The Advancement of Science

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In preparing my presidential lecture I could not help being aware of the long tradition of the American Association for the Advancement of Science (AAAS) and of the procession of distinguished scientists who have bent their efforts to the Association and to science, the advancement of which is our goal. A cursory survey of events over the past 144-odd years is instructive: We have witnessed rapid growth, periods of decline, remarkable anticipations, and recurring crises. The fact that there have been crises before, even periods of discouragement and despair, is not cause for philosophical detachment. There is, in each case, a very different historical context. The Association has lived through a long period of slow evolution of science in America but of fantastic growth in our understanding of the physical and biological universes, most of it within this century. American science exploded after World War II. Many of us "mature" members were swept up in a period of national scientific flowering, brought about by such factors as the influx of European refugees and the new contract between government and science as envisioned by science statesmen including Vannevar Bush, I. I. Rabi, E. O. Lawrence, Karl Compton, William Golden, and many others. A research enterprise took root in the fertile soil of what became known as the research university, in the new national laboratories, and in the research labs of dynamic industrial giants. These institutions often applied new technologies developed in the war and new styles of collaborative research. Out of this mix of exuberance, optimism, and newly recruited talent there poured a torrent of science and technology: semiconductors, solid-state electronics, integrated circuits, computers, nuclear power, microwave telecommunications, antibiotics, high strength alloys, high temperature ceramics, robotics, DNA and genetic engineering, and superconductivity.

Today, science in America is in a mood of uncertainty and discouragement. I want to address this particular period—the present and future and to give you a report of my 2 years, one as president-elect and this last year as president of the AAAS—to tell you what I have learned and to give you the dubious benefit of my experience and my advice.

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The End of the Frontier and Its Aftermath

As many of you know, as president-elect and with the encouragement and able assistance of the AAAS staff (especially Rich Nicholson and Al Teich) I conducted an informal survey of research practitioners in 50 of the major universities. We selected physics, chemistry, and biology (which also seemed to gather in representative subjects such as astrophysics and biochemistry) as among the best supported disciplines. Expecting and understanding the traditional level of griping, we were overwhelmed by the degree to which morale had fallen among the group especially selected to represent the most successful researchers.

What we were trying to do was to measure the health of science, and to do it in a quick way, thinking that the results would suggest a better way. What happened changed our course. The message, although anecdotal and unscientific, was so strong as to override the fear that biased sampling and lack of rigor in the survey would distort the results.

Since that time there have been at least three other surveys that were much more rigorous and followed more closely the technical requirements of attitude and opinion research. The American Physical Society Survey of Young Investigators, the Gallup Poll survey of biomedical researchers, and a survey by the American Society of Neurochemistry all more or less concur. So it is now reasonably well established that many of the nation's academic research scientists are increasingly unhappy with their professional life and, often among younger scientists, with their decision to pursue an academic career in science. The state of depression in academic science has since been further intensified by the effects of the recession and by the fact that our major research universities are all under financial stress.

On the other hand, congressional staff members on science-related committees, Washington-wise science administrators, and some science policy analysts tended to disagree, not with the specific issue of unhappiness, but in their assessment of the health and vitality of the scientific enterprise and in the wisdom of highlighting the plight of scientists. For example, the Office of Technology Assessment in a recent report states (*1*, p. 3):

> Given the extraordinary strength of the U.S. research system and the character of scientific research, there will always be more opportunities than can be funded, more researchers than can be sustained, and more institutions seeking to expand than the federal government can fund.

Whereas we received some hundred letters praising the survey, adding anecdotes, and complaining that we left out geology or anthropology, which are just as badly off and as important as chemistry or physics, there was a fair amount of criticism of the survey, to wit:

1) Scientists are always unhappy because they are insatiable.

2) Morale of scientists is not a test of the health of science.

3) Scientists are whining, self-serving, just another interest group; and they are much better off than the homeless!

4)There are too many scientists.

5)Yes, there is low morale. It will clearly influence career decisions of graduate scientists and even undergraduates, but the reason cannot be the level of research funding, which, as the AAAS report stresses, has been going up. It must be something else.

6)These are hard times, and scientists should suffer with the rest of society.

