Whither the NSF?—
The Higher Derivatives

A changing social environment will make new demands on the science community.

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The 25th anniversary of the establishment of the National Science Foundation (NSF) being observed this year provides an occasion to review the origins and development of this federal agency, and to assess the impact on science of the research it has supported (*1*).

But, if it is a time for retrospect, it is also a time to look ahead, to ask: Where is science going? In what ways is the NSF to grow, and what forces in science and external to it will shape the Foundation's future? In this article I shall address both these matters—the trends in science and the course of the NSF—for I believe that the primary forces that determine the future will have an equal influence and impact on both. If during the discussion I pose more questions than I answer, it is because such questions are just beginning to surface as real challenges. Thus far most remain unanswered, and there is no better time to urge that these hard issues be brought into open discussion and faced squarely by the scientific community, as well as those who are concerned with the future of science as a social force.

My major thesis in this discussion of the future is that in the structure and support of our scientific and technological enterprise we of the science and engineering communities have witnessed a major change and now face a strong challenge in our relationship with society. It is obvious that the social environment in which scientific work is done has changed, is still changing, and will undergo even greater change in the coming years. Such changes will be economic, social, and political. The extent to which scientists and engineers become actively and constructively involved in these evolutionary processes could determine not only the outcome of their professions and of science itself, but of nothing less than the fate of our current civilization. I would like to devote some of my comments to the reasons for these changes and some of the responses that may have to be made by science and scientists. From these you may draw several conclusions about the shape of our enterprise in the years ahead.

Dr. Stever is the director of the National Science Foundation. This article is adapted from an address given on 21 April 1975 at the National Academy of Sciences to commemorate the 25th anniversary of the National Science Foundation.

Economic Aspects

Economics and the economic aspects of science and technology are subjects that today are on many minds. Historically, and recently, a great many important scientific discoveries have been made, and important theories arrived at, through research that was relatively low in cost. We might call these "intellectual-intensive" projects. Much good research today still falls in this category. But much does not. And the cost of conducting that other segment of the nation's scientific and engineering business has reached capital-intensive proportions. Furthermore, we are just seeing the tip of the iceberg. Here I refer to work in both the most basic science and the most advanced applied engineering. For example, in basic research a new accelerator is now a $250-million investment with a multimillion-dollar-per-year level of effort thereafter. In applied research and development we must recognize the multibillion-dollar costs involved in such projects as the construction and testing of the demonstration breeder reactor. Similar large investments lie ahead in other energy fields. We should not underestimate the economic outlays that will be required for the full-scale demonstration and application of coal gasification and liquefaction as well as the cost over the next few decades of making the transition to a solar and fusion age. These too will become multibillion-dollar projects for the government, and eventually involve trillion-dollar enterprises for the nation as a whole. Today's energy programs, in their incipient stages, give us only an inkling of the enormous long-range costs in both public and private investments that will be required to bring all aspects of our energy transition to their fullest fruition.

Unrealized by many people is the fact that we face similarly large investments in advancing and making the fullest economic and humane use of the fine work being done today in the biological and chemical fields, particularly as they relate to the world's food problem and the revamping of industry to meet the requirements of global growth within the confines of the new environmental criteria being set. We are now a world of 4 billion people. Should we achieve the demographic feat of leveling off at between 7 billion and 8 billion as we enter the next century, we will still have to come up with some miraculous accomplishments in agricultural yields, nutrition improvements, pest control, fertilizer and water developments, and land utilization even to maintain such a population at a subsistence level. However, even present evidence that a large part of this population will not settle for mere subsistence should warn us that, unless we can mesh our industrial and environmental requirements at a much higher level than today, we face pressures that could lead to a period of social and political chaos unprecedented in human history.

To me, all this points to a tremendous growth of economic involvement for science and technology and a related growth of responsibility and accountability for scientists and engineers. We are going to be involved as never before in the economic success or failure of this country and the rest of the world, and we are going to be taking the praise and the blame for far more than we have ever bargained for. We now must get used to the idea of such involvement—and not only economically, but ethically and socially, as I will discuss shortly.

