# Science and Technology: The Road Ahead

Frank Press

Recent public opinion surveys indicate a continuing, if not growing, high regard for scientists and engineers (*1*). They are seen as being responsible for much of our country's past success. They are looked to as those members of our society whose work will most likely be responsible for our succeeding in the future.

This is a great vote of confidence. But to many of us, this comes as something of a surprise. Some, I am sure, feel ambivalent about it. Do we deserve this trust and faith? Or is the public too naive?

On the other hand, do we underrate ourselves—our past performances and our current capabilities? Could it be that, in view of the immense problems and uncertainties ahead, we are suffering from a new lack of confidence—a failure of nerve?

Still more questions come to mind: To what extent are we responsible for the technological backlashes of our previous successes, and can we correct them and avoid others in the future? Finally—and perhaps most important—can we justify the public's confidence in us by generating further advances in science and technology that can be used creatively to build a better world?

These are among the questions I would like to address in this article, trying to place my comments in some perspective with the realities we all recognize, and particularly with those that have been thrust before me since I have assumed the role of Science and Technology Adviser to the President.

The answers are important. For, if the public is right—and I believe that in large measure they are—it may be time for some new attitudes and actions on the part of the science and engineering communities. Among them must be a new spirit of self-renewal and cooperation among our professions, new self-assertion and positive attitudes about our future roles, new confidence in the future creativity of science and technology. In short, we should rise to meet the public's image and expectations of us. And, in doing so, we may just find that the hard support—the federal budgets proposed and the congressional appropriations and authorizations approved—will grow accordingly. We may also find that our institutions and political factions may yield to the changes necessary to allow our best science and technology to shine through.

Many may be skeptical about this. Many may have doubts about the appropriateness of this kind of clarion call to science, so let me spend some time justifying it. As I go on, perhaps you will see some of the reasons for my optimism and for the need for initiating new attitudes and ideas to promote the positive power of our professions.

I will begin with some basics. Everywhere one looks today, it is apparent that the success of science is essential to human survival. Human numbers, human institutions, and human expectations demand the extension and application of human knowledge. Not to meet that demand does not mean limiting growth or moving toward any kind of stability. In the dynamic world we have created, it means fomenting human misery, economic collapse, social upheaval, and, at worst, war. The choice before us then is not one of growth or no growth—as was popular to debate a few years ago—but between various approaches to controlling and directing growth in the most constructive and humane manner. It is toward this end that science and government and industry and the public must all work together, building not only the technological systems but the institutional ones that will make our complex society serve the best interests of all.

On this account, let me turn to some interactions between science and government—particularly this Administration, which I have had an opportunity to come to know. I have been encouraged during my contacts in Washington—in the White House, the agencies and the Congress—by the attitudes I have discovered toward science and technology. Working with these people on the difficult problems of science and technology policy, the problems of university research, and the budget has shown me that there is an underlying confidence in our ability to search out the answers to these problems.

The President, in particular, holds a strong belief in the capabilities and potential of science and technology and has, on several occasions, expressed his personal concern over maintaining their health in America (*2*). The latest of these expressions was in his State of the Union Message to the Congress, wherein he spoke of the Administration's proposed budget increases for basic research (*3*). In viewing the President's attitude and ideas on science and technology, one must be cognizant of a number of things—dilemmas of politics and national priorities.

First and foremost is the matter of national security—which has become, over the years, a euphemism for the complex issues of war and peace. Every president who comes to power perceives himself as a man of peace and hopes that the history of his administration will prove him so. But each one also finds himself inheriting a classic dilemma, that of having to perpetuate peace through military strength, when he recognizes that the ultimate security lies in other directions. It is still one of our greatest human tragedies that we must depend on military superiority—to the point of today's massive concentration of nuclear might—more than using the same capabilities and resources that gave us that superiority to attack the underlying causes of global insecurity and war. The situation, of course, is universal. Today, world military expenditures exceed $350 billion, of which some $30 billion is for military R & D (*4*). An enormous amount of good works could result if such capital and intellectual resources were channeled in other directions.