7)The real problem is (these critics will hasten to add): (a) We have to set priorities. (b) The entire research function of the university has grown too large and at the expense of the teaching function. (c) Increasingly, "research" means marginally useful data collection with vast numbers of articles never cited in literature. As Stanford University's former president Donald Kennedy said, it means "Overproduction of routine scholarship." (d) There is plenty of money, but it's all going to big science or to the National Science Foundation centers or to the Space Station or to Harvard. (e) In the present budget climate, it is unrealistic to expect significant new funding. (f) Besides, how much science do we need?

Please understand that not all of these arguments are without merit. Some have validity and even cogency if you put them back into the context from which I extracted them. Nevertheless, I would not have listed them if I didn't have very crushing

rebuttals to at least some of these and concerns about others.

Rather than answering the critics point by point or by reviewing (as I have many times in my own mind) how my report to the AAAS Board could have been better written, I would like to present to you my viewpoint on the state of science and fold in my concerns—and the results of some personal experience—about the intimately related problems of science education. Then, I would like to propose a plan of action, which is what an experimental scientist does when it is perceived that something is wrong. Let me clear up one thing: when I say science I will often use the word in its original connotation of "knowing," knowledge, wissenschaft, thereby including engineering research, art history, medieval music, in short, scholarship in the most general meaning of the term: I am including more or less everything that goes on in the university.

How Much Science Do We Need?

There is, however, one aspect of the criticisms that needs to be addressed, the issue of "How much science do we need?" and "How many scientists do we need?" One can answer on many levels, for example, the scientific opportunities that are displayed so lavishly at the AAAS Annual Meeting; some of these, invented here, are being exploited elsewhere for lack of resources. These opportunities are cataloged in everyone's 16 favorite emerging technologies. And we must add progress in planetary astronomy and experimental cosmology, designer molecules, biomimetrics and nanostructures, buckeyballs, molecular medicine, the search for the top quark, and so much more. These rich opportunities must be exploited, and we are nowhere near addressing them adequately. Nor are we, at the same time, paying adequate attention to the education of students, both the potential scientist and the potential science-literate citizen. Exploiting scientific opportunities and the educational function are the traditional occupations of academic scientists. And I would be very surprised if the work ethic has changed very much: 70-hour-weeks are still pretty normal. Academic scientists can work differently, but, on the whole, they can't work harder, "prof scam" wisecracks notwithstanding.

But there are new urgencies having to do with new obligations related to understanding and preserving and restoring our damaged environment while simultaneously attending to the inequity between the industrial North and the poor nations of the South. It is in the Third World that poverty and a population explosion threatens the stability of any conceivable "new world order." This is a major concern even if compassion and social fairness were not relevant. This must be addressed by raising the standard of living of the South without further burdening the planetary environment, a problem with scientific and technical dimensions beyond what we now know.

And is the fundamental understanding of viruses on the molecular level receiving the attention that the devastation of new diseases requires? Think about the macroengineering problem of repairing the ozone layer, should that become urgently necessary. Toxic and nuclear wastes, urban air, and water pollution are socioeconomic problems that would be enormously helped by imaginative science and engineering thought. These are just a few of the new tasks, a complete listing of which can easily be compared to a wartime crisis—without the immediacy of black headlines and hourly CNN coverage.

In view of all this, how could it be claimed that we have enough scientists and engineers? We surely don't know enough science and engineering. And at still another level we can compare our science with that of our economic competitors who are spending more per unit of gross domestic product on research and who are training a greater proportion of their workforce in science and technology.

Demographic analyses and the growing disinterest of Americans in science and engineering, given all their uncertainties, still project large shortages of natural scientists, engineers, and technicians without including the new tasks listed above (*3*). I've seen similar estimates for the social sciences and humanities. Can you imagine the Japanese asking if they are training too many scientists?

On an even deeper level, "How much science do we need?" is the question of how far are we from what some thinkers believe is a kind of saturation—of having enough knowledge because knowledge is finite.

After all, the laws of physics, it is argued, have largely been discovered and by the power of their general applicability we are left with filling in the details. In the long term, one can debate this point of view versus the concept of "endless frontier." In my own field of research, it is true that we have achieved a radically new view of reality in the microworld and in the understanding of the creation and evolution of the universe.