The Compression of Time

Another reason for this direct and intense involvement, in addition to the economic costs and social expectations tied to scientific and technological advances, rests in the shrinking time span between the understanding and widespread application and influence of a scientific phenomenon. It took roughly 2000 years to capitalize fully on some of the discoveries of the ancient civilizations. It took a few centuries to realize many of the technical concepts that came out of the Renaissance. It took 50 years to reap the benefits of the Industrial Revolution. In the post-World War II period, the time between a scientific discovery or major invention and its wide utilization shrank to perhaps 10 to 15 years. Today, the compression of time between a scientific advance, the proposal of an idea based on it, and its widespread application has reached a point where this process is operating within the attention span and the operating lifetime of most persons in positions of political and economic power. One of the most dramatic examples of this rapid interfacing of science and politics is the fact that only weeks after the announcement of the hypothesis that man's release of fluorocarbons into the atmosphere may be dangerously affecting the ozone shield, there was already congressional activity on the matter (*2*). As Robert Heilbroner stated in *The Future as History*, "Advances in science and technology have rewritten the very terms and conditions of the human contract with no more warning than the morning's headlines" (*3*). And as a footnote to that observation I would add that any retreats, such as from the use of DDT, that we make in pursuing science and technology will have a similar short warning.

The Politicizing of Science

In addition to this time span phenomenon, there has also been an increasingly close linkage between the physical and social effects of scientific advances. The combination of these effects has contributed to a certain politicizing of science that will be a major characteristic of our activities for years to come. I do not mean to imply that the science community is about to be locked in mortal combat with any segment of society. But it is obvious that the days when the scientific community, or certain segments of it, could stand aloof from the mainstream of social and political activity are over. Science may still be esteemed—and it is now, according to recent opinion polls. But we know that it is no longer sacred. It has been shown that we make mistakes. We have publicly expressed uncertainties and doubts about the extent of our knowledge. We have argued among ourselves in public. This is not necessarily bad, but it has shown us to be mortal, and as such we become as accountable, and vulnerable, as any other segment of society.

If, as a result of all this, recent years have seen the beginnings of a change in the public and governmental attitude toward science and technology, the coming years will probably see the solidifying and institutionalizing of some very different relationships between science and society. And much of that will be reflected in national science policy and the relations between the science community and government on all levels and in all its manifestations. There have been many who have recognized the seeds of this in the growing science-related activities in government and the science involvement of Congress—from the enactment of the National Environmental Policy Act (NEPA) to the current deliberations and debates on energy, resources, and the social sciences. But all this was, and is, just the beginning. As these deliberations and the debates increase, as all the subtle and not so subtle relationships between scientific advances and their effects on society become more apparent, we will most likely see an even greater involvement of the science community in the affairs of state and of the world.

The Response

Now I come to the crux of the matter. If in the context of what is happening today and its dynamics we are to ask: Whither the NSF?—or, more broadly, to question how science itself will fare over the next 5, 10, or 25 years—the answer depends largely on the response of the science community. Certain patterns have been set that should affect the growth and direction of science over this period. We know, for example, what extensive demands energy R & D will make on us during this time. Studies by the National Academy of Sciences and the Food and Agriculture Organization have indicated many of the advances necessary to alleviate the world food situation (*4*). Similarly, we are getting a better picture of the challenges involved in meeting our material needs. And in recent years many criteria for a healthier environment have been set, and some measures instituted toward achieving them. But the country has yet to face fully many of the difficult questions involving the trade-offs between economic and environmental matters and the growing number of energy-environmental balances. Granted that scientific and engineering advances can eventually improve this situation with some technological fixes at added costs, much of the solution of this dilemma rests on the attainment of further knowledge and on the value judgments of society.