This situation, however, is of the greatest concern to this President. And, while he knows he cannot reverse it overnight, he wants very much to begin to take measures in that direction. A first step has been toward holding back on the introduction of unnecessary new systems, such as the B1 bomber. This is being coupled with a move toward greater efficiency and proficiency to hold

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down the cost of military expenditures without compromising our technological advantages.

On the other side of the scale—the more positive one—the President is directing the Administration toward resolving some of the underlying causes of global unrest and strife. Along this line, new initiatives are being taken to aid developing nations, attack hunger and poverty, improve world health, and stimulate economic growth. The Panama Canal Treaty is a key example.

In the coming year, we will be reviewing and possibly revising our entire foreign aid system. We will be taking new initiatives to improve the policy underlying East-West and North-South technology transfer, as well as examining our exchanges with the U.S.S.R. and other countries. And we are already at work on constructive proposals for the forthcoming United Nations Conference on Science and Technology for Development, now scheduled to be held in Austria in 1979.

In moving in these directions, we are working in the belief once expressed by Robert A. Millikan when he said, "War will disappear like the dinosaur when changes in world conditions have destroyed its survivor value" (*5*). In initiating and carrying out such changes, I can assure you that the President looks to the science and engineering communities for a great deal of help. Knowing these communities, I am confident such help will be forthcoming. And I will use my office to cooperate with you in bringing your ideas and your interests to the attention of the Administration and to keeping you informed of ours. We have tried to do this over the past year and will continue to do so even more effectively in the days ahead.

In working together to "make the dinosaur disappear"—to build a better world—what are some of the major issues on which we must focus strongly? Where does the Administration's interests lie? And where can the greatest contributions come from science and technology?

Let us first look at the economy. Next to the weather it is a subject on everyone's mind. This is not because we are in a recession, but because many economic analyses raise doubts about our ability to maintain the vitality of future economic growth. Such growth is not only essential to our domestic well-being but is a keystone to global economic progress, to economic conditions among other industrial nations and to our ability to assist the developing countries.

Some of the conditions that now seem to be chronic here are also endemic throughout the world—persistent inflation, a high rate of unemployment, and a decline in the rate of our productivity growth.

An interesting point about productivity growth is that, while it is slipping in the advanced countries, it is rising in the developing ones. The reasons for this have a profound implication for science and technology, particularly for industrial R & D. They have to do with the fact that many of our intermediate technologies and even some of our high technologies are being successfully adopted by the developing countries, which, on some items, can now successfully compete with us. A recent study by economists with the General Agreement on Tariffs and Trade (GATT) (*6*) reveals that, after growing at a rate of about 6.5 percent per year in the early 1960's, overall manufacturing production in the developed countries slipped to a rate of 4.7 percent in the early 1970's, and, since then, has been essentially flat. In such areas as steel, textiles, and light manufacturing, productivity rates since 1973 have actually declined in the advanced nations. At the same time, however, the developing nations have been increasing their share of trade, based on industrial items such as textiles and light manufactured goods; and this includes some higher technology goods such as electronic items. This kind of production in the developing countries grew at a rate of 8.5 percent last year, while, in the advanced nations, it barely rose to its 1974 level (4.7 percent) (*6*).

Along with this, it should also be noted that innovations and new industries provide the highest rates of productivity, which tend to decline as the industry matures. This is one of the factors behind Japan's economic success, a factor not widely recognized.

There is a significance to all this, which we should ponder and heed. To some extent, we can applaud the fact that there are developing countries successfully adopting manufacturing that will raise their productivity and living standard. The whole point of development is "to make the poor productive" (*7*). However, as this transfer of technology and industrial capacity takes place at one level, it is essential that the advanced nations continue to advance in their innovation and productivity. Otherwise, the major markets will begin to collapse around the world, we will be resorting to protectionism instead of industrial creativity to save our domestic economies, and eventually global economic chaos will ensue.

In speaking of making the poor productive, we must consider this an international imperative of the highest priority. We in the advanced nations have given the poverty-stricken people of the world aspirations for a better life. But, under current conditions, these can never be achieved. The resources—food, energy, materials—are not available in the amount or at the cost that can make this possible. Unless science and technology can help to bring this about, we all face profound economic and social stress.

