

HOPEFUL TALK ON SCIENCE AS PRESS LEAVES ACADEMY

It was "kind of wistful," Senator John D. (Jay) Rockefeller IV, a West Virginia Democrat, said about Frank Press's last day as president of the National Academy of Sciences. Seated in the marble-walled auditorium of the Senate's Dirksen Building on 22 June, Press had come to testify before Rockefeller's science, technology and space subcommittee about a report bearing the vapid title of "Science, Technology and Government" and had informed Rockefeller that the occasion was his last official act as the academy's president. With that appearance, Press completed his second six-year term as he might have wished for himself: advising the government on ways to improve its support of basic research, of advanced technology and of the education of scientists, engineers and the wider public.

Press's influence has resonated in Washington for decades. His work in seismology, notably developing seismic techniques for detecting and measuring earthquakes and for investigating the rock layers below the Earth's crust, proved fundamental in advancing US capability to detect underground nuclear explosions. This turned out to be critical to President Kennedy's decision to sign the limited nuclear test ban treaty in 1963.

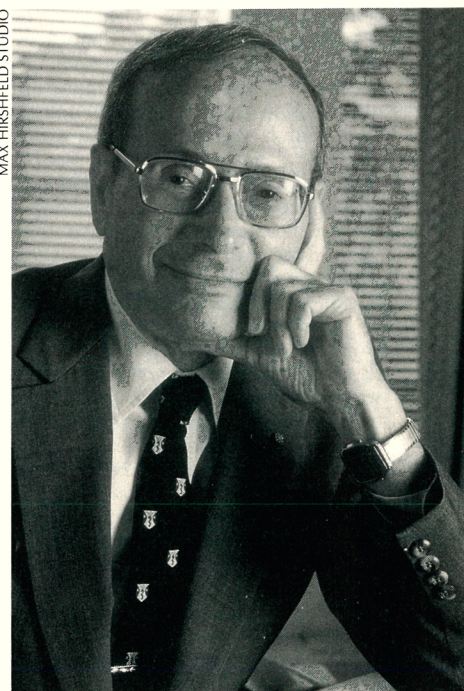
While Kennedy was in the White House and during the early years of the Johnson Administration, Press served on the President's Science Advisory Committee. In 1972, President Nixon sacked his science adviser and abolished the advisory committee for opposing his plans to develop a Supersonic Transport aircraft and for disagreeing with the escalation of the Vietnam War. Nixon's successor, Gerald Ford, seeking to reassemble the science advisory structure, appointed two committees, headed respectively by Simon Ramo and William O. Baker, that proposed giving statutory authority for a White House Office of Science and Technology Policy. Press was a member of each committee.

Within months after the National Science Act was passed in 1976, Jimmy Carter became President and selected Press the first director of OSTP.

In an examination of Carter's domestic policy staff, completed in 1984, Walter Williams, a political scientist at the University of Washington, found that "Press's White House peers saw him exactly as he saw himself—that is, as a scientist, not as a politician." While other heads of policy offices at the White House came in for criticism, wrote Williams, Press alone emerged unscathed from the recollections of Carter aides.

Press received his PhD in geophysics from Columbia University in 1949 and joined its faculty. He worked closely with W. Maurice Ewing, director of the university's Lamont Geological Laboratories, and together they developed a seismograph capable of recording shock waves with durations longer than one minute, when previous instruments could only register on the scale of seconds. In 1955 Press became a professor of geophysics at Caltech and two years later he succeeded the retiring Beno Gutenberg as director of Caltech's Seismological Laboratory. During the International Geophysical Year (1957-58), Press headed a Caltech expedition to Antarctica to analyze seismic data proving the theory that Antarctica is a true continent and not merely a floating mass of ice and debris. In recognition of Press's contribution to this discovery, IGY explorers named a mountain after him on the continent at latitude 78° 05" and longitude 86° 05".

During the IGY, Press and his students also found that the continental crust and in particular the Mohorovičić discontinuity vary in depth under the oceans and continents—a discovery that helps explain geologic formations on the Earth's surface. After the 1959 earthquake in Chile, Press was part of a team that discovered that the Earth vibrates like a ringing bell for one to two weeks



Press: After 12 years, a wistful finale.

following a sizable quake. That year he also was a member of a team from Caltech and Columbia that designed seismometers for exploring the Moon.

