literate populace with the skills and understanding needed for the workforce of the next century. Some of these activities take the form of projects dedicated specifically to education and human resource development; others take place in the context of projects aimed at advancing the frontiers of knowledge or addressing strategic national goals.

NSF provides crucial leadership at all educational levels. At the precollege level, NSF has recently expanded its systemic reform activities: now complementing the Statewide Systemic Initiatives are the Urban Systemic Initiatives and the Rural Systemic Initiatives. This same leadership is evident in undergraduate education through NSF's programs to improve advanced technology education and the curricula used for introductory courses in science, mathematics, and engineering.

BOOTSTRAPPING THE CLASSROOM

Making the U.S. first in the world in science, mathematics, and engineering education by the year 2000 is a stated national goal. NSF's Statewide Systemic Initiatives, launched in 1991, are helping to lay the groundwork in grades K-12.

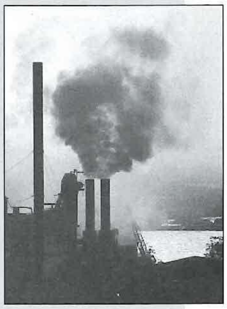
In 24 states and the Commonwealth of Puerto Rico, the SSI is fostering experimental strategies designed to ensure high quality science and math instruction for *all* students. Collectively this involves training teachers and school administrators to implement reform, including enlisting public support, mobilizing state and local funds to match NSF grants, setting up demonstration schools, training teams to assist classroom teachers, and reforming the way future teachers are taught.

Other NSF programs are also spreading across the country. Half of California has adopted a new interactive math program built around problem-solving that crosses the boundaries of algebra, geometry, trigonometry, probability, and statistics. Preliminary data show that interactive math students are much more likely than their predecessors to go on to take more advanced math courses.

The Illinois Rivers Project, adopted by more than 250 Midwestern schools, uses a river as the focus for student lab exercises involving interdisciplinary study of chemistry, biology, earth sciences, geography, and language arts.

HOW EARTH ADJUSTS

Among the NSF projects concerned with global change are major, multidisciplinary studies showing the way human communities adjust to climatic change; how land and water ecosystems adjust to changes in the environment and, in turn, cause other changes to take place; and the effects of human land use on rivers and forests. These broad-based investigations generate the knowledge required for the development of enlightened public policies and programs.



The overarching goal of such research is to increase understanding in order to prevent the destructive effects of human activity and also survive the global changes over which cannot be controlled.

NSF-funded studies, for example, have more clearly defined the role played by forests in CO_2 absorption and conversion to oxygen; some studies have even quantified the CO_2 uptake of a large forest. These studies provide the basis for reforestation and improved forest management as a way of reducing the atmospheric and environmental buildup of the global carbon "budget."

As a result of strengthened collaborations involving NSF, the university community, and industry, new data is emerging with regard to the minimization, treatment, and management of hazardous substances and solid wastes.

One highlight is the NSF-supported Calculus renewal project centered at Harvard, which has developed teaching materials that are now in use at over 300 colleges and universities. At the graduate level, the watchword for NSF's leadership is flexibility — broadening the educational experience of students to prepare them for a range of careers that will draw upon their advanced scientific and technical training.

Furthermore, while the specific issues vary considerably between the different levels of education, all of the activities NSF supports are dedicated to the premise that science cannot live by science alone. Research builds on education, just as education thrives when it is conducted in an atmosphere of inquiry and discovery. When students are able to learn by doing, they gain the general understanding needed to approach a wide range of complex problems. For these reasons, the Foundation has assigned very high priority to overcoming the unfortunate and artificial separation of research and education that has arisen in many institutions.

Conclusion

All of the highlights and examples contained in this Annual Report describe in detail the many services that NSF provides to our society. In some ways, the Foundation is akin to a societal venture capitalist — investing in high risk/high payoff activities like fundamental research and education that strengthen the nation's economy and our social fabric. In other ways, NSF serves as an agent of change — providing the leadership necessary to bring the nation's science and engineering capabilities to bear on strategic national priorities. NSF also acts as a steward and upholder of scientific quality and integrity — promoting excellence and accountability in all aspects of science, mathematics, and engineering. The Foundation is truly all of these things and more, as it works to ensure that the nation receives the highest possible return from its investments in research and education.

There is an old saying — if what you did yesterday still looks good to you, then your goals for tomorrow aren't big enough. NSF certainly has many reasons to be proud of its

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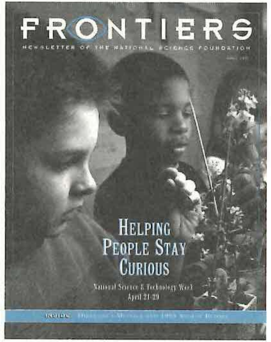

FRONTIERS

past successes and the wealth of contributions it has made to our society over its 44 years. But the agency also knows better than to even contemplate resting on its laurels. As this Annual Report goes to press, the Foundation has completed its strategic plan *NSF in a Changing World* that will enable the agency to continue its tradition of success in this era of increasing expectations and tightening budgets.

In closing, as we look toward the Foundation's 45th year and beyond, the agency's importance to the nation is more apparent than ever. By providing leadership and stewardship for activities at the many frontiers of research and education in science and engineering, the NSF is in a pivotal position to help the nation enter a new era of scientific achievement and technological progress.

