TECHNOLOGICAL PROGRESS AS A NATIONAL RESOURCE

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CAPTAIN MARCY: General Holman, gentlemen: My purpose this afternoon is to fire the opening gun of the Technological Progress course, which, as you have noted, is unit II of the college curriculum. This unit is presented by the Production Branch, which I head.

I would like you to meet the members of the Production Branch: Colonel Diehl, Air Force; Mr. Swaren, civilian staff; Colonel Cave, Army; Colonel Seaward, Army; Lieutenant Colonel Meetze, Army; Mr. Baum, of our civilian staff; and Commander Hartman.

I hope you will consider these gentlemen not as instructors, in the usual sense of the word, but rather as members of a steering committee who have been over this road before and can therefore help you around or over the roadblocks and through the bottlenecks which may otherwise impede your progress. Consult them freely and frequently; get to know them. These gentlemen will meet with you in smaller groups later this afternoon to clear up any questions you may have on the curriculum book, preparation of your reports, or on other matters which I may not cover in detail here.

Now, with the introductions out of the way, let us take a look at the subject of "Technological Progress as a National Resource." We might well start with an attempt at a definition of technological progress. For those of you who like to wrap everything up in a neat little definitive package, the best formal definition so far developed here at the college is the following: "Technological progress is the improvement of man's control over his natural environment through the application and utilization of scientific and engineering knowledge in any of the practical arts and sciences." Let me repeat that. "Technological progress is the improvement of man's control over his natural environment through the application and utilization of scientific and engineering knowledge in any of the practical arts and sciences." There we have it, all neatly defined. But a moment's reflection and we can see that it covers the waterfront, and is about as broad as it is long. So in terms of real understanding of our subject, we are back about where we started. Therefore, instead of a precise definition, let's see if perhaps we can gain a better understanding by examining a few examples of the application of technological progress in everyday affairs.

First, take the productivity of labor. According to the best available figures—although there is a wide variation between industries—over the past half century technological advances have increased the output of the American workman at an average rate of about two and a half percent

per year. Or to put it another way, if this rate is maintained, the output will be doubled every 40 years without any increase in the labor force. Thus, we might supplement our definition by saying: "Technological progress is a means by which we can multiply our labor force."

Then consider for a moment our natural resources. Rubber is an outstanding example of a basic commodity which is vital to either a peacetime or a war economy. In 1940, the United States was completely dependent upon distant foreign sources. By 1945, when the United States rubber industry was consuming new rubber at a higher rate than at any previous time in its history, over 85 percent of this new rubber was American-made synthetic rubber. So we might further amplify our definition by saying, "Technological progress is a means by which we can conserve and extend the use of our natural resources."

Next let us consider the financial aspects of technological progress--how much does it cost? How do we pay for it? To see if it pays, let's take as an example a large industrial concern which has been built mainly upon research and development--the Dupont Company. This company existed for almost a century concentrating on the manufacture of black powder, dynamite, and smokeless powder, with such research as was done limited to explosives. It was a good steady business but it showed no indication of becoming the industrial giant it is today. In 1902, the company established its first formal research laboratory and extended its research to other fields. Since the opening of this first laboratory, the corporation's stock has increased in value by 1,080 percent. Today about one-third of the company's gross sales are of products that did not exist, or were not made in commercial quantities, as recently as 1938. To quote a Research Director of Eastman Kodak, another company built largely upon research, "I've never heard of a company going broke because it spent too much on research."

To summarize, then, and to place it in terms of three of the five big "M's" of economic mobilization--men, materials, and money--we can now define technological progress as, "The application of scientific and engineering knowledge as a means of multiplying our manpower, conserving and extending the use of our natural resources, and making it pay."

Having defined our subject, let us consider for a moment some of its elements, after which I shall outline for you some of the principal problem areas. Basic or pure science underlies and provides the foundation for all technological progress. Here again we come up against the need for definition, and, again, instead of a precise, pat definition, I am going to make an end run and quote Dr. DuBridge, president of California Institute of Technology, in a lecture to the General Advisory Committee to the AEC last year.

"The chief goal of science is not to develop weapons of war; it is not to develop new or improved industrial products, not even to find cures for human disease. The primary goal of science is to understand nature. Its purpose is not to invent but to comprehend; its aim is not to produce gadgets, but to discover knowledge; its most valuable and important products are not atomic bombs, radar, or penicillin, but new facts and new laws concerning the behavior of the natural world."

If we accept this definition of science, the question immediately arises--How, then, do we get our atomic bombs, our radar, and our penicillin? Dr. Vannevar Bush, in a lecture at the Industrial College in 1947, listed eight essential steps or phases in the research and development cycle, and I shall now trace them for you.

First, there must be an expanding body of science in general, a storehouse of fundamental ideas constantly being replenished through basic research.

Second--and this is all too easily taken for granted rather than recognized as a distinct step in the cycle--there must be a constant alertness to discern in the growing body of basic knowledge those points from which practical applications may grow.