In 1965 Press joined MIT to head its department of geology and geophysics and soon set up a joint program with the Woods Hole Oceanographic Institution. After his years as Carter's science adviser, he returned to MIT as Institute Professor. In 1981 he was elected president of the academy. During three surveys of scientists conducted by US News and World Report during the early 1980s, Press was named the most influential American scientist. In September, after a summer of sailing off Cape Cod, he will become the Cecil and Ida Green Senior Fellow at the most influential Institution of Washington, which should allow him

MAX HIRSCHFELD STUDIO

to take part in discussions and studies of science policy and education and the interconnections of science, technology and economic growth.

In the following interview with *Press* in his academy office on 8 June, PHYSICS TODAY's Irwin Goodwin asked him about his years at the academy, his impressions of the scientific enterprise and other matters. Edited excerpts of that conversation follow:

Q. As your term of office draws to a close, it is appropriate to ask you about your accomplishments at the Academy over the past 12 years.

A. I would say involving the National Research Council, which is the key organization of the academy complex in terms of that question, in addressing the nation's important questions in science and technology. This didn't require redirecting any traditional activities. The Research Council was doing this long before I was elected the academy's president but we became more engaged each year. One can see this in several ways: growth in the number of requests to the Research Council from Congress and in the calls for advice from Executive Branch agencies. At the same time, on our own initiative, we continue to examine just about every field of science in terms of its problems and opportunities.

Q. Can you cite a few reports that had some impact on the government?

A. Our reports have led at times to programmatic impulses in an agency and to statements in Presidential budget requests for some special initiative. An example of the influence of Research Council studies was the quick response to the recommendation to increase government support

responding to requests from Congress and the executive branch to solve specific national problems on the other—is my legacy to the academy.

Q. How do you account for the increase in requests to the Research Council from the Federal government? Is it because science is no longer seen as a discrete enterprise but is interwoven into the nation's economic and cultural fabric?

A. I would put it this way: The nation's problems have become more numerous, more frequent, more severe and in some cases more crisis-related. I said in one of my presidential addresses to members of the academy a few years ago that there is a "new reality"—a more immediate connection between basic science and engineering to commercial technologies. Some of the nation's fastest-growing industries are science-based. So the involvement of the National Research Council has been driven, one, by changing world conditions and, two, by our ability to respond when called upon.

Q. Does the government's increasing need for advice on issues of science and technology suggest that the time has come for a full-fledged Department of Science and Technology?

A. We've never had a Department of Science or, like some countries, a Ministry of Research and Technology, yet we were able to become preeminent in world science and technology without one. So you might ask, what is it that made us so great under the circumstances? It's certainly not top-down direction of science from Washington. Scientific research and industrial technology have been characterized by decentralization and diversification in this country. The

ties and the national labs.

I'm not convinced that pulling programs and projects out of different departments and agencies and placing them in one large Department of Science would be the best arrangement. It seems to me that, for instance, when a shortage of equipment affects several agencies, it would be best to coordinate the responses across all the multiple sources of funds and interests rather than to vest the decision about what to do in one Department of Science. What worries many people who have thought for more than a few minutes about the effectiveness of a Department of Science is the concentration of power in a single government office. One can cite examples of a minister of science or research whose mistakes have devastated a country's scientific capability for a decade or longer. To put that much power in the hands of one Cabinet official can lead to dire consequences. This is less likely to happen in the present setup because of the decentralization and diversification of research programs. Our system was designed to support the work of the best scientists in large numbers across the country, so it's not surprising that scientists are essentially skeptical, if not negative, about a Department of Science.

Q. Isn't that essentially the key job of the President's science adviser through his direction of the Office of Science and Technology Policy?

A. Yes, and that's why the Research Council has stated in its reports, as have the Carnegie Commission and most other observers of the government's activities in science and technology, that OSTP is the centerpiece for coordinating programs and budgets, for setting priorities and for establishing partnerships with science organizations abroad.

