Science Serves Society

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No matter how much a university professor or president has dealt with the government from the outside, he begins to really learn about the problems of science and government only when he is on the inside. And no matter how much he may learn during his first 3 months in office, the main thing he realizes is that he really knows very little. There are, I think, three simple reasons for this: (i) Science is very complicated; (ii) government is very complicated; and (iii) when you multiply the complications of science by those of government, you get a very large number of complications indeed.

We are all familiar with the complications of science and of scientists. We know the enormous spectrum of activities covered by the phrase "science and technology." We know that there are several hundred thousand people in the United States working on scientific and engineering projects, and each one, I am sure, thinks that his field of interest is just about the most important one there is.

This is one reason why scientists and engineers are complicated. We are all devoted to our own pursuits and are unanimous in our belief that science and engineering are important to the country and to the world. However, that is about the only thing we are unanimous about. We are not unanimous about the relative importance of various fields of basic science; we are not unanimous about the relative merits of basic and applied science; and we are surely not unanimous on priorities in the field of applied science—about the uses to which scientific knowledge should be put. Thus, when anyone seeks to find the opinion of the scientific world on a particular public issue—whether it be the ABM, the SST, the space program, government support of research, or many others—the layman is understandably astounded at the wide variety of very strong opinions that may be offered. "Can't the scientists make up their minds?" we hear it asked.

Now the spectrum of opinion among scientists is quite understandable. Public issues of the sort which I have mentioned are not purely scientific issues. They are issues in which science and technology constitute only one component. Other components may involve fiscal affairs, political matters, social conditions, international relations, inflation, taxes, and even moral judgments. In these areas we are all laymen and in these areas we find ourselves in the strange situation (strange to us as scientists) of being asked to render judgments on the basis of data which are inexact, incomplete, often conflicting, and surely not obtained under the rigid conditions of the controlled experiment which we take for granted in our scientific laboratories.

Thus while scientists may well come to substantial agreement on such questions as the validity of the special theory of relativity, or of quantum mechanics, or the structure of protein or DNA molecules, we find ourselves in wide disagreement on whether the government should invest funds in enterprises which involve both technical and nontechnical factors. We also disagree on the priorities which the nation should assign in funding various fields of applied or pure science; for example, space, oceanography, astronomy, high energy physics, microbiology, urban development, and others.

This leads me to my second point, namely, the government is complicated. I have personally known for a long time that the U.S. government is a complex enterprise. The last 3 months have revealed complexities of which I was previously unaware—or only dimly aware. I shall discuss only one of the government's many complexities: its involvement in pure and applied science. It was once true—say 40 years ago—that the government involvement in science was quite simple: it didn't exist. Actually, that is not quite true. We did have the National Bureau of Standards, the Smithsonian Institution, the Geological Survey, the Naval Research Laboratory, and a few other scientific establishments—often excellent and important in their own fields but small enough *in toto* to attract very little attention from the Congress or the public. There were not too many scientists and they did not spend much federal money. So no one had to pay attention to them.

We are all aware of how that situation has changed. Now there are many scientists and they spend quite a lot of money. Every old-line department of government, plus a great array of new departments and agencies, are now heavily involved in science and technology. Hundreds of thousands of scientists and engineers now work for the government, directly or through its contractors. The government annually spends some $2 billion for research and $15 billion for development. And no one, in or out of government, would assert that there are not some difficult problems and complexities involved in this enterprise.

The government does not spend billions of dollars a year on science and technology without getting involved with those complex people called scientists and engineers. And when the complex array of people and agencies in government get mixed up with the complex scientific community, the result is almost bound to be utter confusion. And, indeed, confusion is what we find.

And yet, if one looks a little deeper one can find that within the dense cloud of confusion there are areas of brightness, areas of directed and purposeful motion, areas where chaos has given way—or is giving way—to order.

Scientific Achievements

Let us then look at a few things on which we can all agree—things on which we as scientists agree and things on which most educated laymen will also agree. The first is one we often forget or at least neglect to emphasize: namely, that during the past 300 years the worldwide community of scientists has built up an astounding, indeed a miraculous, structure of accurate and verifiable facts and principles about the physical universe including the uni-

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verse of living things. I never can resist a sense of awe and wonder as I reflect on the things we all know today which no one knew 100 years ago, or 50 years ago, or even 5 years ago. In fact, somewhere, someone has very probably learned today something that no one knew yesterday. Surely the scientific enterprise, judged in terms of attaining its primary objective—the accumulation of knowledge and understanding—has been the most brilliantly successful enterprise in human history. We are proud to be scientists because we are proud of the opportunity to be able to contribute, if only a little bit, to this magnificent and rapidly growing structure of knowledge and understanding.