The harsh truth is that we are now very much locked into a dynamic system of global economic growth, and it is one based largely on technological change and innovation. This is a major concern, not just for the United States, but for all the industrial nations and the rest of the world. There are enormous pressures ahead for us to innovate and improve productivity.

One driving factor is employment. During the next decade, it is essential that this country create jobs for a rapidly expanding labor force. The situation is even more urgent on a worldwide basis. While there is some hope that global population growth may level off in the decades ahead—leaving the world with between 6 to 8 billion people to feed, house, and clothe in the next century—we know that, by the year 2000 (only 22 years away) there will be some 1.9 billion potential workers in the world. This means an additional 1 billion newcomers to accommodate in the global work force. On the basis of the same conservative growth calculations, *that* labor force will grow to between 3 to 4 billion by the year 2050 (*8*). I am sure that I need not dwell on the economic and social consequences of all this.

The crucial point is the need for innovation. And a principal basis of innovation today is research and development. This is one reason why we are concerned with the state of industrial R & D in this country and why the Administration will be focusing much attention on it in the coming year.

Of course, all our hopes for increased industrial production, and economic growth in general, are contingent upon an adequate supply of energy. The energy situation has been particularly agonizing. It represents a political, as well as a scientific and technological challenge of the first order. We know that some time in the next century, we will achieve a virtually unlimited, renewable and clean energy supply. The immediate problem, that of the coming decades, is getting from here to there in the face of diminishing oil resources without large-scale economic dislocation.

To achieve this essential energy transition without severe economic problems, we have to take certain measures. We must make a major effort in conservation. We must switch to coal as our principal fossil fuel. And we must rely on the best nuclear technologies to serve as the balance of our energy budget. All of this will be required to buy us the time to develop and bring on line the other energy resources we will be depending on in the future.

Energy is so important that we have to pursue many bets; we have to develop technologies that involve taking both the hard and soft paths. We are taking this approach in our new energy R & D budget. In that budget, support for geothermal is up 23 percent; solar electric is up 23 percent; conservation is up 27 percent; biomass is up 28 percent, basic energy science is up 26 percent; advance reactor and breeder research is up 22 percent (even with the cutback on the Clinch River project); and fusion is up 18 percent (*9*).

Another important human need and its source—food and agriculture—can be set set forth by a few facts.

Here are some of them, and not particularly in order of importance: (i) Agriculture is this country's largest industry, with assets of over $531 billion. (ii) The food and fiber industries are the nation's biggest employers, with between 14 and 17 million people working in some phase of them from growth to sales. (iii) Since 1971, U.S. agricultural exports have tripled, to a record $24 billion last year. This has made a net contribution of $10 billion to our balance of payments. (iv) The United States supplies about half of the grain that moves in world trade and three-fourths of the soybeans. It provides about 70 percent of all the food aid (*10*).

But on the other side of the coin are the following: (i) Most nations are chronic importers of food, with the situation growing worse. While 45 exported food or were self-sufficient in 1950, only 19 nations did so in 1974, with four countries, including the United States, accounting for more than 90 percent of the exports. (ii) During the period from 1961 to 1974, 39 of the 86 developing countries, accounting for 24 percent of the Third World, had population growth in excess of food supplies. Eighty percent of the entire Third World's population demand for food was in excess of its supply. (iv) U.N. demographers point out that, merely to maintain the present desperately low level of per capita consumption, cereal output would have to increase by something like 30 million tons a year, which amounts to two-thirds of the Third World's average imports during the years 1970 to 1975. By the year 2000, with a population of about 6.2 billion and an annual growth of 110 million, the grain shortfall, other things being equal, will have increased by 70 percent.

Taken all together, these facts indicate a remarkable success story for American agriculture while, at the same time, throwing up an awesome new challenge to our agricultural research community. I emphasize the latter, especially because it appears that the heaviest burden, for developing ways to meet future food needs, lies with them. The key to future agricultural productivity in our country, and to development of agriculture in the Third World—the tropics and arid regions where those countries lie—is in new research. It is in such research areas as: (i) biological nitrogen fixation to reduce the demand for chemical fertilization, their energy use, cost, and environmental impact; (ii) photosynthesis increase to improve plant efficiency and hence crop yield; (iii) genetic research to allow the rapid development of crop plants that can withstand stresses associated with weather and climate change, diseases and pests; (iv) integrated pest management systems to help reduce the use of chemical pesticides and alleviate the huge food losses attributed to pests.

