THE DIRECTOR'S STATEMENT

Science and technology in our time have taken on a new order of magnitude that promises bold new achievements and poses problems of new dimensions. Nations have come to regard scientific and technological achievement as essential not only to national goals but as symbolic of national prestige and the object of international competition. More and more the responsibility for financing and often for operating research and educational enterprises is being assumed by national governments. The scope of today's research and development programs—some of them global and even extraterrestrial—have created extraordinary requirements for both funds and skilled manpower, thus making them the direct concern of government. Science, and especially technology, have become the subject of long-range planning and special management techniques. But the most important new dimension that science has acquired—and the one most fraught with far-reaching social problems—is its potentiality for creating radical or large-scale changes in man's environment.

The period since the war has witnessed in many countries a resurgence of engineering and industrial technology, radical and far-reaching advances in military research, and brilliant discoveries in science itself. These developments have given rise to large national undertakings in engineering and technology such as nuclear energy, nuclear-powered propulsion, ballistic missiles, and space vehicles. Such projects require very large budgets and engage the attention of management and labor in unprecedented ways.

Of one thing we can be certain: the advancement of science is inevitable and its consequences must be faced. Progress would be retarded by a devastating war or by some natural catastrophe, but it is inconceivable that mankind would now deliberately attempt to limit the forward march of science.

The breathtaking acceleration of science and technology is a phenomenon that carries with it a critical need for increasing study and attention, first because of the urgent requirement for planning that it forces and, second, as a social problem of far-reaching significance. Certain problems can already be identified that are of such magnitude, global significance, or involvement in human survival as to preclude confinement within national boundaries. Others will ultimately be forthcoming. Besides, from the scientific viewpoint alone, there are many aspects of modern basic research in which international cooperation and consultation are highly desirable, even essential.

On the planning side, one is necessarily concerned with objectives, feasibility, efficiency, and economy. These points become all important nowadays because of the necessity for overall planning. In private enterprise, in business and commerce, the element of competition has traditionally taken care of the quality of this type of planning. When planning is national in character, one has to compensate somehow for the lack of the corrective influence of this competitive factor. Unfortunately, our experience with program planning has grown far less rapidly than our organizations, so that the sheer task of collecting and analyzing data on which so vast an entity as a modern government can make decisions is one that is still to be solved.

Nevertheless, certain general considerations stand out. Recognizing the overall limitation in national terms with respect to what can be done in science and technology, a study of priorities indicates that a large proportion of the major undertakings stem from military requirements, others from promising and desirable commercial enterprises, still others from national needs apart from defense, such as health, housing, transportation, and communications. As a relatively new factor in modern times, there are increasingly insistent demands for elaborate basic research programs and facilities, such as high-energy nuclear accelerators, radio telescopes, high-altitude observations by balloons and rockets, and studies of the deep crust and upper mantle of the earth. Notable among such ambitious research and development plans are the exploration of space and broad programs such as oceanography and atmospheric sciences. All have varying degrees of justification for other than purely scientific purposes.

Any analysis of this huge and complicated problem should, in principle, start with a consideration of objectives. In an obvious but narrow sense, the objectives are clear, namely, military defense, health and welfare and other national needs, competitive trade, national prestige, and so on. Not so clear an objective is the degree of emphasis and support for novel research and determined probing into the unknown. The extent to which a nation provides for this type of research will depend upon its traditions, its maturity, and the state of its economy.

Closely related to the last point—the exploration of the unknown in science—is the broad objective of cultivating liberal and imaginative thought in science, not only for itself but as a major aspect of the development of human progress and culture. Because basic research in science is closely related to scholarly work in all disciplines and to the arts, it is the mark of a mature nation to allow full play to exploration of the mind in these directions.

Although the desirability and importance of such an ideal is surely understood by thoughtful people everywhere, it appears to be one that is very difficult for a country to adopt as a national objective. In the past, when science was not so closely related to technology, this goal could be pursued by private institutions, scientific and scholarly societies, and similar groups. However, as nations have become increasingly dependent upon science and technology, the outlook has altered radically. For one thing, the central government tends to become the principal source of support. For another, the sheer size of the effort, both in money and in manpower, forces the following courses of action: careful analysis of the specific objectives to be attained; appraisal of their significance, feasibility and cost; and full attention to planning and projections for the future.

The first major limitation to be encountered in the overall planning process is the one of funding, which sets an upper limit on the programs undertaken. Here the simplest solution would appear to be to identify the immediate objectives; to proceed, on the basis of careful studies of practicability, organization and procedures, with a selected series of undertakings;

and finally, to base the support of all scientific and technological activities, including the necessary basic research and allocation of manpower, on these specific objectives. This approach has its appeal from the standpoint of sound management practice and efficiency.

