THE DIRECTOR'S STATEMENT

Anyone who follows world developments is struck by the growing realization on the part of all countries that their future is strongly dependent upon the advancement of their own science and technology, and that, because many problems are the common concern of many nations some can be most effectively solved through international collaboration.

What is not yet fully realized is the rate of acceleration in the direction of scientific and technological progress. The term, "rate of acceleration," is used deliberately in its scientific sense, i.e., the rate of the trend is not steady but is itself rising. In the case of the United States, a few simple statistics suffice to illustrate the point: The population has doubled in the past 50 years. The gross national product has doubled in the last 20 years. The percent of an age group attaining baccalaureate degrees in our colleges and universities is doubling every 18 years. Of all people who reach "doctoral age" each year, the percent who earn doctorates in science and engineering is doubling every 12 years. (Incidentally, the output of baccalaureates and doctorates has maintained this rate for about 40 years despite fluctuations in wars and depressions.) The total labor force is increasing about 1.4 percent per year, while the number of professional scientists and engineers is increasing about four times as fast, or 6 percent. Finally, the research and development in dollars have approximately doubled in the past 5 years. Doubtless the relative progress in these various categories is similar in most industrialized countries.

A recent study by the National Science Foundation, "Investing in Scientific Progress," produced several highly significant conclusions, as follows:

(1) The output of scientists and engineers is expected to double by 1970. The steadiness of this increasing trend

in output of scientific manpower seems to indicate real interest and purpose on the part of the population—certainly on the part of the younger generation—in the values of scientific and engineering careers. Because of the growing importance of scientific and technical achievements and the extent to which these are publicized, this trend may be expected to increase.

(2) This trend must be maintained and possibly accelerated to provide the estimated number of scientists and engineers who will be needed during this decade.

(3) The desired number of scientists and engineers can be realized without reducing the numbers required for other professional careers. More precisely, the output of scientists and engineers is expected to tap only about 4 percent of the country's top talent in IQ. Thus there should be plenty of opportunity to develop talents other than science.

On the face of it, this would appear to be reassuring. However, further analysis discloses the alarming fact that we are not coming close to making adequate provision for these essential increases in trained manpower—not even for the numbers involved, to say nothing of maintaining the quality of training. Simple estimates of the cost of needed equipment and facilities for academic research and education in science indicate that we are already in arrears to the tune of $1.5 billion. Adequate provision for the expected ten-year expansion in these same items will require an estimated $10 billion more.

Nor is this all. When we consider the growing number and variety of large-scale and expensive programs in research and development that are judged to be important, we observe that increases in the number of these huge and costly efforts will make correspondingly large drains on both dollars and trained manpower. The scientific and technological effort in these large ventures will require even larger numbers of technicians and other skilled labor and run the risk of bringing about major dislocations in a host of other occupations.

Thus, barring some major disaster or other drastic change in circumstances, the country is headed steadily toward an accelerating general activity in science and technology, without adequate provision for the magnitude and the cost of the effort.

Even under the best circumstances, it is difficult enough to keep pace with an acceleration of this kind; if one falls behind, the cause is well nigh hopeless.

Perhaps this is being unduly pessimistic. One may well ask, does not the continuing upward trend in the numbers of trained scientific manpower mean that the country will indeed make the effort—that our citizens are already convinced? Superficially, such would appear to be true but actually it is the coming generation that has so decided. As always, it is the older generation that must make provision. It is here that efforts are thus far inadequate. There have been increasing signs of improvement, to be sure, but it is also clear that the rate of improvement is far less than the rate of expansion which is taking place. Those who point the finger at the Government must realize, moreover, that the Government cannot undertake to commit itself to any such large undertaking unless it has a clear mandate from the people. In the last analysis, then, provision for this apparently inevitable and essential trend must take place in an atmosphere of public understanding and public backing.

But let us look further ahead. The trends that have been mentioned obviously cannot continue indefinitely. There are obvious limiting factors: the national wealth; the gross cost of other national endeavors; the limit in number of those with capacity for higher education, for special advanced training, and for leadership. These are all factors worthy of study—indeed we need to know much more about the interplay of science and technology with the economy, and the degree to which technological innovations, such as automation, may aid progress. Even if we succeed in providing funds and facilities for maintaining only the present quality of instruction and training, we shall need to determine priorities of effort which are necessary to attain our objectives. And most important and baffling of all perhaps—a more precise determination of our goals. The excellent report of the President's Commission on National Goals published in 1960 makes this point very clearly.