Still, what remains to be learned must surely dwarf the imagination—or in Bentley Glass's metaphor (*4*), in the accumulation of human knowledge, we may be like small children on the shores of a vast ocean, throwing pebbles in the waves. Just to suggest who is on my side, it was Einstein who said, "The deeper we search the more we find there is to know, and as long as human life exists, I believe it will always be so." Surely in fields where complexity dominates—in biology I suspect, in our understanding of neurophysiology and of anthropological and historical knowledge, and in the study of ourselves—surely these horizons must be as boundless as the number of sonnets and quartets that human genius will create.

And finally, some kind of an endless frontier is really an essential need of humankind—we need the challenge, we need the frontiers. The question "How much science do we need?" will very likely be retrieved by future historians as an indication of the insecurity and the confusion of our times.

A Rationale for Increased Investment

Let me state my assumptions:

1) There are strong indications that U.S. research—as carried out in universities but also in U.S. industry—that basic research and applied research are in trouble. Although we still have a fairly robust enterprise, the trends are largely in the wrong direction. There are so many problems, such as regulatory burdens, animal rights zealots and other anti-rational activists bordering on fundamentalism, overhead problems, and the new atmosphere of governmental suspicion of both the research universities and the scientist-as-crook. Inevitably this threatens the traditional but fragile relationship of science and the general public, which has always been composed, in equal mixtures, of incomprehension and trust.

Comment: As an experimental physicist, my job is to observe and to measure, and I suspect that most of science comes under this rubric, so to put a perspective on scientific malfeasance I learned who invented measures: It was, according to an unimpeachable source, Cain (*5*)—"This wicked son of Adam and Eve, having killed his brother Abel, went on to invent weights and measures—an innovation which changed a world of innocent and noble simplicity . . . into one forever filled with dishonesty!" In the Biblical tradition, the notion of measure—science—is inherently associated with sin!

In spite of all the issues I listed, the primary problem, if you ask the scientists, is that there is not enough funding to milk the scientific opportunities, to keep the postdoc and graduate student fed and working, to try new and risky ideas.

2) Investments in research pay off, and we can duel on this with economists at 30 paces, but we can also look around and see

how science through technology continues to provide means for adding to and enhancing our health, our wealth, and our wisdom through culture. The payoff can be measured and it is large (6).

3) I am impressed with that school of economists, led by Robert Reich at Harvard, who stress the importance of investment in human resources and infrastructure—in research capability, in a highly skilled work force with solid grounding in mathematical basics, science, reading, and communication skills. Let me quote from Reich's book (7, p. 8):

> As almost every factor of production—money, technology, factories, and equipment—moves effortlessly across borders, the very idea of an American economy is becoming meaningless, as are the notions of an American corporation, American capital, American products, and American technology. A similar transformation is affecting every other nation, some faster and more profoundly than others; witness Europe, hurtling toward economic union.
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> So who is "us"? The answer lies in the only aspect of a national economy that is relatively immobile internationally: the American work force, the American people. The real economic challenge facing the United States in the years ahead—the same as that facing every other nation—is to increase the potential value of what its citizens can add to the global economy, by enhancing their skills and capacities and by improving their means of linking those skills and capacities to the world market.

The Health of Research and Education

My personal efforts, the campus visits, the many thoughtful letters, and my interaction with members of Congress increase my concern for the health of science. The fiscal year 1993 budget continues to illustrate the fact that science is "well treated" in this Administration at least by its own lights. Academic R&D (nonmilitary) will receive a 5% increase, that is, a 1 to 2% increase over inflation ($11.5 billion) if Congress goes along. Other targeted areas of research will do better. And there is no doubt that this is impressive testimony to the regard in which science is held in Washington. Perhaps we can get by with these incremental additions, but I am not at all sure. I am afraid that the slide of our science will continue and that, at some point, it will become nonlinear. The word gets out. Graduate students defect. The best and the brightest go elsewhere, to Singapore, Korea, or law school. A weaker and less dynamic science infrastructure becomes incapable of exciting and recruiting and so it goes.

What is needed, in my view, is a much more dramatic change in the government-science relationship, indeed the government-university connection that was forged in the late 1940s and that has sustained America's leadership for the past 50 years.