Q. As a former director of OSTP, did you find it possible to do all that effectively?

A. Much depends on the leadership in the White House. The world is different today from when I was at OSTP [during the Carter Administration] and the urgency for coordination is much greater today. When I was at OSTP the major tool I had for coordinating science was my participation in the budget process. That is still available to the OSTP director. In addition, the director has the capability to push some buttons in the Federal Coordinating Council for Science, Engineering and Technology. I used FCCSET but not to the extent or with the effectiveness that Allan Bromley did [when he was OSTP director and science adviser to President Bush].

**'... since public funds are involved,
scientists can't disdain the political process.'**

of research on new materials and composites; it was adopted as a Presidential initiative by a half dozen agencies. Another example was a recommendation to step up studies of environmental issues, such as global climate warming. A third instance was the conclusion to strengthen semiconductor manufacturing technology, which was then in danger of falling below world standards. So augmenting this dual approach—examining the health of specific fields and subfields of American science and technology on the one hand and

government, along with our great research universities and our major corporations, has encouraged and supported research, driven by the curiosity of individual investigators. New factors, such as the end of the cold war and the combination of global competition in science and technology and the depressed state of the world economy make it necessary that we bring more coordination into addressing issues of science and technology—within the Federal departments and agencies and in the new collaborations of industry, universi-

FCCSET now consists of Cabinet secretaries and directors of research agencies such as the National Science Foundation and the National Institutes of Health. And perhaps just as important is the orchestration by the President himself. In this regard the statements issued in the first few weeks of the Clinton-Gore Administration and even before they took office ["Technology for America's Economic Growth" and "A Vision of Change for America"] show that they are moving in the direction of better coordination and of better under-

A. We are about to issue a major report—perhaps the most important report of my 12 years. (See page 67 for an account of the report.) It addresses the issues you ask about. It sets out a template against which to make judgments—for the first time—about allocating resources, field by field, and how one would go about doing that for science research.

Q. Does this report reach any conclusions about whether we have too many or too few scientists?

A. No, but it tells you how to go about finding out.

'It's unbecoming [and] intellectually dishonest for scientists to [use hype or exaggeration] solely for the purpose of getting funds. . . . it detracts from science as a credible intellectual endeavor.'

standing of the importance of science and technology to economic growth and to international collaboration. As a nation, we are moving in that direction with this last election, and I think in the future we will move forward even more.

Q. Despite your enthusiasm for FCCSET, some academic scientists will argue that its programs lead to funds being diverted from basic science to applied research and technology. So university researchers are wary of FCCSET. Is this view prevalent among scientists you meet in your travels?

A. Well, I think the anxiety reflects the growing concern in America's universities that the government's ability to fund good research projects is getting harder. There are many reasons for this and none have anything to do with the FCCSET-initiated programs. For one thing, Federal budgets haven't kept pace with the research opportunities that are appearing at an accelerating pace. For another, there is a possibility that we have too many scientists applying for the available Federal funds. I'm not sure that this is the case, but I am sure the subject should be explored.

Q. Would you elaborate on how the White House and Congress might know when the time is right to spend more on a promising field of research and also how they are to know when a shortage or surplus of scientists exists? Such questions perplex those who run the government's science agencies as well as those lawmakers on Capitol Hill who deal with the research and education budgets.

Q. At one time science and government were disengaged. In recent years they have developed a symbiotic relationship. In our country that relationship is said to have started flourishing nearly 50 years ago with the publication of Vannevar Bush's little report to President Truman, *Science—The Endless Frontier*. It seems also to have marked the beginnings of the politicization of science. In the years since, do you think science has become too politicized?

A. In a sense, science has been politicized since Archimedes did military research, since Galileo and Da Vinci and others were supported by their patrons because of the strategic implications of their work. Work on the proximity fuze and radar and nuclear weapons were political decisions driven by military needs at the time. The involvement of science in the affairs of governments, for reasons of national security and economic benefits, has a long history. So in that sense I think what we're seeing is not something new so much as it is an accelerating trend for science to be more relevant to society. In the post-cold-war era, science may not be so important for military security, but as long as national security is also assured by a nation's economic performance, the quality of its health, education and environment, and so on, it will be seen as part of the political fabric.

