MOVING FROM ANALYSIS TO ACTION

A Speech by Bruce Alberts, President
National Academy of Sciences
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Welcome to this 135th annual meeting of the Academy. We had a very exciting year in Washington in 1997. When I spoke last April, our role as an independent adviser to the nation was threatened by a legal ruling that applied the Federal Advisory Committee Act to the operations of the Academy. Because of a great deal of very hard work by many people, the crisis that started in January 1997 ended in November, when Congress passed a bill that ensures that our committees are kept free from government control. The tremendous support we received from the federal administration and from so many members of Congress is deeply appreciated, and it is great testimony to the value they place on the objective advice that we provide to the nation.

As is appropriate, much of the advice we provide focuses on the policies needed to support our vigorous scientific research enterprise. Especially influential are the reports of our Committee on Science, Engineering, and Public Policy, known as COSEPUP, under the leadership of Academy member Phil Griffiths. Their analysis of President Clinton's 1999 budget was released last week. This report focuses on the federal science and technology component of that budget, an important concept that was developed in the 1995 report of an Academy committee chaired by Frank Press. COSEPUP will provide this analysis every year, making sure that this crucial part of the federal investment in science is closely watched.

COSEPUP also is deeply engaged in a very important study dealing with the implications that the Government Performance and Results Act has for basic research. This new law, known as GPRA, requires all agencies to set goals and to use performance measures for

Bruce Alberts, NAS president, with children of Academy employees on Bring Your Child to Work Day

management and budgeting. It is intended to encourage greater efficiency and accountability in federal programs. But if not implemented wisely, it could have a negative effect on the research enterprise — an effect that we are working hard to avoid.

For the remainder of this talk, I want to focus on just two issues: education, and science in its international context. I start with the education imperative.

The Education Imperative

At this session last year, I discussed the eighth-grade results in the Third International Mathematics and Science Study, or TIMSS, where U.S. students ranked about average in both science and math among 41 countries. This spring, the test results for our high school seniors showed that they had done even worse in this international comparison. Many Americans didn't believe it. Column after column ran on the opinion pages of the nation's major newspapers, challenging the results. How can the world's undisputed leader in science and technology produce a population of young people with such poor science and mathematics skills? Recall that this was a test in which students at the end of secondary school from 21 countries participated, and U.S. students outperformed only two countries. Could these poor results reflect either a flaw in the exam, or an unusual bimodal distribution in the U.S. performance — with the top 10 percent of our students doing very well? Unfortunately, the answer is no. TIMSS also included a comparison across countries of the very best students in both advanced mathematics and physics [Figure 1]. Here, there was not a single nation that we outperformed!

If we examine U.S. scores on our own national examinations, we find that the performance of our students has been improving at a gradual pace since 1970. What the TIMSS results mean in fact is that, while we have been improving our science and mathematics education slowly, many other nations of the world have been doing so at a faster rate.

Clearly, we can and must do better if we are to remain a strong and productive nation throughout the next century. This Academy has been trying to play a major role in science and math education for many years. I would like to talk about some ways in which we can be even more effective, given that there is so much that needs to be done.

As you know, through the National Research Council, we led the development of this nation's first-ever set

Third International Mathematics and Science Study (TIMSS)

Advanced Knowledge of 12th-Grade Students
(14 percent of U.S. Age Group)

Comparative Performance	Mathematics	Physics
Number of nations better than the United States	11	14
Number of nations similar to the United States	4	1
Number of nations worse than the United States	0	0

Average Scores	Mathematics	Physics
International Students	501	501
U.S. Students	442	423

Figure 1

of National Science Education Standards. We have made these voluntary Standards freely available on the World Wide Web, and we also have published special user-friendly guides for parents. And just this month we released a new type of product for the Academy — a book produced for teachers to help them teach evolution and the nature of science. Some 15,000 free copies of this book have been sent to science teachers across the country, and anyone in the world can get it free from the Web. Academy member Don Kennedy, who led this highly successful effort, is encouraging us to produce more documents along these lines. Please take a close look at the evolution book, and then send us your ideas for further projects.