It is even easier to apply the same conclusion to education. One of the burdens we have as scientists is the obsessive need to ensure a flow of young people into our field and to see to a general public that is amenable to arguments about the support of science and scholarship. But the education problem is even deeper than that—deeper than the need to have a science-literate work force in order to maintain our prosperity and standard of living—deeper than ensuring a supply of scientists. It is really a question of cementing the national community, which, through unequal educational experiences, is in the process of partitioning into increasingly antagonistic communities. Our nation will not survive as most of us would want to have it with a permanent and growing underclass. So, in both education and science, which weave together to form the tapestry of our hopes for the future, we have serious problems.

Federal expenditures for precollege education represent about 1.5% of the federal budget and 6% of the total expended by states and localities. In the pre-Reagan era it had been 10%. In any case it is small, and so we must concentrate on the kinds of initiatives that will leverage federal dollars in the places where they are most needed, in the inner cities and in the poor, rural areas. Here is a huge pool of untapped talent for the science-literate work force, the minorities who by any and all demographic projections, will be desperately needed as the proportion of white males in the work force continues to shrink and as the foreigners, upon whom we have grown dependent, become increasingly unreliable as a source of scientific workers. Competition for their skills is more and more intense. The thing about foreigners is that they speak languages—whereas Americans abroad hang on desperately to their English but may occasionally attempt some broken Fortran.

It is also here in our cities that the cycle of failure and dropout and poverty and crime and drugs and teenage pregnancy flourishes, but it is also here that quality education, decent schools, and well-trained teachers can break that deadly cycle and offer hope. A key to successful intervention is science teaching: yes, hands-on, activity-based, inquiry-led. These are the buzzwords and I've personally seen this work in the ghetto schools of Chicago. I've seen a program that retrains inner-city teachers to deliver math-science curricula. I've seen it work for first and second graders and through sixth grade. It can open the door to the joy of learning so that these children begin to flourish in their communication skills and, hallelujah, math and science are being taught where they never were before. But to deploy these new techniques requires real money, perhaps $1 billion for in-service teacher renewal alone to reach 25 cities like Chicago.

If we have the vision to see the importance of this, then we must summon the resources, the investment to deal with it, to think about the whole problem, from teenage counseling to prenatal care to a much more extensive Head Start to a reform of the K–12 system. One very encouraging trend is the increasing involvement of universities in precollege education. Outreach, the initiatives of scientists, is beginning to have a real effect, at least in the vicinity of universities that are involved. What relevance does all of this have for the research enterprise we foresee for the future?

Increasingly, research will be transnational as huge facilities will be shared and the national origin of companies becomes less interesting. An increasing number of nations will enter the R&D community. Here we can include Korea, Singapore, Eastern Europe, and the former Soviet Union as well as Brazil, Mexico, Argentina, and other developing nations now enjoying democratic reform but suffering from transitional economic problems. Competition for who will have the best educated, best equipped, most acceptable sites for new commercial activities will increase. Let's not forget that, while we are intent on becoming #1 by the year 2000, the present #1's are not standing still, waiting to be overtaken.

The summary here is that in spite of hundreds of national and state reports and the commitment of Congress and of this Administration, very little has been accomplished; our report card is still poor. My conclusion is that the public is still not on-board in this "gulf" war—the gulf between ignorance and education.

Do We Have the Money?

Now what I hear over and over in the science business is that "in these times of budget deficit, there is no way that dramatic changes in support of science can be achieved." Next to the crack about the homeless, this is the favorite of the critics. Yet I find this a most curious objection, in view of a $6-trillion gross national product (GNP) and a $1.5-trillion federal budget. "You don't understand," I'm told, "the discretionary part of the budget is only 20% of the total, and the $10-billion research budget is a significant part of that." The longer you spend in Washington, the more of these curious arguments you hear.

Nevertheless, if there were a real appreciation of the importance of science and

scholarship and education, if the president and the congressional leaders were really stirred up—something like to the level of 5% of the Persian Gulf frenzy or to the level of 15% of S&L bailout fervor—then $20 billion or $40 billion could be found. Time and time again we have been shown that this nation can afford anything it really wants to do. As a simple country physicist, I maintain that a doubling of the research budget and the education initiative at the level of adding $10 billion to $20 billion out of a federal budget of $1.5 trillion or a GNP of $6 trillion is not a matter of funding, it is simply a matter of choice. These would be prudent, long-term investments. Had such investments been made in the 1970–1990 period there may well have been far fewer homeless, far fewer of our citizens trapped in the ghettos of our cities.