Q. Are you saying that science has always answered the voices and needs of society?

A. That's right. Perhaps on occa-

sion ideologically motivated; on other occasions, motivated by the resources that are made available when science does the bidding of government or business or some other sector.

Q. It was Allan Bromley who said on more than one occasion that science has shifted from being viewed as an investment to being considered as a procurement. By that I think he meant that science is politicized in the sense that politicians support certain programs or projects to win favors or votes and not to invest in discoveries or developments that might generate economic benefits in the future. The Superconducting Super Collider is often cited as a case in point: To particle physicists it is an investment to advance the search for understanding the fundamental structure of matter and the laws that govern all physical phenomena. But in political circles the SSC gains its support for the same reasons as fighter planes or interstate highways.

A. There's no question that science should be viewed as an investment. But like many investments, the payback is unpredictable and it is usually long-term. If there is a payback, it can come in the form of intellectual benefits or as a solution to a problem or as a new application or technology. Unfortunately, in many government agencies, science is viewed in the narrow sense of a contract procurement, with little or no understanding of the nature of scientific research. Then, too, the regulatory aspects of a contract often produce inefficiency in scientific work. So the procurement process, in a very real sense, leads to inefficiency and inflexibility for the researcher and lowers productivity. If the project were considered an investment and if the scientific method were better understood by some government people in charge of contracts, I think the nation would achieve more benefits out of research in terms of cost and usefulness, without question. Still, since public funds are involved, scientists can't disdain the political process. When a Congressman asks a scientist, "Who voted for you?" that's a legitimate question. We are right to ask that political decisions should be guided by the knowledge and insights that scientists can provide. But it's not conceivable to me that scientists should make decisions about allocating resources.

When I was President Carter's science adviser, I was asked by the director of the Office of Management and Budget, "When do you scientists know that you have enough money for everything you want to do?" It sometimes appears to people in Washing-

ton that scientists are insatiable.

Q. The academy was involved a few years ago in one of the celebrated—and controversial—instances of scientific decision making, the site selection for the SSC. The Department of Energy asked the academy to review the site proposals submitted by more than 30 states and to pick the best seven or eight locations. Of course, the final decision on where to build the SSC was left to political forces.

A. The SSC is an instance when the scientific process worked. I suppose sufficient time has passed for me to say—I read all the proposals—that the best proposal was from Texas. Whether that was the basis for the decision, or whether it was strictly politics, or both, we'll never know. I don't think Texas could have been selected if we had eliminated it. The academy's committee made a careful, informed, balanced choice, but the ultimate decision was political, as it has to be when a multibillion dollar investment is at stake.

Q. Many scientists, some physicists included, have opposed the SSC on the grounds of its expense and argue that it will result in diverting funds from their own field or some other field of science. I'm sure the project has been a topic at meetings of academy members. As the country undertakes larger, more costly projects, whether for particle physics or astronomy or space science and technology, are there perils for so-called small science?

A. There are very few people who say that big science, under all circumstances, should not be undertaken, whether it's ground-based telescopes, which are now in the \$100 million range, or the SSC, which is estimated will cost more than \$8 billion. Consider what these facilities can accomplish! In my own field, geophysics, the deep-sea drilling project had an enormous impact on understanding plate tectonics. Sequencing the human genome may not be as expensive as an SSC, but its results may revolutionize genetics. I would not want to discuss the space station because I don't think it's in the category of science research. Look, to attack big science projects is naive and simplistic. I don't know anybody—even those hardy souls who shout down the SSC—who will say categorically, "I'm against big science." Those SSC opponents—many of whom I respect—argue that if it can be shown that the accelerator is being built at the expense of important areas of smaller-scale science, and if it is really siphoning money from key fields of physics, say, then it should be deferred, drawn

out or even stopped until the nation can afford to do it. The debate now turns not on whether big science is good or bad, but what is the source of funding of the SSC, and is it impacting all of science or not. I think Sidney Drell said it best when he laid out the three options for the SSC. (See page 73.) So at a time when the nation is trying to deal with its huge deficit, it's a legitimate question.

