HARNESSING SCIENCE FOR A MORE RATIONAL WORLD

A Speech by Bruce Alberts, President
National Academy of Sciences
Presented at the Academy's 140th Annual Meeting
April 28, 2003

The National Academy of Sciences has become an increasingly valuable and important institution since our beginnings 140 years ago. My recent addresses have outlined our ambitious agenda for spreading science and scientific values throughout our nation and the world. In this year's talk, I would like to present a progress report, emphasizing what we have done to enact this agenda since April 2002.

The National Academies

One of our important missions is to disseminate a broad, evidence-based library of scientific and technical knowledge that can be used to promote wise policy-making — both in the United States and globally. We accomplish this mission through the National Academies, which is the new name for our powerful collaboration with the National Academy of Engineering (NAE) and the Institute of Medicine (IOM), plus the National Research Council. We have generated a rich library of knowledge over the years, consisting of the thousands of reports that have been produced in response to requests from our government. In each case, we were asked to answer a specific set of questions relevant to important decisions that needed to be made by leaders and by citizens.

Even though the questions we answer are primarily technical ones, they often lie at the center of fierce political debates. I will quickly review some important recent examples. What increases in fuel economy can we reasonably expect from our nation's fleet of automobiles? What have been the environmental effects from oil and gas exploration in Alaska? Is there a scientific consensus on the link between CO_2 emissions and global warming? How should we dispose of our high-level radioactive waste? Can we reliably detect any violation of the comprehensive nuclear test ban treaty? Are polygraph tests a reliable tool to screen employees for veracity? Is our nation adequately prepared for an act of

Bruce Alberts, president, National Academy of Sciences

agricultural bioterrorism? Or, what constitutes high-quality research in education, and how can we create new structures that empower education researchers to gather the types of data we need?

All of these reports, and many more, have been well-received by some interest groups, and denounced by others. But, taken as a group, they stake out a firm position for basing policy decisions on scientific evidence. Because our reports are based on the best science, their truths will be long-lasting, surviving long after the personalities and politics of the day have disappeared.

Disseminating an Electronic Science Library

Thanks to modern technologies, we are now able to take the rich library of knowledge that the National Academies have accumulated and make it readily available to the entire world. Through our Web site (Figure 1), anyone with an Internet connection can read the complete text of more than 2,800 books — after quickly accessing what is relevant through a powerful search engine of our own design. When I took office as Academy president nearly 10 years ago, this would have seemed an impossible dream.

We also make the 18,000 pages each year of our scientific journal, the *Proceedings of the National Academy of Sciences*, immediately available for free over the Internet to 130 nations in the developing world. This week, we have added the PDF files of our reports to this resource of free scientific knowledge, creating an electronic library for the scientists and policy-makers in all these nations. Whether for a government official in Bangladesh seeking the latest information on the human toxicity of arsenic in drinking water, or for an educator in the Philippines who needs the latest science on how children learn, the Web site of the National Academies is available as a "gold standard" for reliable, science-based knowledge — a first place to go for the information needed to make wise policy decisions.

There are currently 200,000 visitors a week to our National Academies Press Web site. About one-fourth of these 10 million visits per year are from the developing world. We expect these numbers to rise dramatically in the years ahead, as everyone, everywhere becomes well-connected to the Internet.

FIGURE 1

A Vigorous Cooperative Agenda with Foreign Scientists

Michael Clegg, our new foreign secretary and I have had a very busy and profitable year, interacting closely with the leading scientists of other nations both here and abroad. Here is a photograph of Mike in Nigeria with the founding president of the Nigerian Academy (see Figure 2). These interactions have also taken one or both of us to Brazil, China, Korea, India, France, the Netherlands, the United Kingdom, Belgium, Switzerland, Germany, Italy, Canada, Mexico, and Uganda.

Six weeks ago, Mike and I were both in Trieste, Italy, to participate in a workshop for the scientists from 20 predominantly Muslim nations. Sponsored by the InterAcademy Panel (IAP), this meeting was designed to help these leaders increase the effectiveness and the influence of science in each of their nations. Accompanying us was our only Iraqi-American NAS member, Salih Wakil from Baylor University in Houston.

At the end of the workshop, these scientists from Muslim countries committed themselves to work toward the following goals:

> The Academies of Sciences... should continue to develop the key factors of quality of membership; inclusion of the full range of natural, technological, and social sciences; involvement of women; and excellence in the service to their countries and to humanity at large.... They should develop the ability to provide advice to governments and to the private sector, calling on expertise within and outside their membership, so that they can play a pivotal role in contributing to national development plans."