For the long term, the educational process itself must be regarded as fundamental within this complicated framework. It is not sufficient merely to improve the quality of our present system. Recent studies of the content of elementary science and mathematics courses and certain other fields have shown, on the one hand, that much of the traditional instruction in these subjects is out of date and unnecessary, and, on the other, that young people, especially at an early age, are far more capable of mastering advanced subject matter than had been suspected. If this is true for fields other than mathematics and science, as it probably is, there is room for great improvement in the presentation of fundamental approaches to all disciplines. The conclusion is obvious: The educational process shows promise not only of being improved in quality but also of being accelerated. At the same time, there is a growing realization that the process of higher education and training should concentrate in its early stages on broad fundamentals and provide special training only for those who are unable to assimilate the more fundamental work.

Because of the rapid changes in our way of life and in the activities and associated careers which may become important in the future, it is difficult to anticipate the fields in which specialization will be needed. The rapid growth of the electronics and aerospace industries, for example, and the rise of nuclear engineering, space research, and automation are cases in point. Thus, the best basic education would appear to be a general one designed to enable not only professional groups but the labor force in general to adapt quickly to new situations.

Looking even further ahead: The accelerating pace will ultimately come up against the hard fact that the span of years required for the physical growth and maturing of an individual is still fixed. In order to progress, therefore, we must pay increasing attention to the nature and quality of training in the educational process. Our objectives during this period should be to provide the essentials to enable each individual to travel as far as possible along the path of his chosen career and to achieve an effective place in society. It is of particular importance to find ways of allowing those engaged in highly creative work, such as science, literature, and the arts, to enter upon their professions during their years of greatest creativity, which usually are their early years.

With these projections in mind, the ultimate question is:

Who needs to do what, and how? A first reaction is that science and technology are in need of better overall planning and management. Because these are national issues, the tendency is again to turn to the Federal Government.

One approach that is frequently mentioned is the setting up of some central organization designed to analyze the country's effort in science and come up with specific plans for the research objectives of the future, with special emphasis upon proper apportionment of funds and manpower in the light of necessary and desirable goals and their feasibility. Such a solution is simple in conception but runs at once into formidable difficulties.

In the first place, as related to basic research, such an enterprise tends to rely upon a highly managed form of economy inconsistent with our national policies and practices and one quite foreign to the best interests of progress in science. It is the sort of thing we criticize, in principle at least, in totalitarian countries. The attitude of the scientific community on this issue is specific and emphatic: The progress of science depends upon the personal initiative and independence of the individuals and groups involved in research. It thrives on variety and originality of approach in different environments—educational, governmental, and industrial. Support and a certain amount of leadership are required of the Federal Government, but not centralized direction and control. Diversity in the agencies furnishing support is highly desirable.

In the second place, if such planning is intended to analyze in detail the content of basic research in science and to determine in advance the most significant areas for support, its feasibility may be questioned. A continuing survey for subject content can only be handled effectively in decentralized fashion. To do it in a centralized way is an elaborate job which would require the continuous services of several thousands of persons. By the time such an organization reached its conclusions they would be largely out of date; the practical impossibility of keeping such review current is obvious. The reason for this difficulty is that decisions as to program content and priorities in science are not only continually changing but have to be dealt with in a subjective manner based on the current judgment of active research scientists. In a sense, it would be as unprofitable to attempt such forecasting for basic research as to prescribe for music or art the most promising themes for development. One should avoid at all costs the attempt to dictate for creative work. The best way to ensure intelligent planning in basic research is to provide every encouragement and support for rapid and complete availability and exchange of research information, such as by research publications, abstracts, conferences, and personal contacts.

Of course, in certain respects a degree of management does have to be exercised. Any institution has to plan and, to an extent, manage the programs that it feels it can undertake and even an individual often finds it necessary to choose the most feasible of several research opportunities. The larger the organization, however, the more important it is to broaden and generalize the perspective in order to permit independence of judgment and action; otherwise, planning and policy are in grave danger of becoming rigid and mechanical.

When it comes to development, however, the situation is different. Here it is entirely possible and indeed important to compare needs and priorities with trends and potentialities with respect to manpower, facilities, funds, and research findings. Excellent work of this sort is going on in many technical industries, and the Government has made progress in this direction through studies in the field of science and technology by the National Science Foundation, and in special areas by the President's Science Advisory Committee and the Federal Council for Science and Technology and by other Federal agencies.

It is considerations of this kind which have led the Foundation to undertake intensive, fundamental studies of the country's resources for science and technology—in consultation with the President's Science Advisory Committee and the Federal Council for Science and Technology—in the setting up of its Science Resources Planning Office.

Let us examine how the planning function is presently performed in the U.S. Government. At the highest level, science is now represented in the post of the Special Assistant to the President for Science and Technology and in the President's Science Advisory Committee, which is composed of outstanding scientists from outside the Government. In order to coordinate the research and development activities of the Federal agencies and departments, the President, acting upon the recommendation of the President's Science Advisory Committee, in 1958 created the Federal Council for Science and Technology. Membership on the Council consists of high-ranking officers of each of the agencies with major research and development programs.