Another example of the need to rethink the priorities of our federal budget has to do with our research universities. In Hanna Gray's keynote address to the 1992 AAAS meeting and in the symposium on the future of research in America, the plight of our research universities is highlighted. Stanford, Yale, Columbia, the University of Chicago—institution after institution—are contracting their contribution to research and to scholarship out of fear of financial deficits. These deficits now average about $10 million but are expected to rise. In view of increasing costs, declining interest, and decreased return on investment, the recession, and pressure on the indirect costs, this may rise to as much as $5 billion annually if we relate this to, say, 100 universities. Now I ask whether the contributions of these 100 or more great universities to our health, our economic well-being, our culture—whether these should be put at risk for such savings? For everyone who tells me that there are more urgent needs for the funds I have listed, I'll ask why we need to spend $40 billion on a vast interlocking intelligence structure designed for a previous age or why, after the collapse of the Soviet Union, has our defense budget changed so imperceptibly. I sometimes fantasize about a rational (!) zero-base budget exercise for fiscal year 1993. How would it look compared to the president's request and the congressional alternatives?

It is here that we must acknowledge the need to rethink how universities manage the research-education mixture. There are enough data around to indicate that what is a great strength in the graduate schools is less than successful at the undergraduate level. It is the ultimate waste to have students survive the obstacles of primary and secondary schools, still proclaiming themselves to be natural science majors, and then to lose them after a year of college. This must not be allowed to happen. It is also here that imaginative efforts must be expended to look to the attraction and retention of women and minorities, especially in the natural and engineering sciences. What would surely help is a stronger emphasis on "science as a sense of community," an atmosphere and vibes that can only be established and maintained by an engaged faculty. More of us must be alerted to this subtle but crucial task as we work to make our universities better.

In order to address the problems of science, scholarship, and education proactively, one must, I believe, understand them as part of the societal problems in which they are embedded. Education is perhaps 10 to 20 years ahead of science in its slide toward disaster. But these are, I believe, part of a deeper pathology affecting our society. You see it in the written-off inner cities, in the political mood of our times. The press, on the Sunday of my AAAS presidential lecture, reflects the mood. The Sunday edition of the *New York Times* (9 February) had five relevant articles: The front page article was entitled "Shadow of Pessimism Eclipses a Dream." The *News in Review* had two relevant articles: "Economic Myopia, Obvious Problems, Hidden Causes" and "Making Sure Federal Research Goes for Learning." Then the business section (I hardly ever read it): "Attention America! Snap Out of It!" Finally, the lead editorial: "Crown Jewels at Risk," pleading for help for the beleaguered research universities. A *Time* magazine essay in this same month is called "Fraying of America." Felix Rohatyn, the noted New York financier, fresh from a European trip was quoted as saying that returning to the United States was like coming to the old country from the new world.

This mood also exhibits itself as a loss of national self-confidence: Challenger and the Hubble telescope and President Bush's trip to Japan all contribute, as does, more keenly for people of my generation, the demise of Pan American Airways and Macy's department stores. A common denominator here is a loss of faith in the future, a concentration on what is immediate. The political process has only a few years interval from election to election; increasingly, corporations are transients—and interest in long-term goals and investments has no priority. The once numerous and highly productive industrial research laboratories—RCA, GE, Westinghouse, Bell Labs . . . are gone or going—pale shadows of a once exuberant faith that the company's research investment will indeed pay off. Listen to the *New York Times* (8):

> Consider the stereotypical American company that is losing the innovative race to Japanese rivals because it refuses to invest for the long haul. The managers' motive, apparently, is to please the stockholders (and boost their own pay) by diverting cash from hard research to plush dividends.