As I left California in 1993 to assume my job at the Academy, the state was completing its elaborate process of adopting new science textbooks. This event, which occurs every eight years, culminates with a small list of state-approved science teaching materials, determining what each school district can purchase with state funds. I watched this process closely in San Francisco and was appalled to see what happened at the middle school level. Despite all of the expensive and time-consuming effort involved, San Francisco's middle schools were left with, as an example, a sixth-grade human biology textbook with mindless chapters devoid of any context that could enable readers to understand the content. What is tragic about this is that many of San Francisco's elementary school students are benefiting from an excellent hands-on science curriculum, composed of modules similar to those produced by our National Science Resources Center, a partnership between the Academy and the Smithsonian Institution. When these students leave the fifth grade, many say that science is their favorite subject. But in middle school, textbooks such as the one I have just described make them lose all interest in science.

Outstanding teachers have told us repeatedly that the Science Standards are not enough. In order to teach effectively, teachers need both curriculum materials that match the Standards and high-quality training in how to use them. The Academy has been attempting to help by examining all of the science curricula commercially available and compiling analyses of the best available teaching materials. In 1996, the National Science Resources Center published a book titled *Resources for Teaching Elementary School Science,* and this month they published a sequel, *Resources for Teaching Middle School Science.* These two documents are available on our Web site at no cost.

We also have begun a new project organized by our Center for Science, Mathematics, and Engineering Education. Here a committee chaired by Academy member Maxine Singer is bringing scientists and science teachers together to produce an easy-to-use, effective guide for school districts on how to select curriculum materials that match the Science Standards. Through such devices, we hope to create a more sophisticated market, which should in turn drive the production of higher-quality curricula.

Unfortunately, multiple forces have created within our education system a very stable equilibrium that resists change. Figure 2 shows a diagram of the entire system, based on a figure that was published in one of our education reports. The system is in gridlock, with most of the arrows pointed directly at the teachers. Over the next few minutes, I will explain what the Academy hopes to be able to do in specific areas.

I start with state and national examinations. At present the tests support the vocabulary-laden textbooks, and the textbooks support the tests. Students are taught to memorize terms and regurgitate definitions, and perform procedures without meaning, in order to do well on the exams. Having them learn for meaning is not the main goal — and sometimes not a goal at all. Biology is my field, and I can state with confidence that it is totally unrealistic to try to teach anyone all of biology in one year. But such broad survey courses are exactly what is taught in most high schools, and this type of teaching is strongly reinforced by the national SAT II biology subject test offered by the College Board. The result is pressure on teachers to cover all of biology, with little opportunity to develop concepts, or to give students any feeling for the nature of science.

Consider this quote from a popular 1997 study guide called *Cracking the SAT II: Biology Subject Test:*

"We'll show you that you don't really have to understand anything. You just have to make a couple of simple *associations*, like these. Aerobic respiration with: presence of oxygen more ATP produced.... Anaerobic respiration with: absence of oxygen, less ATP produced.... When we get through, you may not really *understand* much about the difference between aerobic and anaerobic respiration. But you don't have to, and we'll prove it.... Whether or not you understand your answers, the scoring machines at the Educational Testing Service will think you did. Their scoring machines don't look for brilliant scientists and they don't look for understanding.... Stick with us, and you'll make the scoring machines very happy."

The textbooks that teach to such tests, as well as the tests themselves, stand in powerful contrast to our view of education as a valuable experience. Is it any wonder that an extensive analysis of the attitudes toward schooling of 20,000 middle-class American adolescents shows that 40 percent of them are completely disengaged from what is going on in the classroom? These young Americans place no value on what is being taught, and they