I will also attend the next step for these academies, a workshop in June on science education for children, that will be held at the new Library of Alexandria in Egypt.

Earlier this month, we hosted a two-week visit in Washington for leaders from seven African academies of science. This visit was quickly followed by discussions with the vice chancellors of nine major African universities. Central to our interactions with these leaders is an ambitious 10-year plan to increase the ability of the science academies in Africa to provide policy advice to their own governments. This capacity-building program would start with studies that our Academies would carry out jointly with each African academy, focusing on a critical public health issue for that nation.

Work such as this will require funding from sources other than our government. Thus, it is a special privilege for me to acknowledge a generous challenge gift of up to $20 million from George Mitchell, creat-

FIGURE 2

ing the George and Cynthia Mitchell Endowment for Sustainability Science at the National Academies. Special thanks are due NAS member Peter Raven, who helped to inspire this wonderful donation.

Organizing to Strengthen International Science

Our efforts in the international arena will be greatly aided by our recent appointment of two Distinguished Presidential Fellows for International Affairs at the Academies — Public Welfare Medalist David Hamburg, and NAS member Phillip Griffiths. They are now working with Mike Clegg and the foreign secretaries of the NAE and IOM to help steer our ambitious international agenda. This agenda includes providing support for the International Union for Science (ICSU), as well as for two relatively new international organizations that bring together the world's science academies: the InterAcademy Panel of 90 science academies based in Trieste, and the InterAcademy Council (IAC) based in Amsterdam.

The 15 Academy Presidents Who Govern the InterAcademy Council (IAC)

Academy	Population
China	1,240,000,000
India	1,000,000,000
United States	272,000,000
Brazil	171,000,000
Russia	146,000,000
Japan	126,000,000
Mexico	100,000,000
Germany	82,000,000
United Kingdom	59,100,000
France	58,900,000
South Africa	43,400,000
Malaysia	21,300,000
Sweden	8,910,000
Israel	5,740,000
Third World Academy of Sciences	

FIGURE 3

The InterAcademy Council (Figure 3) is governed by a board composed of 15 Academy presidents, with most of the major nations represented. It was created to provide science advice to the world, using study panels and review mechanisms that are similar to those that we employ to advise the U.S. government. The first IAC study is nearing completion. Its topic is building capacity for science and technology in every nation — emphasizing how this capacity can best be attained through both national and international actions. The distinguished authoring panel is co-chaired by scientists from Egypt and Brazil, and its members are from the Philippines, Pakistan, Chile, China, India, the U.K., France, Uganda, South Africa, and the United States.

The IAC's second study was requested by U.N. Secretary General Kofi Annan. It focuses on harnessing science and technology to increase food productivity in Africa. Half of the members of this panel are Africans — including one of the co-chairs, Dr. Speciosa Kazibwe, the vice president of Uganda (Figure 4).

Science for Peace

All of the international efforts that I have described are designed with one overarching goal in mind: We aim to create a much higher profile for science and for scientific institutions in both national and international affairs. As scientists, we have the advantage of sharing a common set of values: Whether from China, India, Russia, or the United States, we are all passionate about basing decisions on evidence that uses rational analysis. And we all recognize that our governments need help in focusing on policies with long-term benefits.

Through our numerous collaborations, we have built many personal relationships of trust and understanding between leading scientists. These can be especially valuable at times when our governments themselves have difficulties communicating.

Consider our ongoing programs with the Iranian Academies of Science and of Medical Sciences, where we are working together on education, environment, and health issues. This year also saw the completion of an important joint report with our Chinese colleagues on the future of automobiles in China. And, in response to the threat of nuclear terrorism, we have greatly increased our counterterrorism collaborations with the Russian Academy.

To quote former Senator Sam Nunn, we are presently engaged in a "new arms race between terrorist efforts to acquire nuclear, biological, and chemical weapons, and our efforts to stop them." If terrorists can acquire enough highly enriched uranium, they can assemble an inefficient but still extremely dangerous nuclear weapon in a city that could equally well be New York or Moscow. Scientists everywhere are deeply concerned and will readily work together to prevent this threat to civilization.

We have an ongoing Joint Committee on U.S.-Russian Cooperation on Nuclear Non-Proliferation — composed of nine distinguished members from each nation and co-chaired by John Holdren from the United States and Nikolai Laverov from Russia. This committee has recommended that the U.S. and Russian Academies urge each of our governments to assign a single senior government official the full-time responsibility of coordinating their nation's efforts to protect nuclear materials and nuclear weapons.