Third, the ideas thus discerned must be tested to determine whether they have merit. This is the stage of primary, applied research. Well done, it results in the elimination of some possibilities, the recognition of those having the greatest promise, and permits major effort to be centered on them.

Fourth, there must be reasoned and deliberate examination of the possible outcome in terms of technical performance and of development of ideas which have stood the test of the primary applied research.

Fifth, the setting up of programs is for the purpose of producing prototypes. It is here that careful attention to the second and fourth steps begins to pay off. Both of these steps are evaluation processes. By one, we increase the number of possibilities to be explored; by the other, we eliminate the least promising of those possibilities; thus the expensive and time-consuming fifth step--the building of prototypes--is undertaken only when a worth-while development is almost a certainty. To pin down an idea often takes only paper and pencil. Building a prototype may take millions.

Sixth is the testing of the prototypes and re-examining them in the light of the test results.

Seventh is the incorporation of changes and adaptations, as indicated by the sixth stage test results, and the setting up of experimental or pilot-line production.

The eighth step is not the production of the final article, as might be supposed, but is another evaluation and analysis, conducted, where possible, through field testing of the experimental or pilot-line articles for final ironing out of difficulties before going into large-scale production.

To Dr. Bush's eight steps, our experience indicates that we must add a ninth to complete the cycle, that is, the continuous follow-up of the article in service with the changes and modifications to meet the ever-changing service requirements. It is through this ninth step that we determine the need for and the timing of new programs to develop improved models or replacement items.

Now let us examine some of the problem areas in the field of technological progress as it relates to our over-all subject of economic mobilization. Let us start at the beginning and consider, first, basic science. Certainly no one can have any quarrel with basic science since by definition its only purpose is the discovery of new knowledge and its only products are new facts and new laws concerning the behavior of the natural world. We have listed basic research as the first step in the research and development cycle as the means of building the stockpile of material we must have on hand before we can start work on the fabrication of the structure. The only problem, then, is to build and maintain this stockpile at a safe level. In many respects the position of the United States in regard to basic research is similar to that in a number of other critical strategic materials, so let us carry this analogy a bit further.

The spectacular growth of American technology to a position of world leadership has been based largely upon foreign sources of basic science, just as our aluminum industry has been built, for the most part, upon importations of high-grade bauxite. It is true that we have some high-grade aluminum ores in this country, and we have some top-ranking scientists; but we do not have enough of either to support our industry for long if our foreign sources are denied us.

We have almost unlimited supplies of low-grade aluminum ore, and, similarly, in our population there is a vast amount of undeveloped scientific talent. To extract pure aluminum metal from even high-grade ores requires a tremendous amount of electrical energy. To produce top-grade scientists from the best raw material requires a vast amount of energy of another sort, and the results are much less predictable.

There is no serious problem in either area so long as the channels of world trade remain open and there is free exchange of scientific information among scientists throughout the world. But when we begin to think in terms of national security and consider the possible circumstances over which we have no control and which may block the channels of world trade and prevent the free exchange of scientific information, we see that we must, by one means or another, attain that degree of self-sufficiency which will see us through any emergency.

To carry on with our analogy, let us examine some of the possible solutions to the aluminum problem and see whether any of them can be applied to the science problem.

First, for aluminum, we can, by various incentives, intensify the search for new sources of high-grade bauxite within our own borders. This certainly applies equally well to the science problem.

Second, for aluminum, we can reduce consumption by the elimination or curtailment of nonessential uses and the substitution of noncritical material. Obviously, this won't work for science.

Third, we can stockpile. For aluminum, this is most effective, for not only do we stockpile the metal, but in effect we stockpile electrical power which may also be in critical supply in an emergency. We can stockpile science to a limited extent by several means, but, generally speaking, science, like fresh eggs, deteriorates quite rapidly in stockpile.

Fourth, and in my judgment the best—and perhaps the only long-term solution in both cases--is the development of methods for refinement of our low-grade reserves. So much for the problem of basic science for the moment.

What are some of the other problems? Generally speaking, they fall under one broad heading, the fourth big "M" of economic mobilization--management. In other phases of the course, you have already studied and will continue to study management, and will examine in some detail the definitions and principles of management as developed by recognized authorities in the field. For our purpose today, we can define management simply as the techniques by which we combine the other "M's"--men, materials, machines, and money--which may be available for the accomplishment of a specific objective. The principles and techniques of good management apply equally as well to scientific research and development as to any other enterprise. There are, however, some management problems peculiar to research and development, for example, which cannot be handled by the same techniques which would be successful in dealing with a production problem. I shall touch on these problems under the headings of personnel, facilities, finance, and timing.

Take personnel first. Much has been written on the difficulties of managing scientific personnel. Most of it makes interesting reading but does little to throw any light on the matter. A sort of mythology has grown up which attributes to every high school science graduate the characteristics of an Einstein or a Steinmetz. The fact is that there is more than a little of the ham actor in all of us and this characteristic is not confined to scientists. If you have an Einstein or a Steinmetz on your hands, you have no problem except to protect him from those who would attempt to manage him. But if you have an ordinary run-of-the-mill research man who allows too much of the ham to come to the surface and he begins to take on what he thinks is the mantle of an Einstein, you do have a problem.