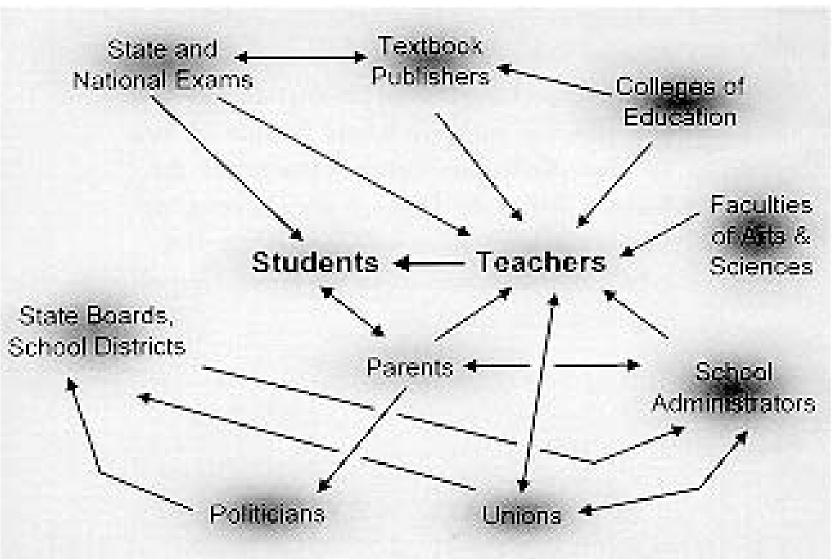

FIGURE 2

correspondingly pay no attention to it. The blame for this often has been placed on a decline of parental and community values. But when one looks at the science curriculum and the science tests that these students are subjected to, one has to wonder whether a great deal of the blame does not instead belong to the excruciatingly boring material that they are expected to learn.

The Academy has been working to improve the science achievement tests used for college admissions for more than six years. We began by engaging both the College Board and the Educational Testing Service in discussions about their science exams. More recently, we have been working with the American College Testing Program and with the Association of American Universities to encourage them to require different, more meaningful measures of science achievement. I am pleased to say that we are seeing modest progress in all of these endeavors.

Let's turn now to the school districts that govern our schools. What can be done about the fact that so many of our school systems are dysfunctional organizations that not only fail to support teachers with the incentives, resources, and training that they need, but place burdens upon teachers that make it almost impossible for them to do their job well?

We will never have quality education for *most* of our children unless school systems can transform themselves into effective organizations that spread good instruction throughout all of their schools. Our Center on Science, Mathematics, and Engineering Education is in the midst of a planning process that focuses on school-district improvement. A small group — led by Ray Cortines, previously San Francisco's school superintendent and former chancellor of the New York City schools, and by Robert Waterman, an expert in corporate management who co-authored *In Search of Excellence* — is attempting to see what can be learned from studies of the 20 or so effective school districts in the United States and Canada that might serve as organizational models. My personal belief is that we will not be able to make major progress in U.S. education until we can successfully attack this issue head-on.

I want to end this part of my discussion by focusing on the education and recruitment of teachers. We know that far too few of them have the understanding of science or math that they need to be able to teach these subjects effectively in schools today. We also know that the preparation for teaching provided in most education schools is inadequate. Teachers are generally taught pedagogy, divorced from any subject matter, whereas to be a good math teacher, one needs focused preparation on how to teach mathematics. And to be a good science teacher, one needs focused preparation on how to teach science. Moreover, we seem to assume that a science or math teacher will learn everything that he or she needs to know during their college years, but in reality a teacher should be provided with an experienced, expert mentor, along with continuous professional development. Doctors don't graduate from medical school and practice medicine for 30 years with only their initial training. Similarly, with science evolving at an ever-increasing rate, the professional development of science teachers must become a non-ending process that is deeply embedded in each school district.

An enormous turnover of teachers will occur during the next 10 years, when it is estimated that some 2 million new teachers will be needed. What might the Academy do to address the urgent national need for talented teachers? I believe that the World Wide Web has an unexploited potential for creating dynamic change in many aspects of education. This summer, our Center on Science, Mathematics, and Engineering Education is planning an experiment in which we bring together the nation's best teacher educators in middle school mathematics. We propose to have these individuals attend a revolving "summer camp" where they demonstrate how they do what they do in teacher development — using their very best videotapes, teaching lessons, and student exercises. The aim is to pool the best of these materials to create high-quality "shareware" for teacher preparation that can be made freely accessible on the Web. We have not yet been able to reform teacher education through policy studies and books aimed at university faculty and deans. But perhaps we can drive reform from below by using such Web sites to make all students aware of the preparation they should expect from their colleges and universities, if they are to become effective teachers.

If the Academy is going to have a profound impact on the quality of science education, we need to encourage all senior scientists who discuss career options with young scientists and mathematicians to stress the importance of teaching as one career option. Simultaneously, we need to lower the barriers that presently prevent many talented young scientists from even considering teaching as a career. Here I cite as a model the Teach for America program, which recruits talented undergraduates to spend two years teaching in some of our nation's most desperate schools. Remarkably, studies show that these teachers perform very well despite an initial handicap stemming from their having received only six weeks of summer "boot camp" training in how to teach. About half of these individuals stay on after their two-year commitment, and many become leaders in their schools and school districts.

In my opinion, we need many more pathways that allow people who know science and mathematics well to readily enter the teaching profession.