NATIONAL SCIENCE FOUNDATION
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as of September 30, 1993

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Director, Office of Information and Resource Management
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NSF Annual Report 1993
Financial Tables for Fiscal Year 1993

Biological Sciences

	Number of Awards	Amount in Millions
Molecular and Cellular Biosciences	917	$81.14
Integrative Biology and Neuroscience	992	74.28
Environmental Biology	734	70.16
Biological Instrumentation and Resources	254	45.74
TOTAL	2,897	$271.32

Computer and Information Science and Engineering

	Number of Awards	Amount in Millions
Computer and Computation Research	426	$34.78
Information, Robotics and Intelligent Systems	353	26.98
Microelectronic Information Processing Systems	193	21.59
Advanced Scientific Computing	72	70.01
Networking and Communications Research and Infrastructure	249	39.90
Cross-Disciplinary Activities	101	22.34
TOTAL	1,394	$215.60

Engineering

	Number of Awards	Amount in Millions
Bioengineering and environmental Systems	483	$20.42
Chemical and Transport Systems	461	34.47
Design, Manufacture, and Industrial Innovation	686	46.20
Electrical and Communications Systems	457	34.12
Engineering Education and Centers	212	81.04
Civil and Mechanical Systems	417	39.80
TOTAL	2.716	$256.05

Geosciences

	Number of Awards	Amount in Millions
Atmospheric Sciences	665	$126.50
Earth Sciences	864	75.75
Ocean Sciences	957	179.35
Total	2,486	$381.60

Mathematical and Physical Sciences

	Number of Awards	Amount in Millions
Mathematical Sciences	1,328	$77.62
Astronomical Sciences	306	103.19
Physics	589	128.28
Chemistry	1,142	112.26
Materials Research	1,041	164.51
Total	4,406	$585.86

Social, Behavioral and Economic Sciences

	Number of Awards	Amount in Millions
Social, Behavioral and Economic Research	1100	$65.64
International Cooperative Scientific Activities	444	13.25
Science Resources Studies	34	11.78
Total	1,578	$90.67

U.S. Polar Programs

	Number of Awards	Amount in Millions
U.S. Polar Research Programs	406	$180.78
U.S. Antarctic Logistical Support Activities	10	63.43
Total	416	$244.21

Critical Technologies Institute

	Number of Awards	Amount in Millions
Critical Technologies Institute	1	$1.00

Education and Human Resources

	Number of Awards	Amount in Millions
Systemic Reform	90	$82.29
Elementary, Secondary and Informal Education	615	184.68
Undergraduate Education	878	61.91
Graduate Education and Research Development	368	85.41
Human Resource Development	182	49.61
Research, Evaluation and Dissemination	122	41.16
Total	2,255	$505.06

Academic Research Infrastructure

	Number of Awards	Amount in Millions
Academic Research Infrastructure	66	$49.75

Major Research Equipment

	Number of Awards	Amount in Millions
Major Research Equipment	2	$34.07

Source: Fiscal Year 1995 Justification of Estimates of Appropriations to the Congress

PATENTS AND INVENTIONS RESULTING FROM NSF SUPPORT

During fiscal year 1993, the Foundation received 362 invention disclosures. Allocations of rights to 156 of those inventions were made by September 30, 1993. These resulted in dedication to the public through publication in 24 cases, retention of principal patent agencies in 6 cases. Licenses were received by the Foundation in 47 patent applications filed by grantees and contractors who retained principal rights in their inventions.

About the National Science Foundation

NSF 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 ensuring the Nation's supply of scientists, engineers, and science educators.

NSF funds research and education in science and engineering. It does this through grants and contracts to more that 2,000 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 approximately 30,000 new proposals each year and processes a total of 60,000 proposal actions for research, graduate and postdoctoral fellowships, and math/science/engineering education project; it makes approximately 20,000 awards. These typically go to universities, colleges, academic consortia, nonprofit institutions, and small businesses. The agency operates no laboratories itself but does support National Research Centers, certain oceanographic vessels, and Antarctic research stations. The Foundation also supports cooperative research between universities and industry and U.S. participation in international scientific efforts.

The Foundation is led by a presidentially appointed director and a National Science Board composed of 24 outstanding scientists, engineers, and educators from universities, colleges, industries, and other organizations involved in research and education.

NSF is structured much like a university, with grants-making divisions for the various disciplines and fields of science and engineering and science education. NSF also uses a formal management process to coordinate research in strategic areas that cross traditional disciplinary boundaries. The Foundation is helped by advisors from the scientific and engineering community and from industry 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 scientist and engineers a year. NSF staff members who are experts in a certain field or area make award recommendations; applicants get anonymous verbatim copies of peer reviews.

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

NSF welcomes proposals on behalf of all qualified scientists and engineers and strongly encourages women, minorities, and people with disabilities to compete fully in its programs. In accordance with federal statues and regulations and NSF policies, no person on grounds of race, color, age, sex, national origin, or disability shall be excluded from participation in, be denied the benefits of, or be subject to discrimination under any program or activity receiving financial assistance from NSF.

Facilitation Awards for Scientists and Engineers with Disabilities (FASED) provide funding for special assistance or equipment to enable persons with disabilities (investigators and other staff, including student research assistants) to work on an NSF project. See the program announcement or contact the program coordinator at (703) 306-1636.

The National Science Foundation has TDD (Telephone Device for the Deaf) capability, which enables individuals with hearing impairments to communicate with the Foundation about NSF programs, employment, or general information. This number is (703) 306-0090.

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