Q. This discussion leads me to ask about your attempt, advanced in another of your presidential addresses a few years ago, to set priorities in the

scientists have managed to create an image of a reasonable, credible and balanced community. Except among Hollywood filmmakers, scientists were generally viewed that way. But in the past few years, with scientists in a state of stress, competing with each other, attacking one another in the news media and the courts, the image has been tarnished, there's no doubt about that. The only way to understand this phenomenon is that scientists are not themselves because of the crisis in funding and their race for grants.

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building of expensive science facilities. How did the science community react to your idea?

A. Quite favorably, though it's hard to judge a reaction accurately without a scientifically designed poll. Based on my conversations and on letters that I've received—and what happened after the talk—I'm happy that I challenged the disciplines to determine their own priorities. The astronomers actually did it, with great success, it turns out. In the biological fields there have been attempts to do this also. In my speech I challenged each of the major fields to examine its own house and to decide which changes or additions were needed and which would be nice but were not essential at the moment. The decisions were to be based on the scientific opportunities that should be seized upon to advance the field and the resources would then be allocated in some sort of sensible way. The more difficult question is how to set priorities across fields.

Q. In setting priorities it sometimes happens that a project or program is oversold—that is, a great deal of hype is used to convince politicians, the press and the public that it's worth doing. Aren't there dangers in making excessive promises and raising expectations for what science can do for society in the way of applications or products?

A. It's unbecoming. It's even intellectually dishonest for scientists to make such statements solely for the purpose of getting funds. And to the extent that this happens, it detracts from science as a credible intellectual endeavor. Over many decades we

Q. Are you saying there is something inherently unethical about hype in science? The academy has issued reports on the subject of scientific ethics and has urged scientists to adhere to certain standards, but the subject of overselling a program or project was not covered in the reports.

A. You have to be careful that you don't get into the issue of the proper behavior of scientists as they perform their work honestly, within the culture and the ethic of scientific method. When you say "unethical," that is what I think of. What we've been talking about is unfortunate. Hyperbole and exaggeration are increasingly common in American society across many sectors. I don't consider hype to be unethical in the sense of scientific dishonesty.

Q. Is it any different from false marketing of products?

A. Look, I don't like it and you don't like it, all right? What I'm saying is that it's not scientific misbehavior, and I wish it didn't happen.

Q. Let's return to a topic we spoke about before: Is science changing course in the sense that both the executive and legislative branches are calling increasingly for more emphasis on more relevance in science and more emphasis on technology? And if this is the trend in research, what is likely to befall the traditional individual investigator?

A. Of course, that is a legitimate fear. If it were the exclusive policy of any Administration, it would be a misguided policy because so much of what we enjoy of the fruits of science was serendipitously achieved. I hesitate to use the word "serendipitous"

because someone on Capitol Hill told me the other day, "I'll scream if you say serendipitous once more." We've been overusing that argument, but nevertheless the argument is true. Science is important to the nation as an intellectual endeavor, and beyond that is its spillover effect—its incremental benefits in the form of new products and industries and, most significantly, in improving GNP and the quality of life. But to insist upon societal relevance in the way you allocate the research budgets is a cardinal error. The Administration, certainly Jack Gibbons [President Clinton's science adviser], understands that. It's something to be wary of, but I am not too nervous about it at this time.

Q. One of the fundamental changes that affects the scientific enterprise is our relationship with other nations, particularly the countries of the former Soviet Union. Do you see this as an opportunity we should grasp?

A. We have a multiple interest in preserving the scientific strengths of the FSU. For one thing, in several important fields of science their contributions are world-class—in mathematics, physics, astronomy, aspects of chemistry, increasingly in biological areas. It would be tragic if their contributions to science were lost or allowed to atrophy. Secondly, with the hopes and aspirations for democratization in those countries, it is clearly apparent that scientists are in the forefront of that movement. In the dangerous situation that took place between the old guard hardliners and Yeltsin's democratic forces, when tanks and troops surrounded the "White House" in Moscow, there was an outpouring of scientists from the academies of science, from the various research institutes and from the universities. They formed a human shield protecting Yeltsin and his fledgling government. As Russia and the other countries of the old Communist bloc develop economically in the years ahead, they need an educated workforce and a scientific cadre. The structure for that already exists. For the sake of those countries and the world it must not be allowed to disintegrate and disappear during this period of transition to political democracy and a market economy.