Let me now change topics completely, and move on to an equally important challenge: the need for a greatly expanded role of U.S. scientists in the developing world.

Science in its International Context

In the early 1990s, the Carnegie Commission on Science, Technology, and Government published a series of reports that emphasized the need for a greatly increased role for science and scientists in international affairs. Several members of this Academy were leaders in that effort. As the Commission pointed out, there are tremendous unexploited opportunities for the scientific community in the international arena. In a world full of conflicting cultural values and competing needs, scientists everywhere share a powerful common culture that respects honesty, generosity, and ideas independent of their source — while rewarding merit. A major aim of this Academy is to strengthen the ties between scientists and their institutions around the world. Our goal is to create a scientific network that becomes a central element in the interactions between nations — increasing the level of rationality in international discourse, while enhancing the influence of scientists everywhere in the decision-making processes of their own governments.

I am pleased to announce that we recently received a letter from the Department of State in which Secretary Madeleine Albright requests that we help the State Department determine "the contributions that science, technology, and health can make to foreign policy, and how the Department might better carry out its responsibilities to that end." This effort has been encouraged by our Public Welfare Medalist William Golden, whose advice and help on this matter have been crucial.

What are the main principles that should underlie our response to the State Department? I would like to suggest consideration of four ideas, which I will briefly discuss in turn.

Science Can Be a Powerful Force For Promoting Democracy

The vitality of a nation's science and technology enterprise is increasingly becoming the main driver of economic advancement around the world. Success requires a free exchange of ideas, as well as universal access to the world's great store of knowledge. Historically, the growth of science has helped to spread democracy, and this is even more true today.

Many governments around the world exert power over their citizens through the control of information. But restricting access to knowledge has proven to be self-destructive to the economic vitality of nations in the modern world. The reason is a simple one: The world is too complex for a few leaders to make wise decisions about all aspects of public policy. Thus, in a recent article in the *Washington Post* titled "Beijing Spring: Talk of Reform," I was pleased to read that the following public statement had just been published in an official Chinese weekly:

"Only in a democratic environment can people dare to voice new opinions and can their intelligence, wisdom, and ability be fully brought into play. If we don't encourage people to think freely and voice new opinions, our society will actually be utterly stagnant, though it may seem tranquil."

New Scientific and Technical Advances Are Essential to Accommodate the World's Rapidly Expanding Population

The rapid increase in the human population in the second half of this century has led to a crowded world — one that will require all of the ingenuity available from science and technology to maintain stability in the face of increasing demands on natural resources. Thus, for example, a potential disaster is looming in Africa. Traditionally, farmers had enough land available to practice shifting cultivation, in which fields were left fallow for 10 or so years between cycles of plantings. But now, because of Africa's dramatically increasing population, there is not enough land to allow these practices. The result is a continuing process of soil degradation that reduces yields, and will make it nearly impossible for Africa to feed itself. The best estimates for the year 2010 predict that fully one-third of the people in Sub-Saharan Africa will have great difficulty obtaining food, versus 12 percent of the people in South Asia and 5 percent in East Asia.

It has been argued that the ethnic conflicts that led to the massacres in Rwanda were in large part triggered by conflicts over limited food resources. We can expect more such conflicts in the future, unless something dramatic is done now. How might the tremendous scientific resources of the developed world be brought to bear on increasing the African food supply? At present, I see large numbers of talented, idealistic young people in our universities who would welcome the challenge of working on such urgent scientific problems. But the many opportunities to use modern science in behalf of the developing world remain invisible to most scientists on our university campuses. As a result, a great potential resource for improving the human condition is being ignored.

Electronic Communication Networks Make Possible a New Kind of World Science

In looking to the future, it is important to recognize that we are only at the very beginning of the communications revolution. For example, by the year 2002 we are promised by several commercial partnerships that good connectivity to the World Wide Web will become available everywhere in the world, at a modest cost, through satellite communications. Moreover, at least some of these partnerships have promised to provide heavily subsidized connections for the developing world.

Developing countries traditionally have had very poor access to the world's store of scientific knowledge. With the electronic publication of scientific journals, we now have the potential to eliminate this lack of access. The Academy has decided to lead the way with our flagship journal, the *Proceedings of the National Academy of Sciences,* making it free on the Web for developing nations. We also are hoping to spread this practice widely among other scientific and technical journals, since there is almost no cost involved in providing such free electronic access.