This makes academic research and the universities even more crucial in securing the future. As U.S. industries decrease their capability to do long-term research, the universities will have an even greater responsibility. Industry will increasingly have to look there to attend to its problems. Increasingly the national labs will look to universities as partners in exploiting their unique facilities, whether they be accelerators, light sources, telescopes, supercomputers, or what have you. The health of the universities is crucial to the future of the nation; they add to the store of knowledge, they look to the education of undergraduates and graduate students, they contribute to culture and are the repository of critical thinking on all aspects of our complex society. Universities can do better, will do better, but putting them at risk is not what America should do.

A Modest Proposal

So what is my plan? What can mere scientists do? The plan I am urging on the AAAS Board is one that has already been taken up by many science societies—it is a sustained, vigorous effort to reach the American public on the issues of science and education, on the issue of investment in human resources, investment in our future. Some of the larger societies are already active. The American Chemical Society has a lively program of TV spots and Sunday supplement inserts. The American Physical Society has had a program and is debating resuming such things. The biomedical community has established Research! America, an organization of 30 or so affiliates designed to advertise the virtues of biomedical research. Another segment of this group is pushing for a much more ambitious program. In my view, the AAAS is a unique organization to lead, coordinate, and implement an order of magnitude greater effort to educate the public on the value, the power, and the limitation of science and the need for a long-term outlook. An appropriate program would use TV, movies, op-ed's, full-page ads, Sunday supplements, the *Reader's Digest*, cereal boxes, and skywriting, where feasible. Intensive efforts to assist the print and TV science journalists must be a part of the program.

Even if the times were not as threatening as they are, the direct communication between the scientific community and the public becomes increasingly important as a way of reaching democratic consensus on the applications of knowledge. Science and

technology increasingly intrude on our lifestyles and behavior and the consequences of discovery shape the future in ways about which scientists can at least make estimations, however imperfect. So in the need to allay public mistrust and secure its support, there is also a recommitment of science to facing up to responsibilities, growing ever more pressing.

A reasonable program would require perhaps $5 million to $10 million a year as a wild guess, and it would need highly professional advice. I have suggested that a board of strategy composed of the leaders of all the major science societies be convened to begin a discussion of the health of research and of the virtues of such a dramatic program. Clearly there is the danger of backlash. The program must be crafted very sensitively. But the risk of doing nothing is far greater than the risk of failing here. If the stories told are interesting and if the effort is more educational than promotional, it need not have a backlash. The goal is an increase in public understanding of science. Just suppose, for example, that Bill Cosby and Sally Ride cohosted a prime-time network show called "This Week in Science" or "New Horizons of the Mind." Just imagine an "L.A. Science" or a "Science Nightline." Such programs could engage tens of millions of people—parents and children. It could have associated classroom materials, be sponsored by several far-sighted technological companies. When it comes to fixing television, while we are at it, we do really need all the help we can get. Even if we could focus the full and awesome power of a unified academia (the mind boggles!), the issues will still be in doubt, no? What is being proposed is a massive program of educating the general public in matters of science, engineering, scholarship, and education. This means competing with dreary sitcoms and a diet of rape and murder trials. It proposes the grandiose goal of raising the level of American culture and bears the burden of saying: "What's good for American science, American scholarship, and education is good for America."

The main point is that it does this in full view of makers of national policy and, if it is done well, this could have a dramatic effect on attitudes and on priorities. When a president, an adviser, a congressman, or key staffer reads, the stories in the *Washington Post* or *Parade* magazine it has a thousand times the clout of your visit to his office to say the same thing. It is crucial that this be a sustained program. Not much will happen in a year or two, but if we commit ourselves to, say, a 5-year program of media activity, something will happen, priorities will be adjusted, and the 3% or so of the federal budget now invested in the kind of science, scholarship, and education we are addressing will grow to serve the needs of a resurgent nation. We will probably never again be the kind of leader we were in the 1950s and 1960s, but we can be among the major players in the new global order.

This is a strong departure from the status quo, where each year we anxiously await a small but appreciated increment. But consider the stakes, not for the scientists here or even those who couldn't afford to come to Chicago. The times they are a'changin'. The world is vastly different today. We see around us and detect, in most of the discernible political voices, uncertainty and an appeal to immediacy. This seems to be independent of political party. As a nation our old frontiers have been converted to shopping malls and used car lots; our old adversaries, which contributed so much to national purpose, are gone. Science research and scholarship offer new horizons, new wealth, an inherent and contagious optimism, and the possibility of restoring the planet and also restoring our own society via the immense power of rational thought molded by aesthetics, compassion, and wise self-interest.