Our Academy's Committee on International Security and Arms Control (CISAC) has held security dialogues with Russia for more than 20 years. More recently, we have also established similar bilateral interactions with both Chinese and Indian colleagues.

A Counterproductive Visa Morass

For understandable reasons, our nation tightened the screening of visa applications from abroad after the September 11 tragedies. Unfortunately, we have done so in such an indiscriminate way that permission to enter the United States is being refused — or greatly delayed, insulting our scientific colleagues and students from abroad and disrupting many planned collaborations. For example, last year's critical Washington meeting of the U.S.-Russian Committee on Nuclear Non-Proliferation came within a day of being cancelled, because no visa could be obtained for its eminent Russian co-chair. Only intervention at the highest levels of the State Department solved that

FIGURE 4

problem. But our Chinese-American Frontiers of Science program last fall was not so fortunate. Despite our vigorous attempts to intervene, visas were not obtained in time for the 40 outstanding young scientists selected to attend by the Chinese Academy of Sciences.

Led by NAS vice president Jim Langer, our Academy has been instrumental in catalyzing recent hearings in the House Science Committee with regard to this dreadful problem. By failing to provide visas for outstanding scientists, our nation has been shooting itself in the foot. The president's science adviser, Jack Marburger, shares this view. Jim Langer and I have become convinced that special legislation for scientists will be required to change the current visa situation. Through a joint statement that I issued with the presidents of the NAE and the IOM, William Wulf and Harvey Fineberg, the National Academies have offered the help of the science and engineering community in future verification processes.

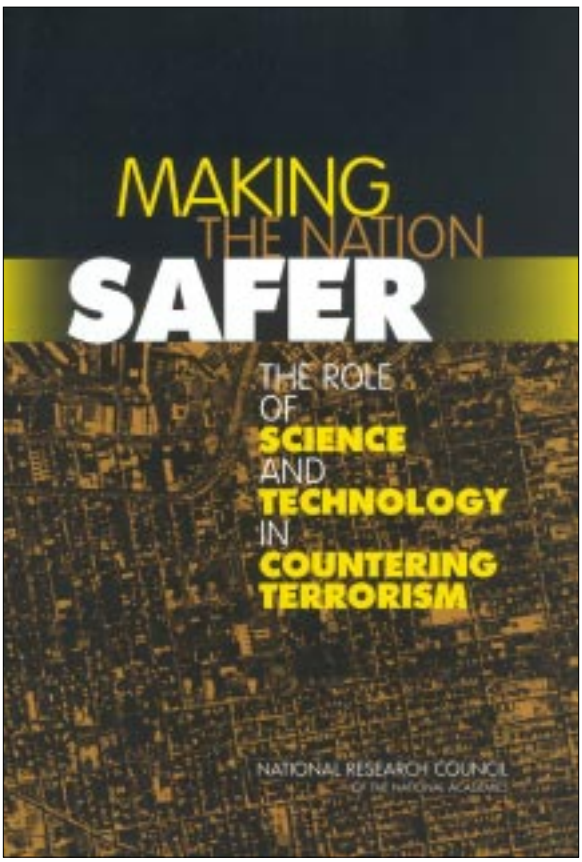


FIGURE 5

Making the Nation Safer

The September 11th events are also responsible for the creation of a new Roundtable on Scientific Communication and National Security which we are co-sponsoring with the Center for Strategic and International Studies (CSIS) in Washington. Co-chaired by NAS members David Baltimore and Harold Brown, it will be composed of an equal number of leaders from the science and the security communities. It has been designed to create a continuing dialogue, so that we can find productive ways to preserve the openness required for scientific progress, while increasing homeland security. Two central concerns of the roundtable will be the visa issue, and how to deal with so-called "sensitive but unclassified" information. These discussions will benefit from a major National Academies' study on the potential misuses of biotechnology by a committee chaired by NAS member Gerry Fink. Their report should be released this summer.

One of the real triumphs of the past year was the successful completion of the major report (Figure 5) addressing homeland security that I highlighted in last year's address. Co-chaired by NAS members Lewis Branscomb and Richard Klausner, it was completed in six months by a committee and subpanels composed of 118 volunteers, and it was reviewed by another 46 experts. Titled *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism*,

this report's 400 pages have set the science and technology agenda for the new Department of Homeland Security. Its first Undersecretary for Science and Technology, Charles McQuery, was sworn in two weeks ago by Secretary Tom Ridge here in the Great Hall of the Academy; this was especially appropriate because it was our report that urged Congress to establish this position.