The next problem that scientists in developing countries will face is that of finding the information they need in the mass of published literature. In 1997, the U.S. government set an important precedent. It announced that the National Library of Medicine's indexing of the complete biomedical literature would be made electronically available for free around the world, at their cleverly named Web site, "PubMed." A similar ability to search the complete agricultural and environmental literature should follow. The director of the PubMed effort, David Lipman, is presently

Countries and Regions Represented on InterAcademy Panel

Africa	China	India	Mexico	Slovenia
Albania	Colombia	Indonesia	Moldova	Slovak Republic
Argentina	Croatia	Iran	Mongolia	South Africa
Armenia	Cuba	Ireland	Morocco	Spain
Australia	Czech Republic	Israel	Nepal	Sri Lanka
Austria	Denmark	Italy	Netherlands	Sweden
Bangladesh	Egypt	Japan	New Zealand	Switzerland
Belarus	Estonia	Jordan	Nigeria	Thailand
Belgium	Finland	Kazakstan	Norway	Third World
Bolivia	France	Kenya	Pakistan	Turkey
Bosnia Herzegovina	Georgia	Korea DPR	Philippines	Ukraine
	Germany	Korea ROK	Poland	United Kingdom
Brazil	Ghana	Latin America	Portugal	United States
Bulgaria	Greece	Latvia	Romania	Uzbekistan
Canada	Guatemala	Lithuania	Russia	Vatican
Caribbean	Hungary	Macedonia	Singapore	Venezuela
Chile		Malaysia		

FIGURE 3

investigating what can be done to produce such a site.

The communications revolution also is driving a great transformation in education. Already, the Web is being used as a direct teaching tool, providing virtual classrooms of interacting students and faculty, in what are known as "asynchronous learning networks." This tool allows a course taught at one site to be taken by students anywhere in the world. Such technologies present an enormous opportunity to spread the ability to use scientific and technical knowledge everywhere — an ability that will be absolutely essential if we are to head for a more rational and sustainable world in the 21st century.

Science Academies Can Be a Strong Force for Wise Policy-making

In preparing for the future, we need to remember that we are only a tiny part of the world's people. In 1998, seven out of every eight children born will be growing up in a developing nation. As the Carnegie Commission emphasized, we need more effective mechanisms for providing scientific advice internationally — particularly in view of the overwhelming needs of this huge population.

In 1993, the scientific academies of the world met for the first time in New Delhi in order to address world population issues. The report developed by this group of 60 Academies was presented a year later at the 1994 U.N. Conference at Cairo. Its success has now led to a more formal collaboration between Academies, known as the Inter-Academy Panel (IAP). The countries thus far represented in this group are listed in Figure 3. A common Web site for the entire group will soon be online, overseen by this Academy. As you will hear on Tuesday from Foreign Secretary Sherry Rowland, the IAP is working toward a major conference in Tokyo in May of 2000, focused on the challenges for science and technology in the transition to a more sustainable world.

The major link to the Year 2000 Conference is the National Research Council's Board on Sustainable Development and its report on the sustainability transition, due to be released at the end of this year. The Academy is grateful to George P. Mitchell, chairman and chief executive officer of Mitchell Energy & Development Corp., for his generous support — through the Global Commons project — of the work of the Board on Sustainable Development.

Inspired by a successful joint study with the Mexican Academy that produced a report on Mexico City's water supply, we began a study in 1996 titled "Sustaining Freshwater Resources in the Middle East," as a collaboration between our Academy, the Royal Scientific Society of Jordan, the Israel Academy of Sciences and Humanities, and the Palestine Health Council [Figure 4]. The final version

Sustaining Freshwater Resources in the Middle East

Committee of 3 Jordanians, 3 Israelis, 3 Palestinians, and 6 North Americans, chaired by Gilbert White.

Guidelines:

- The view taken should be regional.
- The demands and needs of both present and future generations must be taken into account.
- All options should be considered for balancing water supplies and demand.
- The maintenance of ecosystem services should be viewed as essential for achieving sustainability of water resources.
- The close relationships of water quality and quantity should be clearly recognized.

Public report is expected in late summer 1998.