Also to be included in this list should be the work to develop food, fiber, and other new commodity crops that can be economically grown in arid lands, in saline soils, in the humid tropics, and on other lands and under other conditions not now amenable to agriculture. There are encouraging signs today that this can be done; among these are the tropical leucaena plant which may be an important new source of forage (*11*); the winged bean, a protein-rich food for humans; the jojoba plant, a potentially important source of wax and oil; and the guayule bush that has produced a successful rubber, both able to grow and be cultivated in the desert (*12*).

These offer just some of the proof that today we are using only a small fraction, about 1 percent, of the world's 350,000 species of plants. In fact, we depend on less than 20 of them for our major food and fiber crops (*13*). There is also a growing interest today in the potential use of crops, crop residues, and biomass in general for fuels. Bioconversion is rapidly becoming a household word in energy circles.

All this indicates that the great agricultural revolutions still lie ahead of us, and the key to them is research. I think we are recognizing this in our new agricultural programs with their emphasis on basic research. For example, in the coming fiscal year, the U.S. Department of Agriculture will double the funding of its recently initiated extramural competitive grants program—from $15 million to $30 million—and most of this will go for basic research in the areas of interest I mentioned before (*14*). The National Science Foundation also is supporting increased basic research in the biological sciences related to plants.

We cannot discuss agriculture without thinking about climate and weather. And these have been things it is difficult *not* to think about these past 2 years. Our most immediate concern, of course, has been with weather variability as this is where the impact has been—from droughts, severe cold, and, this year, winter storms. Some climatologists believe that such variability is part of the pattern of longer-range climate change. We are interested in both, as they are going to have a widespread impact on human activity—our agriculture, energy needs, and many other aspects of our lives. The Administration and the Congress have both shared their concern over the need for a National Climate Program. We are moving ahead with an interagency climate research program this year. The Department of Commerce's National Oceanic and Atmospheric Administration will serve as the "lead" agency in this program, which will include the departments of Agriculture, Commerce, Defense, Energy, and Interior, along with the Environmental Protection Agency, National Aeronautics and Space Administration (NASA), and National Science Foundation (NSF). The President's 1979 budget for this program will be $104 million, a 39 percent increase over this year's funding of climate research (*14*).

Climate represents, in a sense, one of our major environmental issues, but also one of the least controllable; we will be studying extensively man-induced effects on it, such as that of increased carbon dioxide in the atmosphere as a result of human activity. There are a great many other important, and perhaps more controllable, environmental issues of immediate concern to this Administration. The President maintains his abiding interest in the environment. He feels strongly that it is possible—and essential—for science and technology to help us advance in the most environmentally beneficial way, making certain that our advances today are not made at the expense and to the detriment of future generations. One of his highest priority environmental interests at this time is the Administration's legislative proposal concerning the preservation of Alaska's wilderness and wildlife. This legislation—which proposes the creation of 92.5 million acres of National Parks, Wildlife Refuges, Wild and Scenic Rivers, and National Forests—provides us with a historic opportunity (*15*). As Secretary of Interior, Cecil Andrus, stated before Congress last month:

> Alaska is a rare second chance for us as a people—a chance to preserve a major portion of our natural heritage—to strike a balance between extracting important natural resources and protecting our last great region of wildlands. Through enactment of our proposals, we can be certain that the crown jewels of Alaska—its most spectacular natural environments, recreations areas, and wildlife habitats—will remain intact for the benefit of our Nation's citizens.

Alaska, as you may know, offers enormous opportunities for scientific research. And the Department of Interior sponsors scientific investigations there by biologists, archeologists, anthropologists, and geologists.

While we try to preserve our last pristine environments in Alaska, we face great environmental challenges in the rest of our country. One of the most important of these has become dealing with the numerous toxic substances and other chemicals we introduce into our environment, workplaces, and consumer products. We live in a sea of chemicals. The latest computer registry of the Chemical Abstract Service contains some 4,039,907 distinct entities, and the number of entries is now growing at the rate of 6000 per week. Of these, of course, only some 63,000 are estimated to be in common use (*16*). In any case, you can see in this the great challenge we have in evaluating and controlling the environment and health effects of all this.