As a biochemist and cell biologist, I have taken special interest in our nation's defense against bioterrorism. As *Making the Nation Safer* emphasizes, dual-use strategies that provide multiple benefits should be given the highest priority for security investments. Fortunately, as we develop new methods to guard against bioterrorist attacks, we also protect ourselves and the world from naturally occurring infectious diseases.

Both the AIDS pandemic and the new SARS outbreak are painful reminders that we are poorly prepared to combat the wide range of potential hazards from viruses — whether introduced naturally or by terrorists. A new Institute of Medicine report titled *Microbial Threats to Health* has made this clear. The good news is that our rapidly expanding biological knowledge should make it possible to develop a large set of new drugs that can block viral infections. But to succeed, we will need to re-energize the field of virology with fresh talent and resources, as well as with new ideas.

Through discussions with NAS member Tony Fauci — who is director of the National Institute of Allergy and Infectious Diseases — we have committed the Academies to help move this agenda. In June, we will sponsor a workshop focused on developing new approaches to drugs that could block the smallpox virus. Using a successful format employed previously for another disease, we will invite a few smallpox experts to interact for two days with 20 or so leading scientists from other fields. We expect these scientists with different backgrounds to suggest some novel approaches. In the end, we hope to reach consensus on three or four ambitious new ideas, which the National Institutes of Health might fund using its new Bioshield authority, requested by President Bush.

If this experiment is successful, we would want to repeat it over and over for different viral and bacterial threats. Our aim is to accelerate research advances through novel approaches, and to inject a heightened degree of excitement and energy into this critical field of research.

Maintaining Standards for Scientific Excellence and Conduct

To quote Einstein, "Many people say that it is the intellect which makes a great scientist. They are wrong: It is character." Another important function of the Academy is our role in maintaining the standards for scientific excellence and scientific conduct. Important values lie at the heart of the scientific enterprise. In a nation that has been shocked repeatedly by the conduct of some prominent business leaders, we must continue to insist on integrity in science.

Last year, a committee chaired by IOM member Arthur Rubenstein produced a visionary report aimed mostly at scientists and research institutions, titled *Integrity in Scientific Research: Creating an Environment That Promotes Responsible Conduct*. And in a recent report with a related, but more focused agenda, a committee chaired by NAS member Tom Cech has produced a set of standards for sharing publication-related data and materials.

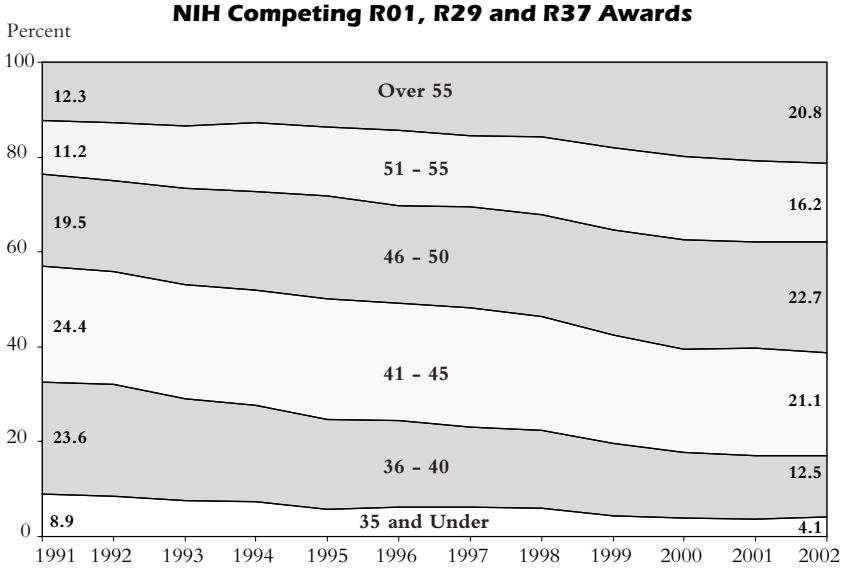
By virtue of our election as members of this Academy, each of us automatically serves as a role model for both scientific excellence and scientific integrity — a responsibility that we all need to keep constantly in mind.