But at once we face a curious ambiguity in our feelings. While we take pride in what we have learned, we are, at the same time, humble as we face the things we do not know or understand. We are still in the position of Isaac Newton who beheld with awe the seas of ignorance which extended beyond his beachhead of knowledge. How we can, at the same time, be proud of our collective and cumulated knowledge and distressed at our ignorance is something which many laymen find hard to understand. But there it is, and it is a basic fact in our lives. Our urge to push ahead on the frontiers of ignorance quickly overcomes any temptation we might have to sit back and compliment ourselves on what we have learned. Yet, I suggest that now and then we should do that too.

There is another fact on which we can all agree: that, in spite of some doubts and reservations here and there, we are certain that this great body of scientific knowledge has been of enormous benefit to the human race. Since some people are questioning this today, we should take another hard look at the balance sheet. Even though we can spot some red figures here and there, we must conclude that the assets far exceed the liabilities. To prove this we need only look back 100 years and ask how men lived and thought and worked then as compared to today. The material changes are obvious. In those areas of the world where scientific knowledge has really been put to use, man's health, comfort, wealth, and welfare have been enormously enhanced. A substantial segment of the human race—even if not all of it—has lifted itself to heights of comfort, leisure, and affluence undreamed of, and yet desperately desired, a century ago. Indeed, as we contemplate the contrasts in living standards between various parts of the world today, we speak immediately of the technological gap. And that is just what it is. In some parts of the world, scientific knowledge, through technology, has been brought to the benefit of the people; in other parts, it has not. Whether we look around the world or look backward in time, the vast benefits of scientific knowledge are clearly evident.

Social Progress Aided by Science

But we need not confine attention to material things. Many thoughtful people have noted that it is surely no accident that the rise of science and technology has been paralleled in time and in place with the rise of democratic governments—governments based on a recognition of the dignity and worth of every human being. Men who can understand the universe and life cannot easily tolerate human misery and injustice. When knowledge replaces superstition, men think and act differently. Once, man in his ignorance looked upon poverty and disease as inevitable—and possibly even ordained by the gods. Today he knows these things can be conquered and he is impatient to get on with the job.

In fact, I firmly believe that the ideals of men for the betterment of the lot of human beings are higher today than ever before in history—and that the advance of science and technology, which has helped us to achieve many ideals, has also enhanced our determination to move on to the attainment of even higher ideals. As we eliminate one cause of human suffering, we yearn to eliminate them all, and we become ever more impatient with our slow progress—even though the rate of progress is in fact accelerating. For example, air pollution in many of our cities is far less today than it was 30 years ago when the pall of soft-coal smoke used to choke us and turn day into night. But as technology, based on scientific knowledge, abated that source of pollution, we lifted our sights and are now determined to eliminate all sources—both old and new. Our ideals have advanced faster than our ability to keep up with them.

This indeed is not an uncommon situation in the world today. The success of our technology in solving some problems has elevated our determination to solve many more human problems more rapidly. There are those who say that science and technology have moved ahead more rapidly than our moral and social standards. There is a case to be made for the reverse: that our humane goals have advanced faster than the ability of our science and technology—plus the ability of our economic, social and political institutions and skills—to keep up. Every success of technology only seems to widen the gap between what we can do and what we want to do. Thus the pride in our successes is overshadowed by disappointment in our failures to fulfill our rising expectations.

I do not decry this situation; indeed, I applaud it. But I think we should at least recognize it. And we should recognize the corollary: that the scientific community is today a leading influence in advancing our social morality.

To say this is not, of course, to claim that we have been eminently successful. There are many elements in our society who do not share our high ideals for a better world or who do not share our confidence that a better world can be attained. Indeed, we ourselves become often discouraged as we see the gap between the power of our constructive technological skills and the weakness of our economic and political machinery. There are those who will say that the way to close this gap is to weaken our scientific and technological competence. This is pure defeatism. We must, of course, work harder to improve our knowledge and competence in social, economic, and political areas. But as we do so, we will need more than ever a strong science and technology to provide the tools to move ahead toward our goals.

Basic Research Is Essential

If we agree on this last point then the question is, what do we do about it?

The first thing we must do, I think, is to readdress ourselves to the task of insuring the strength and vitality of basic science, both in this country and throughout the world. Our first responsibility in this direction is obvious: to continue to do good science; to continue to use all the talent and all the resources at our disposal to discover the important secrets of nature which still lie hidden from our view. The American scientific community needs no exhortation from me on this subject. But I would be remiss if I did not reemphasize its basic importance,

and the importance of conveying this spirit to all our colleagues and students.