Of all the problem areas that are setting the pattern for scientific research in the years ahead, perhaps the most difficult may be that which the National Science Board has categorized in its 1975 report under the heading of the "Challenges of Society." As the report stated, "The challenges in this category are almost limitless," and it cited a few—including international strife, discrimination, crime and delinquency, and the spectrum of interpersonal and intergroup conflicts. The report goes on to discuss some of the obstacles to understanding and meeting these challenges. Among the important conclusions that the Board reached concerning this matter were the following (*5*):

> The tasks which these problems pose for science are immense. Although they involve the whole of science, the tasks apply particularly to the least developed of the disciplines—the behavioral and social sciences. These disciplines need to be significantly strengthened, in both their basic and applied aspects, if the Nation is to respond more successfully to its social problems. Although knowledge alone does not guarantee success, its lack almost certainly reduces the chance and extent of progress.

I believe this is a very important message that the science community should help convey to the American public and its representatives in the government.

Ethics and Human Values

Related to the subject of man's understanding of man and his society is another issue that will have a profound bearing on the future of science, and that is the matter of ethics and human values. The influences and the pursuits of science and technology have been drawn into an even closer relationship with the ethical decisions and value judgments of the society in which they operate. Over the 25 years during which the NSF has grown, certain developments in science have made it clear that the scientific community cannot conduct its affairs as a pure search for truth apart from serious considerations of its human consequences. This was not quite so apparent back in 1950 when Elvin Stakman, who was then president of the American Association for the Advancement of Science (AAAS), stated publicly: "Science cannot stop while ethics catches up—and nobody should expect scientists to do all the thinking for the country" (*6*). Certainly that statement still has some elements of truth in it, but the prevailing situation in science today is much closer to the one described in the April 1975 issue of *Fortune*, which comments: "The world of science is searching its soul for a code of ethics and a scale of human values to govern its new professional responsibilities" (*7*, p. 147).

Much has been written recently and many scientists have been personally involved in the deliberations and decisions related to the ethical aspects of biological and behavioral research. Ethical and human value issues are surfacing with increasing frequency and are taking on ever-increasing significance for the enterprise of science and technology as well as for the welfare of the general population. External pressures have recently led to the initiation of a careful analysis and evaluation of the traditional values of the scientific enterprise on which the peer review process (as currently used by the NSF and most scientific journals) is based, as well as of the larger questions concerning the procedures for making value judgments about the allocation of resources (funding, personnel, materials, and other factors) for both basic and applied research. Also, in response to public pressures, Congress recently established a National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, which is charged with establishing ethical guidelines for the conduct of a significant portion of basic and applied research. And the time has long passed since we have been able to develop major new technologies—the supersonic transport and the antiballistic missile cases are but two examples—without precipitating a public debate about their possible social and human consequences.

We are at a point where we should make a most substantial commitment of our best people to the examination of these issues. Dealing with this situation involves all the difficulties of fostering public understanding, of settling conflicts of interest, and of becoming enmeshed in adversary proceedings characteristic of our democratic society. We in the science community can wait to be drawn into these issues at times when they have been clouded by misinformation and prejudicial thinking (as in the cases of the peer review evaluation and the guidelines for human experimentation), or even wait to try to reverse decisions detrimental to science *after* they have been made. Or, we can begin to demonstrate leadership in this area, as a select group of scientists has done recently in taking the initiative in the establishment of guidelines for the conduct of research on recombinant DNA molecules (*8*).

I am not claiming that scientists should attempt to assume an elitist position in trying to make decisions for the general public with regard to these important value issues. Certainly Dr. Stakman was correct in asserting that "nobody should expect scientists to do *all* the thinking for the country." But I believe that we will be expected—and we have an obligation both to the public and to our own professions—to do much more than we have in the past. However, in our efforts to make a significant contribution to the public discussion of these issues, we must remember that the key to the communications process is the ability to *listen* with the intent of understanding what others are saying and to sense whether others are in fact understanding us. We certainly cannot reasonably expect others to listen to us, no matter how important we consider our ideas to be or how impressive we feel our credentials to be, if we do not respect and make every effort to understand those to whom we are trying to communicate our ideas. How successful we are at it will have much to do with the public support of science and the answer to "Whither the NSF?"