Promoting Innovation in Science

It takes effort to maintain scientific excellence. Our Academy's attempt to introduce new ideas and approaches into research on microbial threat agents is just one example of a much more general need in science today. I base my comments on the biological research areas that I know best, but I suspect that similar considerations also apply in many other areas of science.

Briefly, we have developed an incentive system for young scientists that is much too risk averse. In many ways, we are our own worst enemies. The study sections that we establish to review requests for grant funds are composed of peers who claim that they admire scientific risk-taking, but who generally invest in safe science when allocating resources. The damping effect on innovation is enormous, because our research universities look for assistant professors who can be assured of grant funding when they select new faculty appointments. This helps to explain why so many of our best young people are doing "me too" science, working in areas where they compete head-to-head with other scientists who have gone before them — often their mentors or those who have trained in the same laboratory.

During a period when the total amount of federal funds available to support science at the National Institutes of Health has doubled, it is incredible to me that the average age at which scientists first become funded continues to rise. Many of my colleagues and I were awarded our first independent funding when we were under 30 years old. We did not have preliminary results, because we were trying something completely new. Figure 6 shows what has happened to the age distribution of investigators at the NIH during the past 10 years. Almost no one finds it possible to start an independent scientific career under the age of 35. Moreover, whereas in 1991 one-third of the principal investigators with NIH funds were under 40, by the year 2002 this fraction had dropped to one-sixth. Even the most talented of our young people seem to be forced to endure several years of rejected grant applications before they finally acquire enough "preliminary data" to assure the reviewers that they are likely to accomplish their stated goals. I know



Data courtesy of National Institutes of Health.

FIGURE 6

that the new director of the National Institutes of Health, IOM member Elias Zerhouni, is very concerned about the phenomenon that I have just described, and that he is struggling to find a way to break this cycle of ever older independent investigators.

The National Academies are trying to do our part to stimulate more risk-taking and innovation in science. Early this month, we announced a $40 million gift from the Keck Foundation to establish the National Academies Keck Futures Initiative. This initiative is specifically designed to stimulate the generation of new ideas at the interface between the standard disciplines. Figure 7 shows our new building at 500 Fifth Street being named the Keck Center of the National Academies.

The first Keck Futures symposium will be held this November at our Beckman Center in Irvine, California.

Stimulating the Next Generation of Scientists

Since the end of World War II, the United States has enjoyed an unprecedented period of world scientific leadership. In the 21st century, it is clear that science will flourish in many other nations of the world as well. Figure 8 (see page 10) compares the current production of scientists and engineers in the United States to that in Asia and Europe, as compiled by the National Science Foundation, showing that Asia and Europe are producing five times as many scientists and engineers as is North America. Increasingly, we find that U.S. business and industry are taking advantage of these highly skilled individuals elsewhere, moving both manufacturing and research laboratories overseas. All this is good because it will increase worldwide prosperity, as well as the interdependence and mutual understanding of nations — thereby reducing the possibility of future conflicts. But it means that we in the United States must pay close attention to developing and supporting our own scientific talent in every way that we can.

To encourage this talent, we must start with the young. In 1996, the National Academies produced the first-ever *National Science Education Standards* for the United States. Its focus was on teaching science as inquiry, with the motto "every child a scientist." The good news is that inquiry-based science education precisely fits the needs for workforce skills that have been widely expressed by business and industry. These include a "high capacity for abstract, conceptual thinking, and the ability to apply that thinking to complex real-world problems that are nonstandard, full of ambiguities, and have more than one right answer."

But we have a system in gridlock, where the main goal of science teaching seems to be imparting the knowledge of what scientists have discovered, rather than "learning how to learn" thorough acquiring the skills of a scientist. The problem originates with us — from the way that we have traditionally

FIGURE 7

taught our introductory college science classes. As just one example, why do we continue to treat our introductory laboratories in science courses as exercises in following directions, rather than challenging students to use inquiry to solve a problem with scientific tools?

We should also be very concerned that, nationwide, our introductory science courses are driving away half of those who had originally intended to be science majors. A seminal study by Elaine Seymour and Nancy Hewitt reveals that the reason for the large dropout is *not* student quality, but an adverse reaction even by students with great ability to the nature of the introductory science courses that they experience. This is an important problem that we can solve, and we have a Committee on Undergraduate Science Education, chaired by NAS member Dick McCray, that is trying to solve it.