The Special Assistant to the President for Science and Technology is available to the President at all times for firsthand advice, and thus he is in a position to know the situations in which science and technology are likely to have important bearing upon national policy. The President can turn to the President's Science Advisory Committee to provide advice on important questions in science and technology that relate to national issues of all kinds.

The function of the Federal Council for Science and Technology is to provide a forum for discussion among the agencies on matters of common interest, to achieve coordination on scientific programs involving more than one agency, and to exercise planning and policy roles in connection with governmentwide science and technology matters. For consideration of overall budgetary problems in research and development, the Federal Council and each individual agency can contribute its advice and counsel to the Bureau of the Budget and the President. Under present circumstances it appears that this administrative arrangement will be able to deal responsibly with the issues that arise, and to do so in a more satisfactory manner than would a single department. In any event, the arrangement has hardly been in operation long enough to permit a judgment as to its ultimate effectiveness or whether further changes may be needed.

The National Science Foundation, through its 24-member National Science Board, consisting of individuals distinguished in research, education, or public affairs, has responsibility for developing national science policy. Its deliberations are especially valuable to the Government in the area of government-university relations.

It should be noted, too, that the Government constantly has available to it on scientific questions the advice and experience of the National Academy of Science-National Research Council. The Academy-Council has always enjoyed close and friendly relations with the Federal Government and has worked cooperatively with it on a wide variety of projects in times of peace as well as war.

The question of central coordination and planning inevitably raises the question of policy—concerning which there has been much discussion. The insistent question is: What is our policy with respect to science and technology? Since one of the statutory functions of the National Science Foundation is the development and recommendations of national science policy, a statement may appropriately be made here regarding policy on the part of the Federal Government.

But, before answering that question, let us examine what is meant by policy.

What is the meaning of a national policy for science? Is it the same as policy for scientific research and education? If not, with what is it concerned? Does national policy mean the policy of the Federal Government, for the country, or in terms of its own activities?

Webster's New International defines policy as "A settled or definite course or method adopted and followed by a government, institution, body, or individual." By extension, this means the principles under which an organized group consciously and deliberately operates or aims to conduct itself and its activities. An essential element is awareness, that is, the planned and purposeful nature of the theory and practice of the activities of the organization. Thus, policy may run all the extremes between complete laissez-faire and rigid autocracy, but neither is policy unless planned and encouraged.

The programs of the National Science Foundation and its recommendations for the Federal Government incorporate policy in this sense; they have received careful and full consideration by the National Science Board, based upon staff studies, with frequent consultation elsewhere in government. A common practice has been to precede policy or program formalities with experimental or pilot projects to determine the most effective approach.

The major policies for the support of research and development are recognized throughout the Federal Government, and the National Science Foundation has taken a leading part in their formulation. For example:

The present policy of the Federal Government with respect to the support of basic research was formally announced in 1954 by Executive Order 10521. This establishes the degree of responsibility of Federal agencies for the conduct and support of basic research; in particular, it specifies that the National Science Foundation shall not be the sole source of support for basic research in the Government. At the same time that it encourages other agencies to conduct and support basic research, however, it limits their activities to basic research related to their missions, i.e., research that can be logically defended in their budgets.

As a next major policy point, responsibility for the planning, organization, and management for research and development is assigned to each Federal agency in line with its mission.

Research and development contracts with industry are clearly designed to assist the supporting agencies in meeting their objectives, but when the support of research at educational institutions is involved, it is general policy to define the research objectives in broad terms and to administer these contracts and grants in such a way as to permit the maximum degree of freedom and initiative on the part of the individuals or groups supported. This is generally true where the support is provided to an integral part of the college or university; it does not apply with the same force to the so-called research centers which are, in general, set up to accomplish a specific mission of interest to the Federal Government and managed by a university or other establishment.

The Foundation is unique in that it has no defined mission other than to support and encourage the progress of science in the national interest. Within the limit of available funds, it has, as a matter of deliberate policy, undertaken to support all the fields of science in a comprehensive way, the criteria for support being primarily the experience and competence of the research investigators and the significance of their research in the overall scientific effort.

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In the conviction that most effective progress in science takes place when it is essentially determined by the nation's scientists, the Foundation's policy is to encourage and consider applications from individual scientists or groups of scientists for support in defined areas of research that may be broad or narrow. Then liberal use is made of individual reviewers, advisory panels, together with the statutory Divisional Committees, in order to obtain the best advice from the scientific community regarding the merit of the proposed research. Finally, the recommended projects under consideration are weighed from the standpoint of national interest and the degree of support by other Federal agencies.

In terms of the progress of science and the factors involved in overall planning, the first essential is to provide to the fullest extent possible for the needs of competent research workers in all fields of science and for the increasingly important interdisciplinary areas of science. In addition to advancing the progress of science on all fronts, such provision assures a steady stream of scientific manpower, fully equipped to meet general needs.