FIGURE 4

of this report is now in review, and we expect it to be released this summer. I would also like to highlight a new energy study that we initiated this year with China [Figure 5]. Here, four Academies — two from the United States and two from China — are collaborating to produce a major, forward-looking study of the energy options for our two countries. Recently, the Indian Science and Engineering Academies have indicated an interest in carrying out a similar energy study with us. I believe that these Indian and Chinese collaborations are likely to lead us all toward a wiser use of global energy resources.

My dream for the IAP is to have it become recognized as a major provider of international advice for developing nations, the World Bank, and many similar agencies that require expert scientific and technical assistance. Through an IAP mechanism, any country or organization seeking advice could immediately call on a small group of Academies of its choosing to provide it with politically balanced input coupled with the appropriate scientific and technical expertise.

I would like to end my talk by briefly describing three common challenges that we face in reaching out boldly in the two main areas I have emphasized — education and international science.

The importance of a clear vision. For both education and international science, we need a strong consensus for where we are heading and how we want to get there. I would argue that we now have that vision for science education in the United States in the form of the Science Education Standards. In the coming year, we will attempt to prepare an international science road map to help our State Department. My discussions with the leaders of Academies from developing countries convince me that they will need to develop their own road maps in the form of national science policies. To quote José Goldemberg, a distinguished scientific leader from Brazil:

"What my scientist colleagues and national leaders alike failed to understand was that development does not necessarily coincide with the possession of nuclear weapons or the capability to launch satellites. Rather, it requires modern agriculture, industrial systems, and education.... This scenario means that we in developing countries should not expect to follow the research model that led to the scientific enterprise of the United States and elsewhere. Rather, we need to adapt and develop technologies appropriate to our local circumstances, help strengthen education, and expand our roles as advisers in both government and industry."

Cooperation in the Energy Futures of China and the United States

Joint project of the National Academy of Sciences, National Academy of Engineering, Chinese Academy of Sciences, and Chinese Academy of Engineering, examining the energy sectors of the United States and China through 2020 to promote better management of energy resources.

Tasks:

- Describe likely energy trajectories of both China and the United States, considering different scenarios including increased attention to emissions reduction and climate change.
- Identify the challenges and constraints to such trajectories, including opportunities for technological and institutional responses.
- Identify possibilities for joint research, information sharing, and other collaborative approaches.

Report is expected December 1998.

FIGURE 5

The need to learn from action-oriented research and experience. In his work for the Carnegie Commission, former U.S. President Jimmy Carter made the following observations about global development.

"Hundreds of well-intentioned international aid agencies, with their own priorities and idiosyncrasies, seldom cooperate or even communicate with each other. Instead, they compete for publicity, funding, and access to potential recipients. Overburdened leaders in developing countries, whose governments are often relatively disorganized, confront a cacophony of offers and demands from donors."

Replace a few words, and exactly the same could be said about most of our nation's past attempts at education reform.

My contacts with education projects in the United States and with international development projects in agriculture have made me aware of a common failing in these important human endeavors. Many experiments are carried out to try to improve these systems. A few are very successful, but many turn out to be failures. The natural inclination is to hide all of the failures. But as every experimental scientist knows, progress is made from learning from what did not work, and then improving the process by incorporating this knowledge into a general framework for moving forward. As scientists, I would hope that we could lead the world toward more rational approaches to improving both education and international development efforts.

The need to rethink how we measure progress. As I speak, the U.S. economy is booming. But as I look around our plush shopping malls, observing the rush of our citizens to consume more and more, I wonder whether this is really progress. In thinking about how our nation can prove itself as the world leader it purports to be, we might do well to consider the words of Franklin Roosevelt that are engraved on his new memorial, a short distance from this Academy:

"The test of our progress is not whether we add more to the abundance of those who have much. It is whether we provide enough for those who have little."

As many others have pointed out, every year the inequities of wealth are becoming greater, both within our nation and around the world. At the national level, improving education for all Americans is the best way to reduce such inequities. Likewise, the spread of scientific and technological information throughout the world, involving a generous sharing of knowledge resources by our nation's scientists and engineers, can improve the lives of those who are most in need around the globe.

As I have tried to emphasize in this talk, these are not only challenges for science, they are also major challenges for this Academy. Because of your stature and your achievements, the people in this room have the potential to change the world profoundly. I urge you to view this organization as a lever through which you can exert a beneficial, lasting influence on both the nation and the world.

NOTE: The text of this speech, with direct links to cited reports, and other statements by Bruce Alberts are available on the Academy's Web site in the "Presidents' Corner" at <www.nas.edu/president>.