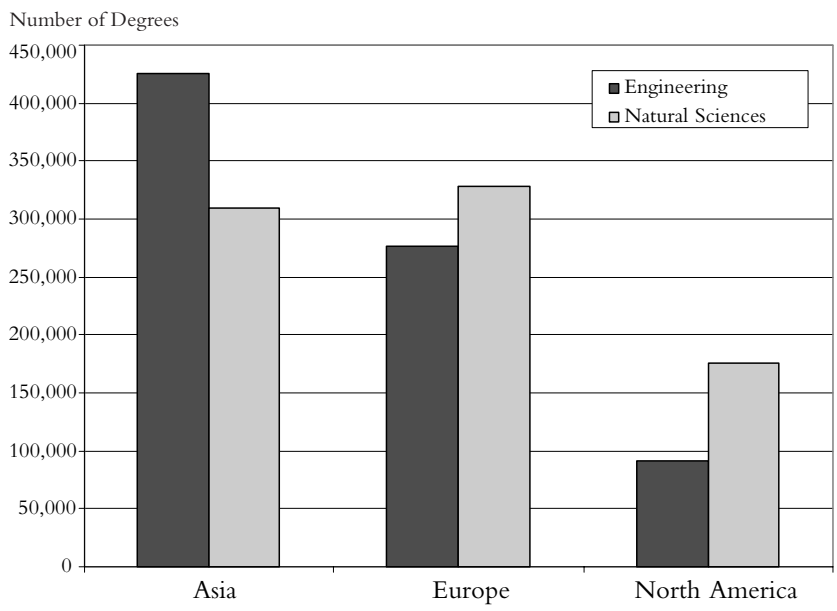
I want briefly to emphasize three other challenges that I see to our agenda of promoting inquiry-based science education at all levels.

First, the latest federal education bill, known as the "No Child Left Behind" Act requires that high-stakes science assessments be implemented in each of the 50 states by the 2007-2008 school year. Unfortunately, it is much easier and less expensive to test for science words than for science understanding and abilities. But the wrong kinds of tests will force the trivialization of science education and drive most students, including many potential scientists, away from science.

Second, much of the U.S. business community remains largely unaware of its own vital interests in promoting inquiry-based science education, being unable to discriminate between good and bad science curricula. This has left science education vulnerable, and it weakens our long-term national security.

Third, to improve U.S. education systems, we need a much larger voice from those on the front lines and less top-down management. We have a national shortage of science and mathematics teachers. Those whom we would want to recruit to our classrooms have the option of other, more lucrative careers. We must provide higher salaries for science and mathematics teachers and show that we respect

First University Degrees in Science and Engineering Fields in Selected Countries, by Region



National Science Board, *Science and Engineering Indicators - 2002.* Arlington, VA: National Science Foundation, 2002

FIGURE 8

them as professionals. Our best science teachers also need to have much more influence on the science education system at every level — from school districts, to states, to the federal government.

The National Academies are attempting to address each of the above three challenges in different ways. There is no time for me to enumerate them here. But I do want to let you know about one of our newest experiments at the Academies. To practice what we preach, we have recently established a new Teacher Advisory Council at the National Academies. It is composed of a highly selected group of the nation's best science and math teachers. Each member is an active K-12 classroom teacher, and thus provides current experience from the front lines. This photo (Figure 9) was taken at the first organizational meeting held at our Jonsson Center in Woods Hole, Massachusetts, last summer.

FIGURE 9

The Teacher Advisory Council has already injected a new sense of reality into many of our education projects. At its recent meeting in March, we also began to connect this group to leaders at the U.S. Department of Education. By supporting our nation's best teachers with the resources and prestige of the Academies, we hope to be able to use this group to inject more teacher wisdom and experience into the decisions that are made in our educational systems.

After the War

I cannot bring this address to an end without taking notice of the events of the past few months that have so dramatically changed the view of the United States by many of those in other nations. Suddenly, we are aware of the need for all Americans to better understand the lifestyles and the aspirations of those who live in very different cultures. We also must build new bridges that can enable those abroad to better understand and appreciate our own values. For the most powerful nation on the Earth to have a population that is so ignorant of how most of the world lives is a threat — both to our nation and to the rest of the world.

As a start, it is critical that we find a way for a large proportion of our nation's young scientists to engage with their colleagues in developing nations. The responsibility that has been thrust upon us is daunting. But it gives an even greater urgency to our efforts to spread scientific values, and scientific rationality, more effectively throughout the world.

NOTE: The text of this speech, with direct links to the full text of cited reports, is available on the Academy's Web site at <www.nas.edu/nas/2003address>.