Superimposed on this broad coverage, particular areas of science may prove to be critical at a given time, either from the standpoint of progress and national interest in science, or because a more thorough knowledge and understanding of a field is important for planning purposes or for solving important developmental problems. Periodically certain areas of science require special attention in the form of symposia or conferences by research workers in the field, or in critical cases, a special study by leading experts whose purpose is to determine the need, feasibility, and scope of coordinated programs. Such critical areas may form the basis for study and special emphasis by the Foundation or other appropriate agency. Recent illustrations are the fields of oceanography and the atmospheric sciences.

In cases where a number of Federal agencies are involved, reports of such studies come up for consideration by the Federal Council for Science and Technology. The Council may then recommend as to the degree of government interest, the scope of the effort, the apportionment of responsibilities, and budget allocation for collaborative effort in an overall Federal program.

Special emphasis may also be necessary for the exploitation of certain fields in order to further the progress of applied research and possible development.

In the latter category belong, for example, the scientific research that underlies the development of weapons and devices of war, provision for the care and cure of disease or, possibly, the establishment of a new field of research important to the national economy. However, the problem of establishing priorities throughout all of research is feasible only through the current identification of a limited number of the most critical areas. This type of management planning depends upon such surveys and analyses of data and trends as may be practicable, coupled with a process of selection by scientists and science administrators in their own organizations.

At the present critical stage of our knowledge and understanding, selections have to be made upon a basis that is mainly subjective, i.e., by suitably chosen study groups for critical areas. The process is often most simply carried out by an organization or agency which is continuously occupied in the support of research and in following research accomplishments. Both of these characteristics are possessed in basic research by the Foundation and, also, in their fields of interest, by other agencies which support research.

The subject of national science policy and its supporting organization is and will continue to be a most important and challenging problem. A number of devices, including careful study methods for improving the speed and accuracy of survey analysis, modern techniques for dealing with masses of detailed information, and the use of methodology borrowed from statistics and communication theory, offer promise of even more effective solutions for the future.

Considerations of this nature have led the Foundation to set up an Office of Science Resources Planning which, in addition to coming to grips with short-range objectives, will start concentrated studies directed toward a solution of the more general problem. The objective is to determine what bits of information concerning science research activities, such as research in progress and the disposition of scientific manpower, are required and how these can be analyzed and presented in optimum form to serve as the basis for planning decisions. Such a system must include as an essential element provision for individual and local initiative and independence within appropriately restricted areas of research, and—in the realm of industrial activity—allowance for private initiative and competition.

CONCLUSION

Viewed in broad perspective, the whole matter of national science policy may be summed up as follows: For any nation, science and technology constitute an essential element of progress and, in particular, of national security and economic strength. For this country to exercise leadership in a competitive world, it is essential that policies and practices be developed along the following lines:

(1) The vigorous cultivation of science not only along the paths of foreseen objectives but also throughout its breadth and depth. In particular, this means thorough attention to the education and training of the scientists and engineers that will be needed. Fortunately, the present trend indicates that this goal is realizable, but only if as a nation we are prepared to provide funds and whatever is essential for the task.

(2) Among the possible developments that may result from science, careful attention must be paid to those that offer greatest promise in the accomplishment of our objectives. Such selectivity is important in maintaining a sound economy.

(3) A strong effort should be undertaken to educate our people to a general understanding of the purposes of science and technology, their potentialities, and their limitations in order that wise and intelligent use may be made of these capabilities.

But we cannot stop here. In an age where science has given us the key to unlock the energy of the atomic nucleus and has shown us the feasibility of escaping our planet and exploring the universe, we must understand that the capital discoveries of science are only just beginning and that science and technology will inevitably raise issues of the deepest social significance. All nations are convinced that their future is bound up closely with their progress and capability in science and technology. Among modern nations this capability is becoming general. Grim competition has developed along both military and economic lines. Onto this scene there enters a host of emerging nations, small and large, impatient to acquire the standards of living and the independence associated with science and technology. To solve these major problems and maintain any kind of equilibrium will require the utmost of all participants. Whether future developments take the form of stupendous power over nature's resources, of influence and control over life or over man's minds, or of traffic with our sister planets, they will certainly create problems of such concern to the human race that mankind must learn to cooperate in their solution.

Outstanding breakthroughs should not be permitted to become the subject of hostile competition nor to be exploited without adequate study of the possible consequences. The emphasis that has been given to nuclear development foreshadows potentialities of other possible undertakings, such as the ability to alter climate materially or to apply genetic research findings without proper safeguards and control. Although these developments have not yet been realized, they are well within the realm of possibility. This nation and all nations have a solemn obligation to maintain an awareness of such possibilities and to make certain that new developments are used constructively and in the interests of mankind.

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