I am encouraged by the many ways we are attacking this problem today and the progress we are making. Just recently, we have taken the important step of organizing an interagency group of the four federal agencies that must deal with this situation—the Food and Drug Administration, the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration, and the Consumer Products Safety Commission. Under this new arrangement, we hope these agencies can effectively coordinate their efforts in establishing uniform standards and guidelines for industry to follow in testing the health and environmental consequences of their products. Together with cooperation by the government and industry in implementing the Toxic Substance Control Act, and newly funded EPA programs to examine and anticipate problems associated with introducing new substances into the environment, I believe we are moving in the right direction. On the broad environmental front, it is encouraging to see that federal outlays to support environmental programs in 19 agencies and departments will increase by 11 percent in 1979 (*14*, p. 287). This covers a wide range of activities in pollution control and abatement, basic environmental sciences, and protection and enhancement efforts.

Environmental factors continue to have a major influence on the state of human health—and I want to say a few words about this important subject. Our progress has been notable. Life expectancy has climbed. The percentage of deaths due to major diseases over the past 25 years has decreased, in some cases remarkably: In heart disease, still our major killer, it is down more than 24 percent; deaths due to stroke have dropped 32.5 percent; influenza-phenomena mortality has dropped 35.5 percent; deaths due to hardening of the arteries has declined 53 percent; and even the mortality due to diabetes, our third largest health problem today, has dropped 12.6 percent (*17*).

While these are encouraging signs, with much credit due to the medical profession and to advances in the basic biomedical sciences, we recognize the great health challenges ahead. Many of them are due to environmental causes and stressful conditions of our society. Cancer, of course, is the prime example. It is one that must be attacked from all fronts—reducing the environmental causes, including those self-inflicted, such as smoking, and working toward a scientific understanding of the biological basis of the disease. In the coming year, such work will be increasingly supported by the addition of funds going into basic research at the National Cancer Institute.

I have placed considerable emphasis throughout this article on the need for research. We have been particularly pleased that, with the President's support, we have been able to increase the 1979 fiscal year federal funding for basic research by about 11 percent (*14*, p. 305). For those of you who wonder how this came about, let me say that it was a process that started during a recent preview when certain issues were identified in the Office of Management and Budget (OMB) planning sessions with the President. Subsequently, there were a number of meetings in which OMB and OSTP met with leaders in science and engineering from universities, industry, and the government to review their impressions of trends, issues, and alternatives. We also worked with the Vice President, Cabinet members, and the heads of NASA and NSF. All this and more culminated in a proposal to the President describing the problem and suggesting new increases in basic research funding. The President agreed to our recommendations. The outcome is that the proposed federal obligational authority for support of the conduct of basic research will total more than $3.6 billion, a 10.9 percent growth over fiscal 1978 (about 5 percent real growth) (*14*, p. 305).

I should note here concerning this outcome that we have been working with executives of the federal science agencies to see that this funding growth will be used appropriately—that is, first, that it is invested into the promising areas of scientific inquiry and, second, that it is used to ameliorate some of the problems associated with the performance of research in colleges and universities, including obsolescence of equipment, lack of opportunities for young investigators, and the paperwork burden associated with proposing new research directions.

During the course of our interactions on research with the departments and agencies, the President queried the Cabinet members on what they thought some of the important research questions of national interest were. Here are a few examples cited by the Cabinet officers: Can simple chemical reactions be discovered that will generate visible radiation? How does the material pervading the universe collect to form complex organic molecules, stars, and galaxies? What are the physical processes that govern climate? How do organisms in the deep sea influence the productivity of the ocean? Can new homogeneous catalysts be prepared that will catalyze chemical processes important to the chemical industry? What are the limits for communications use of the channel capacity in the visible spectrum? What are the factors—social, economic, political, and cultural—which govern population growth? At what rate will atmospheric carbon dioxide concentrations increase as a result of increased use of fossil fuels? How do cracks initiate and propagate in materials? How do cells change during growth and development? What are the mechanisms responsible for sensory signal processing, neural membrane phenomena, and distinct chemical operations of nerve junctions? How can structures be designed and constructed to be both economical and earthquake-resistant? What predisposing factors govern cellular differentiation and function in plants and animals?