In the world today, where the application of scientific advances can have such a strong and pervasive impact, the belief is often advanced that we should first establish our values and goals and set these as the ends toward which we direct our activities in science and technology. But as much as science and technology must operate within a framework of human values, there exists the possibility that advances in human knowledge will alter those values. For example, it is possible that the work of a small group of researchers and teachers led to the development of the environmental movement in this country which in turn has influenced the lives of a limited number of people to the extent that they have formed a type of "back-to-the-earth" movement in their life-styles. On a global scale, there is also considerable interest in what has become known as "alternative" or "intermediate" technologies: the use of small-scale, more labor-intensive and less capital-intensive technologies to support a satisfactory type of development and living in certain parts of the world. No doubt the values that led to these choices were influenced somewhat by the state of our scientific knowledge and our technological capability, and also by previously held values. But what would have been the values of these people and how would they have been expressed had we by now fully developed systems of biological pest control; fertilization and irrigation that posed none of today's pollution, power, or water problems; a virtually limitless supply of clean, cheap energy via solar or fusion technologies; and any other technologies that would negate most of today's environmental problems?

I am not arguing here for ethical relativism but only making the point that advancing human knowledge probably has a strong interplay with human expectations and values, one that should be explored more fully.

Science, the Expanding Frontier

One further word on the relation of ethics and human values to science. This is an area in which we need to have far better knowledge. We need better understanding of how values are established within various communities, including the science community, and the causal interactions between them and the development of science and technology (*9*).

On the subject of advancing knowledge, much reference is being made during this 25th anniversary year to the concept of "science—the endless frontier" (*10*). Let me conclude with a brief comment on our pursuit of that frontier. Never has it been clearer that the realm of science is something like an expanding universe growing even as our capacity and curiosity to explore and understand it grow. The intellectual challenge in understanding nature is as great as or greater than it has ever been. But it is also important now for the science community to highlight the point, one that is being increasingly made today, that basic research supplies the knowledge capital that is the underpinning of our entire structure of applied science and technology. In addition, we should recognize that the administrative arrangements of science support in the years ahead—whether the NSF retains the central role in basic research support, whether more basic research is supported by the mission agencies, or whether there is eventually the creation of any other science support mechanism—are far less important to the health of science and the nation than the caliber of people we have in science and at the helm of our science-related activities. We need the best people possible in science if the nation is to maintain the excellence of its research capability. It is only through this capability, and through its constant upgrading, that we are going to see ourselves through the complex web of problems that constitute today's and tomorrow's crises.

In the coming years, I believe that a good portion of our basic research capability will continue to be centered in the nation's colleges and universities, provided they can solve their institutional problems (*11*). However, there may be much important work done in national laboratories and industrial research centers. Possibly we will see closer and more productive ties between the universities and these other research establishments. Ways should be, and I believe will be, found to stimulate a better flow of scientific and engineering knowledge and talent between these segments of the R & D community.

If in these comments I have not answered the questions of where the NSF will be during its second quarter century, I hope I have at least indicated some of the directions in which it may go. The Foundation was born to serve the nation through advancing the progress of science. I believe it has done this during its youthful 25 years of existence. But that period has also been a learning period for the Foundation and for many of us who have grown and learned with it. Now it is time to move ahead to even more productive days. For, as Oliver Wendell Holmes said, "The greater thing in this world is not where we stand but in what direction we are going."

References

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7. T. Alexander, *Fortune* **91**, 146 (April 1975).