A second task is that we try to speak to the world with one voice on the importance of basic science. Whether we are speaking to our nonscientific colleagues, to administrators in the university or in business and industrial organizations, to representatives of government at any level or to the public at large, we need to speak audibly and forcefully and, if possible, unanimously on this basic point: the discovery of new knowledge is an enterprise of prime importance to the human spirit and to the human condition.

We will not all have the same reasons for expressing this conviction. Some of us will give more emphasis to the cultural values of science; others to the technological values; others to the social or the educational values. All are important; all deserve emphasis. All I suggest is that we do not try to persuade a congressman to support science because it is so much *fun* for the scientists. Fun though it may be to us, we must remember that Congress is not interested in supporting an amusement park for the scientific community. We face a great and difficult task in trying to convince the American people and their elected representatives in Congress that the future of our country, of our people, the future of human beings everywhere, depends in a critical way on the foundation of basic knowledge which we are laying today.

We will not be unanimous about one aspect of this problem, that is, which fields of science are in greatest need of added support. We all know our own field is of great importance; and we all know that our own field is grossly underfunded. Often we may be tempted to argue that certain other fields are overfunded. I hope this temptation can be avoided, at least in our public statements. Our objective should be to increase the total support of basic science. Though we can each present the case for our own field, we should rejoice and not weep if other fields seem, at the moment at least, to be better off.

Priorities in Science

This matter of what we call the priorities of various fields of pure or applied science is one of the most difficult and confusing questions which we face. What do we mean by priorities? And even when we decide on priorities, how do we interpret this in terms of private or government effort or budget allocations? To illustrate the difficulty, let me take a concrete case. What do we mean, let us say, when we talk about the relative priority of microbiology compared to high energy physics. (You may choose any two fields you wish.) Do we mean one field has greater importance? If so, importance to whom or to what purpose? Social importance? Importance to human life? To our economy? To the advance of our culture? To the elevation of the human spirit? Or to satisfying the basic urge of human beings to know and to understand? Or to the welfare of scientists? If we confine attention to any one of these goals, we still face a dilemma. Do we mean immediate or long-range importance? Do we mean the specifically foreseeable importance of the results to be attained or to the long-range effects which might be anticipated or imagined? And how does one even foresee or predict the long- or short-range results and applications of basic investigations? We can all think of too many cases of totally unexpected results of research and their wholly unexpected and unforeseeable impact to have any confidence in anyone's prediction that one field of research will surely lead to beneficial results and another one will not.

You can see that the unanswered questions far exceed the number of clear or possible answers—and thus broad and conclusive and universally agreed-upon priority conclusions remain as unreachable as ever.

But suppose, by some magic, we could agree upon a list of priorities among various fields of science, and we could rank them in order: 1, 2, 3, 4, 5 . . . Then what? Shall we assign, say, $11 million to number 1; $90 million to number 2; $80 million to number 3, and so on, until we run out of money and then assign zero to all the rest? Or suppose two fields, say, microbiology and high energy physics, are assigned equal priority. Does that mean they should get equal money? We all know that to do any high energy physics at all we need to have large and expensive accelerators. So even though $100 million might be all that microbiologists could use effectively, that sum will not give us a superhigh energy accelerator. In other words, the funds needed to pursue two areas of science have no necessary relation at all to the priority question.

It is, of course, a little easier to judge relative importance when it comes to applied science for there we are seeking a very specific goal or product whose intrinsic importance we should be able to judge. But do we find the American people or their congressmen unanimous in those judgments? Even if they were, would the answers to the funding questions not still be difficult? Would you put *all* the federal income into priority number one, and nothing into anything else? Or what?

Unanswerable questions! Yet these are the questions with which the executive and legislative branches of our government are struggling every day. The voice of public opinion will be critical in these decisions. Scientists constitute one element of public opinion. Let their voices be heard! Peacefully, I trust!

As I have suggested, scientists are probably unanimous in their opinion that the progress of basic research is of high importance and deserves federal support. On this point, the present Administration is, I assure you, in agreement. In spite of extreme budget difficulties, we are trying to maintain the support of basic science at or above the level of the last fiscal year. Congress, of course, will make the final determination. If we can all make known to our congressmen, not so much the financial needs as the ultimate values of science, the efforts of the Administration may be sustained.

The members of the Council of the National Academy of Sciences who met with the President on 28 April heard directly from him his views on this issue. He stated that a nation which devotes exclusive attention to its immediate troubles and problems is bound to decay. Rather, we must look outward and upward in order to lay the foundation for a better future. The advance of scientific knowledge, he said, is an essential enterprise in our society.