I began with many questions and I am concluding with many still to be answered. I have covered only some of the many activities in which I and my office have been involved—such issues as human nutrition, dam safety, earthquake hazards, mineral policy, space policy, and many other important matters. We are hard at work on what we feel are some of the major issues of our times. It is essential that all work in the basic scientific disciplines advances and provides a sounder basis for our science policy decisions. The work of the scientist must continue to merit and earn the esteem with which the public holds science and scientists.

We owe those who support us and place their hopes in us a very frank and honest appraisal of what we realistically can and cannot be expected to do, what costs and burdens must be borne to fulfill those expectations, and the uncertainties and risks that lie ahead for all of us. "The business of the future is dangerous," Whitehead warned us.

We must throw back certain challenges to them. Nature holds tightly to her deepest secrets and reveals them grudgingly. Patience and endurance are necessary. As John F. Kennedy once questioned, "I don't understand why we're suddenly so fatigued. The struggle won't be over in this century." There will always be uncertainties and unknowns. The quality of our science will reflect our pursuit of excellence throughout our entire society—our education, our public concerns and interests, and our institutions. Our technology will never be foolproof or fail-safe, but always dependent on the human factor—the quality, dedication, and responsibility of our workforce. There is perhaps a moral lesson in all this—we will get, in the long run, the society and civilization we deserve. And, as I recall someone once saying, "Why not the best?"

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**NEWS AND COMMENT**

# Addiction to Technology Is One Cause of Navy's Shipbuilding Crisis

The Soviet Navy's recent dramatic increase in its oceangoing capabilities has made the U.S. Navy—whose fleet is aging and shrinking—anxious to construct more ships. But one of the chief obstacles is the Navy's own shipbuilding program, which has been plagued by delays, high costs, and acrimonious disputes. Shipbuilders' claims against the Navy have reached an all time high of $2.7 billion and some ships are being built only because courts have so ordered. The problem is so serious as to threaten the Navy's ability to fulfill its strategic role at a time when that very role is the subject of widespread debate.

The Carter Administration has begun to urge general reforms on the Navy by using the shipbuilding claims as a lever. An Administration budget official recently warned a group of Navy admirals and others that the problems with the claims were the "single most influential reason" why President Carter had chosen not to accelerate any major shipbuilding programs in the fiscal 1979 budget. If the Navy didn't make substantial progress on the claims within 1 year, Edward C. Jayne III told a shocked audience, the President would continue to favor Army and Air Force budget requests at the expense of new Navy shipbuilding proposals. In short, the Navy leadership of carrier admirals who dominate Navy policy and feel the most urgent desire for more ships to meet the Soviet threat, are being told that the less glamorous, procurement side of the Navy will determine whether these wishes are granted.

But to ex-Navy man Carter, and many others, such as John Stennis (D.-Miss.), the powerful chairman of the Senate Armed Services Committee, plus the House Appropriations Committee and the General Accounting Office (GAO), the Navy claims are only the tip of the iceberg. The larger problem has been called a "breakdown" in Navy shipbuilding, an "all time low" in relations between the Navy and the private shipyards, and just plain "sick."

The cumulative message of several examinations of the more fundamental aspects of Navy shipbuilding seems to be that the Navy is addicted to buying the most technologically advanced ships, even if this means that initial plans are vague, even if constant changes must be made during construction, and even if costs escalate and production is delayed. Many have contrasted this approach with that the Navy followed in World War II when Liberty-type ships were stamped out very efficiently, for a few million dollars apiece.

A destroyer, which cost $5 million during World War II, now costs some $132 million, but the Navy argues that without the advanced electronics, communications, sensors, and weapons which the extra money buys, its ships would be little more than "million dollar floating targets."

Yet even the Secretary of the Navy, W. Graham Claytor, echoed a popular view when he said "there is enough blame for everyone" in the shipbuilding mess. One charge that has been made is that the biggest problem in the program is Admiral Hyman G. Rickover, the 78-year-old father of naval nuclear propul-


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