On closer examination, however, it is obvious that this solution is too narrow in conception and far too limited in outlook. It is, in fact, totally inadequate in a world of astonishing advances in knowledge, the development of new ideas, and truly sensational insights into an understanding of man's environment, with still more impressive possibilities in the offing. An age that has already embarked for the first time upon the exploration of outer space, of the depths of the oceans, and of the internal structure of the earth should surely include in its blueprint for the future the pursuit of the fundamental knowledge that such efforts uncover.

Thus our planning should encourage research in areas that are highly significant from the scientific point of view whether or not they appear to have any immediate practical application. Basic research should also contribute to the achievement of foreseeable objectives by providing aid along all lines that science itself finds significant and feasible. As a corollary, our system of education and our economy should, insofar as possible, be adaptable to profound changes with a minimum of dislocation. It is reasonable to suppose that the achievement of such adaptability will be greatly enhanced if education is focused on fundamentals and breadth as opposed to the narrow and specialized.

Financing is an important but by no means ultimate limiting condition. Fundamentally the most important limitation on planning is manpower. A firm upper limit is established at the outset by the proportion of the population that has the ability to enter the profession of science or engineering. The problem for a free society is one of identifying and motivating the fraction of the population who have such aptitudes and of providing for their education and training. In general, motivation depends primarily upon career opportunities. For the most highly gifted individuals, however, motivation may largely be the intellectual challenge of the field.

The support and encouragement of future leaders of scientific thought is not the whole story, however. Modern advances in science and technology require a host of skills for their execution. Provision must be made for the training of scientists and engineers at all levels of ability and for the education and training of persons with other skills to be associated with these large undertakings. Specifically, recent studies in this country indicate that the advancement of science and technology in the next decade requires at the least that the number of scientists and engineers with advanced degrees be doubled. Surveys of the distribution of abilities and current trends among the population indicate that this is entirely feasible. The problem is to provide motivation on the one hand and opportunity for training on the other. The primary requirements are provision for financing in terms of competent teaching, physical facilities, and payment of training costs.

Although planning requires attention to every stage of the education process, accomplishment of this objective, namely, the doubling of the number of scientists and engineers during the next decade, focuses attention upon the colleges and universities and their graduate schools. Essential are construction of adequate teaching and research facilities, provision of instructional and research equipment, and provision for the needed increases in research and teaching staff at institutions of higher education. Finally, and most important of all, at least 40 percent of students specializing in science and engineering should go into academic careers in order to provide research and instruction of the high quality that is required if the overall objective is to be met.

But it is not the rapid growth and complexity of science and technology that should concern us most deeply, nor the uncomfortable magnitude of the research and development effort in money and in manpower. Neither is it so much the extent to which progress in science and technology has captured man's minds and attention, though this comes closer to the point. It is man's new capacity to effect major changes in his environment and in himself. This is what should engage our most serious attention. Although every age has probably felt itself unique, it seems safe to say that ours *is* unique in the sense that man's challenge to nature and his increasing power over his environment have reached critical proportions.

Certain types of scientific and technological activities have existed throughout history. In the beginning, of course, man was chiefly interested in using his new discoveries to improve his subsistence, that is in applying them to crop and animal husbandry, to the construction of dwellings, and to other practical arts. Later, when men began to pursue science for its own sake, the body of new knowledge thus acquired contributed in an important way to technological innovation which has grown at a constantly accelerating rate.

Man has achieved great success in turning the forces of nature to his own use in everything from the simple water wheel to the harnessing of nuclear energy for peaceful purposes. Until recently, however, no technological advance has come even close to promising such sweeping accomplishments as weather modification, unlimited commercial power, artificial food, exploration and colonization of our sister planets, or to threatening drastic and sudden change in our environment, such as extermination by nuclear warfare or by lethal air and water pollution. It is true that failure to observe conservation practices with respect to forests and agriculture has seriously affected local living conditions in various parts of the world; but even here evidence is lacking that such neglect has brought about marked climatic changes (although admittedly it may have had long-range serious effects upon the welfare of the resident population).

Now, however, we find that within a relatively brief space of time a number of technological developments directly influence our environment and that the potentialities for the future—both good and bad—are even greater. One could cite by way of example the small but steady increase in the carbon dioxide content of the atmosphere resulting from fuel consumption; widespread pollution, including radioactive fallout; serious attempts at changing the weather; large scale experimentation with the radiation and other layers surrounding the earth; and suggestions for modification of ancient currents in the oceans. These are only a few of the areas actually subject to study or experiment; one must also take into account future developments that will certainly materialize. One has only to look at the progress in selected current research, such as genetics, molecular biology, experimental psychology, development of modern computers and the far-reaching implications of solid state physics, nuclear physics and chemistry, and plasma physics, to anticipate what some of the potentialities might be.