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9. The interest of the NSF in the relation of ethics and science has led to the formal establishment of the Ethical and Human Values in Science and Technology (EHVIST) Program at NSF, a program that is now receiving research proposals. Some investigators working under EHVIST grants do so under grants cosponsored by NSF and the National Endowment for the Humanities.
10. V. Bush, director of the Office of Scientific Research and Development, "Science—The endless frontier," a report to the President on a program for postwar scientific research, July 1945 (reprinted in 1960 by the National Science Foundation, Washington, D.C., on the occasion of its 10th anniversary).
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NEWS AND COMMENT

Nuclear Exports: A U.S. Firm's Troublesome Flirtation with Brazil

The American failure to stop West Germany from selling sensitive nuclear technology to Brazil may have been inevitable even under the best of circumstances. For Washington to suggest that Bonn withdraw its unprecedented offer of uranium enrichment and plutonium processing technology to Brazil was, from the German point of view, a bit like General Motors asking Volkswagen to steer clear of South America. The predictable German response was that the Americans were suffering from sour grapes, and the deal was signed on 27 June.

The State Department's difficult task of convincing Bonn that the paramount U.S. concern was nuclear proliferation—not the protection of American commercial interests—was complicated, moreover, by an odd episode in Brazil last March involving an American corporation in the uranium enrichment business. The episode, repercussions of which continued into mid-April, seems to have resulted from poor communications between government and industry, as well as within the government, in the sensitive area of nuclear export policy.

The company in question is the Bechtel Power Corporation, a subsidiary of the huge Bechtel engineering and construction firm and a major builder of nuclear power plants. The parent firm is also one of about 20 U.S. companies to which the Energy Research and Development Administration (ERDA) has granted access to classified enrichment technology in the hope of bringing private enterprise into the enrichment business.

According to State Department sources, a sales representative of Bechtel Power held discussions last March with Brazilian government officials that left the clear impression the United States might allow construction of an enrichment plant in Brazil, one that Bechtel Power could build. In fact, the advisability of building enrichment plants in foreign countries—even without actually sharing classified details of the technology—is still under debate in the Ford Administration.

As it happened, Bechtel's gambit came just as Brazil and West Germany were moving into final negotiations on the sale of some $5 billion to $8 billion worth of nuclear reactors and fuel facilities—a deal that the Westinghouse Corporation had sought and lost. The timing of Bechtel's gambit, State Department officials say, lent itself to the interpretation that the U.S. government spoke with forked tongue—encouraging American industry in a last resort effort to recapture the Brazilian nuclear market with its own fuel facilities as "sweeteners" while, at the same time, urging Bonn to stop the sale of fuel technology in the interest of international security.

To make matters worse, German officials may have had an inkling of the Bechtel approach (though how accurate an inkling is hard to tell) weeks before such key elements of the State Department as the Arms Control and Disarmament Agency (ACDA) learned of it. Moreover, a four-man delegation the State Department sent to Bonn on 8 April to convey official American concern is said to have heard about the flap only after returning; the last of several clarifying cables sent to U.S. embassies in Bonn and Brasilia did not go out until 17 April.

Not surprisingly, some arms control officials were deeply angered at what appeared to be an American company's blunder into a foreign policy issue of extreme sensitivity. One official, still smoldering, described Bechtel's Brazilian maneuver as "totally unauthorized" and "way out of line." Asked whether it contributed to German intransigence in the matter, he replied brusquely: "Draw your own conclusions."

Another State Department official familiar with the affair said, however, that no one seriously regarded the Bechtel matter as "decisive" in influencing the Germans to conclude their deal with Brazil. Rather, he said, it played into German hands as a piece of "hard evidence" to support a predictable claim that U.S. criticism of the deal stemmed from commercial interests. By this view, the episode was more embarassing than damaging.

Progressive Misunderstanding?

The prevailing view among State Department officials familiar with the Bechtel episode is that it arose from a gradual misunderstanding of U.S. enrichment policy as that policy trickled down the corporate chain of command, ending with an overzealous salesman in Brazil. This explanation, however, is not entirely consistent with others.

The misunderstanding may have begun