Judgments on Applied Science

To turn to another subject, we find that scientists are not in agreement with regard to the uses to which science should be put, when we discuss applied science. Yet scientists properly should be heard on this question. We must bear in mind, however, that the existing knowledge of science, as published in the open scientific books and journals, is public property. It is not our private property as scientists. The observations, theories, and discoveries

which we have made and published are, by the very act of publication, now in the public domain. They are there for all the world to see, and to use. We have no special right, as proprietors, to insist on, or to forbid, the use of this knowledge by others for any purpose whatever. We all believe in open science; without openness we have no viable scientific enterprise at all. But this openness carries with it the risk that the very knowledge which we have produced and published may be used by others for purposes of which we do not approve. What do we do about this?

This, too, is a difficult question to answer. If major public policy decisions are to be made on such matters, the decision-making body will be a properly constituted governmental body, such as the Congress. Usually such bodies are not primarily composed of scientists. And more often than not, the decision must depend on many nonscientific matters—economic, social, political, international affairs, and even moral judgments. On these matters the scientist, as such, is not an expert. But as a citizen he is entitled to express an opinion as much as, and no more than, any other citizen. On the scientific aspects he can and should, of course, give authoritative facts and opinions. When he leaves scientific matters he should disqualify himself as an expert. If he doesn't, some of the congressmen or reporters will anyway, though they may still respect his opinion as an intelligent and concerned citizen. And we all have the right and responsibility to be intelligent, well-informed, and concerned citizens.

Aside from the negative aspects of putting scientific knowledge to use in ways of which we do not approve, what of the positive aspects of promoting the beneficial uses of science? Have we been as active as citizens in promoting these things as we should be? President Nixon has already expressed his interest in this area. One of his first acts as President was to establish an Urban Affairs Council, at the cabinet level, to which he is giving earnest and vigorous leadership. He is setting up a similar Council on Environmental Quality. He is giving active support to the Secretary of Transportation and the Secretary of Housing and Urban Development as they seek to solve the difficult problems in those fields, many of which require more effective use of science and technology. As scientists and as citizens we can support these endeavors.

Funding Problems

However, to say that the Administration is directing the resources of science, social science, and technology to bear on our social problems is not to say there are not grave difficulties ahead. To put it bluntly, no one knows just how to proceed with this task. We are applying massive funds to temporary palliatives in the form of welfare, relief, alleviation of poverty, food for the hungry, public housing, special educational programs, Medicare, and all the rest. But we do not fully understand the basic problems of our cities or of the poorer rural areas. We do not fully understand how to deal with the problems of improving our society or our environment. As we seek solutions to these problems, we run up against barriers of technology, of economics, of political conflicts, and of inadequate knowledge of what happens to our people and environment as we seek to expand our industrial and agricultural economy, on the one hand, and to make our cities and countryside more liveable, on the other.

While we struggle with immediate and obvious problems requiring large monetary expenditures, we must try at the same time to mount research efforts in which scientists, social and political scientists, and engineers work together to seek basic causes, to develop new technologies, to invent new social and political instrumentalities, to identify and experiment with long-range solutions. Unfortunately, there are not many research centers where such things can be done. There are very few trained people available. The methods and traditions of research which we take for granted in the natural sciences are not so highly developed in these new interdisciplinary areas. Nor is it solely a matter of money. The R & D funds for the Department of Housing and Urban Development and the Department of Transportation are being substantially increased next year (if Congress approves!). But where are the people? The ideas? The centers of excellence? Even finding a few knowledgeable and devoted people to come into government to staff the R & D operations is proving most difficult. Many people—including myself—believe it is important to have a massive R & D effort in this area, but the fact is that we will have to be content with modest beginnings. If a few more great universities will initiate or accelerate their efforts in research and education in the urban and environmental fields, an enormous contribution would be made.

Science Is in Politics

I conclude then where I began: the relations between science, technology, government, and the various elements of our society are enormously complex. Science and technology are no longer separable from political and social problems. In these days scientists frequently find themselves engaged in political discussion and activities. When we meet the politicians on their own ground we must not be surprised if they judge us on the basis of our political opinions rather than on the basis of our scientific competence. Whether we like it or not, science is in politics and politics is in science.

Some have said that science is too important to get mixed up in politics. The fact is that today science is too important to stay out of politics. For in our democracy, it is through politics that things get done.

Clearly we all—politicians and scientists—must find ways of adapting ourselves to a new era—an era which began not on 20 January 1969, but really on Hiroshima day in 1945. If we all try, we can accommodate ourselves to the situation.