And something else—let me raise this as a question. A popular involvement in science, education, and scholarship, in the challenge, in the opportunities, in the public confrontation with man-made and natural disasters—can these things be packaged into an activity that will replace our good old communist foe as a more productive unifying element for our increasingly fragmented society?

My plan certainly needs the active collaboration, advice, and creative wisdom of colleagues in behavioral science, in psychology, in the humanities, and in social sciences. We need very professional advice—we need a powerful advocacy group outside of science—from the corporate, financial, labor, law, and congressional communities. There is of course no guarantee of success. Perhaps the malaise eating at American society is much too deep and science and education will continue to decline. What will happen? Science, scholarship, the American period would very likely go into a long slide, which will eventually stop; recovery and reemergence will eventually take place. As we are learning from education, the repair of infrastructure is a long-term problem measured in decades. Life will be much harder for our children and our grandchildren. The question we must all ask ourselves is "Are we convinced enough by these alternatives to dedicate the effort it will take to avoid the decline?"

This program will not fly unless the leaders of the science and engineering societies hear from the rank and file, the bench scientists and trench scholars. This program or some better alternative needs the enthusiastic support and resources from a unified scientific community. AAAS is uniquely organized and superbly staffed to lead this effort. If each of us goes off making our separate cases, not much will happen. However, if we coordinate our message and present a united front, the voice of scholarship, we may achieve this new compact. The goal is to forge anew a vision of a dynamic society in which children can once again expect to do better than their parents.

Epilogue

After delivering the address upon which this paper was based, I became aware of a 1951 policy statement of AAAS (it was known as the Arden House Statement) (9):

> . . . demands that the AAAS not only recognize but attack the broader external problem of the relation of science to society. It seems to us necessary that the AAAS now begin to take seriously one statement of purpose that has long existed in its constitution. To quote: "The objects of the AAAS are . . . to increase public understanding and appreciation of the importance and promise of the methods of science in human progress."

The author, Warren Weaver, called for active reassessment and redirection of AAAS away from technical topics and toward improving the attitude and support for science among members of the nonscientific community (9).

Finally, one of my distinguished predecessors in AAAS, Allan Bromley, in his 1981 presidential address raised many of the issues I have raised (*10*). I reread his talk after giving my own, and since he is today the president's science adviser it is especially interesting to see the parallel channels. He expressed concern about the health of science ("There is a mood of pessimism loose in the science and technology community and in the nation."). He was perceptively concerned with the poor state of science education, citing data and statistics that were to later festoon the "Nation at Risk *et al.*" reports. He gave much attention to the problem of developing nations (". . . And unless we act, and are perceived to be acting to better their lot, we run the serious risk of a world in turmoil, with the developing world making common cause to fight for what they view as a fairer share of the earth's resources."). Bromley especially called on AAAS members to become more active on the public literacy front ("I am convinced that the ultimate answer must lie in an informed, interested public prepared to understand, at least in outline, and support science and technology on their own merits and in recognition of the vital role they play in almost all aspects of contemporary life. . . . We must build a

new public constituency for science and technology."). Finally, to my great delight, he calls on general scholarship ("Only by working together—humanists, social scientists, and natural scientists—can we hope for success in attacking our most important problems."). I cite both parts of the epilogue to emphasize not that the problems are so perennial as to induce resignation, but that they are stubborn. The sharpest lesson we can draw is that the failure to act boldly and decisively compounds the problem. In the past decade, not only have things gotten worse but events have conspired to raise the stakes for the nation and the world. Now we require efforts more strenuous and more imaginative than have ever before been attempted. The advancement of science deserves no less.

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6. For anecdotes, see L. M. Lederman, *Sci. Am.* **251**, 40 (November 1984). For economists who have studied the economic returns of research, see, for example, Theodore Schultz, Edwin Mansfield, Zvi Grilliches, and Robert Solow.
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9. W. Weaver, *Science* **114**, 471 (1951).
10. D. A. Bromley, *ibid.* **215**, 1035 (1982).
11. President's address to the 1992 Meeting of AAAS, 9 February 1992, Chicago.