From the historical point of view, all of this may be regarded as a new stage in the struggle for existence of man and society—the stage where man has far more active and aggressive control over his environment than ever before. One may well raise the question as to whether in his new found freedom he is also giving ample consideration to the potential consequences of his experimentation.

The inescapable conclusion is that we should all be fully aware of the dangers as well as the benefits that may ensue from modern research programs. If every possible precaution is to be taken in dealing with experiments and pilot operations on a global scale, then it would seem indisputable that the careful traditional process of research be observed, so that each forward step in thought or procedure may be properly weighed and tested.

International cooperation is a time-honored tradition of science, and certainly there has never been a time in which such cooperation could be more fruitfully brought to bear on the problems of science than now. The hazards inherent in radioactive fallout, in nuclear explosions above the earth's atmosphere, in air and water pollution, and in the manipulation of weather and climate are problems for the entire world. Therefore, all nations should get together in the effort to determine the extent of the hazards and the types of controls that should be instituted.

Still other opportunities for fruitful cooperation are research areas large in scope and immense in cost—the exploration of space, upper atmosphere studies, meteorology, and oceanography. The efforts of the scientists and engineers of many nations are needed to maximize the accomplishments of projects of this magnitude. In undertakings such as space exploration, where the objectives must be weighed against what the economy can bear, several nations might find it possible to cooperate on projects that no single nation could afford to undertake.

We already have precedent for international cooperation in science in such highly successful ventures as the International Geophysical Year and programs that grew out of it—the Antarctic Program, the Indian Ocean Expedition, the International Year of the Quiet Sun, and research on the upper mantle of the earth's crust.

Much of the strength and success of these programs lies in the fact that they originated among the scientists themselves, growing naturally out of the progress of science and at the same time receiving the necessary support from the governments concerned.

Other striking examples of successful international cooperation in science are to be found in the regulatory and service agencies of the United Nations, such as the World Health Organization, the Food and Agricultural Organization, and the World Meteorological Organization. UNESCO has also played an important role in science, especially among the underdeveloped nations, to the extent of the funds provided by the member nations. Thus we find abundant precedent for successful international cooperation in solving some of the larger problems posed by modern scientific progress.

Necessity still mothers invention. But necessity as a primary motivation is fast disappearing. For a long time in his upward climb man was preoccupied with meeting his creature needs—food, shelter, clothing, protection against his natural enemies. When he acquired first technology and then science, he used the skills and knowledge these afforded to meet these basic needs more easily and efficiently. As he developed more sophisticated societies, the satisfaction of such needs gradually became a part of the social system and no longer required special attention except in case of natural catastrophe such as drought, floods, or epidemics that altered the normal course of things. In recent times man has employed science and technology to improve his material condition, increase his longevity, push back the frontiers of knowledge, and improve the lot of less advanced peoples. The question before him now is not one of further improvement but of innovation on a constantly growing scale. Man asks, both literally and figuratively: What new worlds can I conquer?

Science provides knowledge and we have had abundant evidence that knowledge is power. How are we going to use this power? Are we going to select the most promising opportunities and in single-minded fashion concentrate upon them? We must bear in mind that the more ambitious the program and the more elaborate the effort, the fewer such efforts can we undertake. Or, as a consequence of widespread pressures shall we pay first attention to serious problems of human welfare and existence?

Are we going to continue to exploit nature, including man, for immediate practical objectives, with minimum regard for possible long-range consequences? Will we go on ignoring conservation of natural resources? Is it likely that in the excitement of the chase or in the heat of competition we may fail to recognize certain risks or limitations, unforeseen at the outset? On the other hand, perhaps as the result of some disastrous undertaking, shall we become excessively timid about large-scale innovations or exploration?

We must not lose sight of the fact that the greater the innovation and the larger the effort, the heavier the responsibility for a thorough study of such matters as purpose, motivation, and consequence. Our aim should be not merely knowledge but understanding, and to the extent possible, wisdom. Thus, no matter to what degree we may commit ourselves to large and daring enterprises, we should now more than ever cultivate the basic research and concentrated study in science and other fields of learning that can provide this understanding and set us on the road to wisdom.

One thing is certain. Whatever major objectives or high adventures mankind undertakes, the highest degree of originality and the deepest insight will come from individual minds. Accordingly, not only the progress of science but its meaning and future promise are best fulfilled by ensuring the right and the opportunity for individuals to pursue research of their own choosing.

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