So for all of these reasons, we have an interest in seeing science preserved in the FSU.

Q. In this period of recession in the US and Europe, many students in the scientific professions—physics particularly—are fearful that they will not find jobs after they receive advanced degrees. You are undoubtedly

aware of this and have given some thought to their misfortune of coming into the job market in hard times.

A. I worry about the state of alarm that exists among physicists on this matter. At a recent American Physical Society meeting this was quite apparent. There are bright young graduate students and postdocs experiencing a difficult time finding positions in this period of layoffs in the aerospace and defense companies, cutbacks at some major corporate research laboratories and retrenchments at financially strapped universities. As a nation we have never solved the problem of the cyclical disconnect in the demands of the market and the supply of university graduates. So it is entirely possible there will be fewer students seeking careers in physics and other sciences because of what they see occurring around them. Then when times are better and the demand increases, as it surely will, there will be a shortage of scientists. The discontinuity is happening in my field of geophysics, with ghastly effects on some young people. How we go about solving this dilemma I really don't know. It deserves careful study.

There is no question in my mind that in the next century this country and the rest of the world will depend on science and engineering much more than today—developing new methods and whole new industries. The comparative advantage of our nation's economy in the increasingly competitive world may well be principally in science and engineering. So

of "The Perils of Pauline," only in this instance the rescue may come too late for some young scientists.

A. I have one other suggestion. It's not original with me. Some of us have been talking about it: It's to change the PhD program in such a way that education in physics or chemistry or mathematics or geophysics is broadened, so that along with the specialization the candidate receives some training in engineering, say, or in applied mathematics or in computational science. Graduate training would be strengthened by an augmented, multidisciplinary approach so that until one enters the thesis stage many of the courses and experiences would apply to a wide range of possible jobs. This can be done now with little academic upheaval.

Q. It would require a lot of flexibility in graduate schooling.

A. Exactly.

Q. Under this scheme, narrowly specialized graduate education in the basic sciences would be redefined and redirected to include applications. The approach might help forge a stronger alliance between science and industry. It may not work miracles but it may provide added value for increasing the nation's pool of technological talent. Education in the sciences and technology is clearly important for economic growth.

A. President Clinton says this all the time—and President Bush also had that on his agenda. We have all heard the rhetoric. I think the problem is well understood. Notwithstanding, the ability of governments

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there may be an argument for a special budget initiative to bring the phases into synchronicity and to keep these people working within science. The case can be made that a great deal of time and resources were invested in their training and their talents will contribute to the public benefit. Along with this initiative, a reasonable method will need to be found to monitor the number of students emerging from universities against the needs in industry and the government.

Q. The situation is something out

at all levels to deliver is uncertain.

Q. Is the academy engaged in seeking to improve precollege education?

A. Education is the fastest-growing subject at the academy right now. We're major players in establishing national standards for science and mathematics. It's something members of the academy are nearly unanimous on. In all my regional meetings over the past decade, over and over again, members have said to me, "The academy as an institution must do more to help solve the horrible situation in K to 12 education." I

think any intelligent person sees pre-college education in terms of a crisis. If there is anything that will prevent us from achieving economic gains in the future, it's the fact that we are turning out too many people who are intellectually unqualified and technically untrained. Unless we mend our ways, we will confront a disaster.

Q. What is the academy doing to stimulate science and math literacy?

A. For one thing, we elected Bruce Alberts the academy's next president. He considers education his first priority. It's not just a philosophical goal for him. He was involved in San Francisco's schools, K to 12. As a university scientist, he brought other university scientists into the schools, working with teachers and students, developing enrichment programs and providing intellectual incentives.

We recently held a big symposium on educational technology. Our nation pays more for education and gets less than many other countries, so it isn't a matter of money. The academy's undertaking in science standards involves literally thousands of people across the country. We have circulated a draft of the report widely for comment.

Q. Did you receive support for the standards or are people in the states and localities upset about accepting some national norms?