On the other side of the picture, the scientist, by inclination, education, and training is seldom a competent executive or administrator. There are exceptions, of course, but it is usually a mistake to so organize a project that the scientific personnel involved are responsible for administrative matters. This does not, and should not, operate to exclude the scientists from the top policy-making group.

There is another myth in this area that I would like to run down. That is the one about the inability of the military mind to comprehend the scientific mind and vice versa. Much has been written and published supporting this fallacy. The fact is that both the scientist and the military man use the same method, the scientific method which we hear so much about and which many who call themselves scientists place on a pedestal and worship as a deity which is imcomprehensible to ordinary mortals.

What is this scientific method? Let me quote from the last paper of an outstanding scientist, Dr. Thomas Midgely, who at the time of his death, in November 1944, was president and chairman of the board of the American Chemical Society and vice-chairman of the National Inventor's Council. He had this to say:

> "What is this scientific process? Indeed all to often the term is used to glamorize simple common sense, and then again it is used by charlatans to give respectability to what otherwise obviously would be in conflict with common sense. A better definition is desirable. To my mind the basis of the scientific process is the reproducible experiment."

Wherein does this method of the reproducible experiment differ from the time-honored military method of holding maneuvers, battle exercises, fleet problems, and the like, in order to develop the tactics or maneuver that can be reproduced successfully in the face of an enemy? It differs only in that the scientist can afford repeated failures, whereas the general or the admiral, the lieutenant or the sergeant seldom has the

opportunity to rerun his unsuccessful experiment. And so I say that men of good faith and of intellectual honesty, regardless of whether they be scientists, military men, industrialists, or what have you, can work together and understand one another. It is only when one group or the other foregoes its intellectual honesty by taking refuge in the lingo of its specialty that the normal barriers to understanding become insurmountable roadblocks.

Let us consider now the research and development facilities problem. Time was when fundamental discoveries in science were made with very little in the way of facilities or elaborate equipment. For example, if we believe the legend, Newton needed only an apple tree and a balmy afternoon to formulate the law of gravity; and Franklin required only a simple kite and a brass key to discover the nature of some electrical phenomena. Such inspirational discoveries are still possible, but, by and large, with the growth of science, the complexity and cost of the tools have grown by leaps and bounds until today we have cyclotrons whose power is measured in billions of electron volts and whose cost is measured in millions of dollars; supersonic wind tunnels accelerating air to mach numbers undreamed of by the obscure scientist whose name we use with a number to measure these high speeds. These and many other costly and complex installations are the necessary tools of the modern researcher in many of the sciences.

But here we have another seeming paradox. If we have a plant in production which is turning out, say, 10 finished articles per day, and we wish to increase the output to 100, we expand the plant, retool with more efficient machine tools, break down the operations requiring lower skills, hire more unskilled and semiskilled workers, and our production goes up to the desired output. This technique, when applied to the problem of accelerating research and development, almost invariably results in decreased output and skyrockety costs. A Faraday could make fundamental discoveries in electricity with the crudest of equipment; Joe Zilch might operate the General Electric laboratories from now on and bankrupt the company without contributing anything to the fund of human knowledge.

Financing research and development is another problem that merits the closest scrutiny. In the past, much fundamental research in universities and in scientific societies and foundations was financed almost entirely by private grants and bequests of individuals. Increasing costs and more stringent income and inheritance tax laws have now reduced this source of research money to insignificance as compared to the total required, and these institutions now look increasingly to government and industry for support. Government has greatly expanded its field of effort in research and, as a result, has drawn heavily upon universities, private institutions, and industry for scientific personnel to man the elaborate laboratories which only government can afford to build. There are many who

advocate more government money and more big government laboratories. I do not wish to take issue with those ideas here, but I do want to suggest that there may be other answers to the problem. Some revisions of tax policy, careful and searching review of patent laws and their administration, special inducements to small business to undertake research--to mention only a few--are measures which might give us a better return on our research dollar.

Timing and coordination of research and development efforts are other factors which deserve the most careful consideration. In pure or basic science the time is now, tomorrow, and every day to keep up a relentless search for knowledge and understanding of natural law. In applied research and development a balanced effort is essential if we are to get a dollar's worth of development for each dollar expended. It is patently foolish, for example, in the development of a long-range guided missile, to devote major effort to the propulsion problem and trust to the Almighty to provide us with a free solution to the guidance problem. I do not imply that this is being done, but I do wish to make the point that you can program research and development but you cannot schedule it, and if that is a flight into semantics, it is intentional.

Gentlemen, I hope you will enjoy our presentation of this subject over the next eight weeks, and that you will take away from it some knowledge and understanding to which you do not now lay claim.

Thank you.

(8 Nov 1950--150)S