A. The country has moved beyond the old concept of local control of schools. The idea that nobody can tell us what to teach better than our local school board is no longer so prevalent. In the past it was political suicide for anyone to propose anything other than local decisions for public schools. But when we say "standards" we're not promulgating a single textbook and a single way of teaching. What we're saying is, "This is what we expect a student to know." How you teach that student, what you use in the classroom in the way of curriculums or materials or teacher qualifications is up to the local school boards. We want diversity; we want individual initiative among teachers. But when students finish grade 12, say, this is what you should expect of them. When we say standards we also speak of evaluation. We talk about consensus-building. It's not something that's promulgated, like the Ten Commandments carried down a mountain, which is what was attempted more or less after the Soviet Sputniks in 1957. Our approach is to involve thousands of educators, politicians, businesspeople and scientists so that with such wide participation the country is ready to receive the results.

Q. When you speak of evaluation do you mean educational testing?

A. We're doing this on a conceptual basis. We're not writing any tests. We are saying, however, that true-false and multiple-choice questions are not the way to gauge what a student knows and that such tests are not the way to determine a student's conceptual understanding of math and science.

Q. In your farewell message to members of the academy you stated that you believe that the National Research Council has attained a "maximum management size." You reached this conclusion, you said, because it is unlikely that the Research Council can call on more volunteer experts to serve on committees. Does this mean the Research Council is at the limits of its capacity to advise the government and to take on studies of its own on critical national issues?

A. My successor was asked the same question and I like his answer: The quality of the work should be the guide. It's the answer that I would have given. If the quality goes down because of our inability to manage or find the best people to examine the important national problems, that means we've gotten too big. It is my sense that 8,000 volunteers at work on our committees right now is a very large number, even for a country the size of ours. Sometimes when I ask a scientist to volunteer his service on one of our committees, I hear, "Gee, that's the fifth time you've asked me, and I'm still too busy in my lab." While it's true that we can probably cast a wider net for volunteers, we have the additional problem of managing the studies and maintaining quality controls. It's my belief that we've reached the point where we can no longer expand, but it will be the decision of my successor, Bruce Alberts, whether to involve more people and perhaps find more efficient and effective ways to operate. I have raised the warning flag, but if we can manage our growth and still maintain our high quality then the Research Council can continue to meet the country's needs for objective advice in science, technology and education.

Because of the way we work, several academies in other countries use us as a model for building advisory relationships with their governments. I was pleased to see that the Royal Society in Britain has gotten together with the Royal Society of Engineering to establish something like our own National Research Council. I expect our Research Council will evolve over the years. I encourage Alberts to

make the necessary changes: Increase its productivity, involve more members; take on the hard questions that are bound to come up.

Q. In the past 50 years the academy has taken the lead in internationalizing science, and I would think this activity will continue.

A. Yes, without question. I'm very proud of the role of the academy in China in the early days when diplomatic relations did not exist; we made the earliest contacts with China—at first against the opposition of our own government, and then with the active encouragement of the government. Then, throughout the cold war and during the terrible days of [Andrei] Sakharov's exile, we tried to maintain linkages with Soviet science and to apply pressure in the Soviet Union to do better. And I am particularly proud that as a result of our initiative, together with the British Royal Society, many academies of science will meet in New Delhi this fall to address the issue of population. That's never happened before.

Q. Arms control has been a major concern of the academy and that was one of the reasons why the National Academy and the Soviet Academy kept their relations going during the worst days of the cold war. Now that the cold war has ended, and the Soviet Union has broken up into 15 independent nations, what is the extent of your efforts in arms control?

A. We have recently honored [Wolfgang] Pief Panofsky, who retired as chairman of our arms control committee. It was under his leadership, to his credit, that we enlisted the Royal Society in London and the Amaldi Conferences in Europe to become engaged in arms control issues, and they are involving East European countries. Pief also began discussions with leaders of the military-industrial complex in China, and they are now meeting with us regularly. I am told that Indian scientists are now interested in joining our discussions. The issues are different from those in the cold-war era. Nonproliferation is a great concern now. We should worry about the export of dual-use technologies. A fertilizer plant might be exported with all good intentions and end up producing chemical weapons. In addition, there are issues left over from the cold war: What is going to happen to the 100 to 150 tons of Russian plutonium in warheads? The requests for our advice, which came from the Bush Administration on this matter, have been endorsed by the Clinton Administration. The academy will continue to be very busy.