SCIENCE

VOL. 99 FRIDAY, JANUARY 7, 1944 No. 2558

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. MCKEEN CATTELL; WARE CATTELL, assistant editor. Published every Friday by

THE SCIENCE PRESS

Lancaster, Pennsylvania

Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary in the Smithsonian Institution Building, Washington 25, D. C.

THE PROMISE OF TECHNOLOGY[1]

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PROGNOSTICATION, and especially long-range prognostication of technological advances, particularly those related to new sectors, is an extremely hazardous performance even in normal times. When one attempts to make prognostications for a postwar peacetime period, when one is in the midst of the turmoil of war, it is a hazardous undertaking raised to the nth power. The reason for this is because of certain very fundamental conditions affecting science and technology during a war era.

In the first place, technology is itself so vast a subject and covers such a wide range of applied science that no man in the world is wise enough at any time to predict the future except for a very short distance ahead and in very limited sectors. Even so, he can not have any great assurance of being right.

During the war period there is added to the normal uncertainties the fact that no one in the world has the slightest idea of what kind of a world we are destined to live in when the show is over. Further, no one can say with certainty when the period of active warfare will cease and the period of peace will begin. Nor can any one say with assurance what changes in science and technology will occur during the interval of active warfare still ahead of us. The present tempo of applied science to the art of human destruction and defense against that destruction is

[1] The ninth address of the second series of conferences on "Postwar Goals and Economic Reconstruction" held under the auspices of the Institute on Postwar Reconstruction of New York University. Dr. Arnold J. Zurcher, director of the institute, presented Dr. Jewett and said in part: "We have not only an engineer this evening, but we also have, I suppose, one of the most distinguished engineers in the country. In a long list of persons who have been submitted to our attention as the kind of person whom we ought to invite, Dr. Jewett stood at the head, and we are very fortunate indeed in getting him to consent to come over here this evening and talk to us." This address, together with the discussion, will become part of a volume on "Postwar Goals and Economic Reconstruction," published by the university.

exceedingly great, and quite unforeseen things are still sure to arise.

Further than that, we have not only the vaguest of ideas concerning our own internal situation, but likewise not the slightest idea of what kind of neighbors we are going to have in this world. We don't know whether the so-called peace that will follow active warfare is really peace as we like to understand it, or is to be in fact merely an armed truce during which we are permitted a breathing spell in which to prepare for a further and greater conflict. When present hostilities formally cease our mass conception of the conditions of the future will have a controlling effect not alone on our adventures in technology, but likewise on our whole national life. If we are convinced that the peace is but an armistice, many of the controls that must obtain in war but which are abhorrent in peace will be accepted and our procedures will be ordered accordingly.

Again, irrespective of whether the years ahead are to be those of a lasting peace or of an armed truce, we are not likely to be completely free masters of our own house in much that we do technologically. Even in an ostensibly peaceful world, where the competition between races and peoples and nations is a purely commercial and economic one, what others elect to do will to a large extent govern our own acting in many directions and cause us to proceed in ways and in directions which we would not choose if left to our own devices. In other words, in our present highly mechanized world what others elect to do to a large extent controls what we must do.

We know that in the past the philosophies of different nations with regard to industry generally, and to applied science in particular, have varied widely, and in many cases have been quite different from our own. Here in America for the past forty or fifty years we have lived in the shadow of a fear of the size of industries—the fear that industries might grow to such dimensions as to be beyond the control of the state. Despite this lurking fear, which has crystallized in our several anti-trust laws, industries have grown to huge proportions notwithstanding the punitive measures and the restraints we have attempted to impose. So far as the applied science industries are concerned, this anomaly is the direct result of the fact that in many cases the maximum benefits, whether in price or in quality and quantity of services to the public which are inherent in the thing to be done, can only be obtained through big units. Examples of this are legion, and the fact that it is so seems to me an indication that subconsciously and despite our professed fears we have realized that our own interests lay in pursuing the course indicated by the factors of technology.

Whether or not this is correct, the fact remains that in many directions the vast achievements of war preparation simply could not have been had, had we not built up over the years our enormous units of production and trained untold thousands of men and women in their efficient operation.

Contrasted to our expressed anti-monopoly anti-trust philosophy, many countries (and England and Germany are, I think, among them) have developed under a different philosophy. While they, no more than we, would welcome the prospect of a situation where industry dominated the state, they have not hesitated to foster the growth of great units and to trust to the ability of political government to prevent their getting out of hand. Possibly they were more far-seeing than we, but largely, I suspect, they saw the possibility of war as a background drop more clearly than we in our isolated position were able to do. The fact that the industrial and manufacturing units which grew up under these two somewhat different philosophies were larger in the United States than elsewhere is of course the direct result of our peculiar geographic situation, and because of our size our huge domestic market, our high standard of living and our urge to develop our natural resources as rapidly as possible, all made for an industrial expansion for which there was no parallel.

Any attempt at the present time therefore, except in quite narrow sectors, to make a prophecy as to what is the promise of technology in the future, with any assurance that that prophecy is a reasonable one, is quite small. In consequence, I think that what we can do most profitably this evening is to take a look at some of the fundamentals, or what seem to be fundamentals, in the science and technology sector in any postwar era.

The best way to do this, I think, is to approach the matter by taking a look at the science and technology of the prewar era; to see what they now are and what they appear likely to be when at some indefinite future date we once again lay off our uniforms.

In what I am going to say, and I suspect in the discussion afterwards, I am proposing to use the word "technology" in its very broadest aspect to include not only the things which we normally think of as technology, which are mainly the applications of the physical sciences to utilitarian ends, but also the applications of the biological sciences. This seems to me both legitimate and desirable, since such things as medicine, public health and agriculture are really technology in the sense that they are utilitarian applications of fundamental biological science.

Moreover, there is an additional reason for doing this because in looking over the wide variety of science as applied to war activities there is a marked differ-

ence in the prospective postwar utilization of war science as between the biological and physical science domains. In other words, it seems to me that the chances of direct immediate and large-scale application in a peacetime economy are greater in those things which are based on technological developments of the biological sciences for war than in those which are based on the technological developments which are concerned primarily with the creation of instruments and instrumentalities of destruction.

The reason for this feeling is that the medical technologist during a war period is dealing primarily not with attempts to destroy life but in an endeavor to prevent that destruction and to save lives endangered by wounds or disease.

In a word, the biological science technologist in war is merely continuing in a different sector, on an enlarged scale and with clinical facilities not obtainable in peacetime, more nearly the normal course of everyday life. The result is that at the conclusion of hostilities practically all that he has learned will be immediately applicable to peacetime.

Contrasted to this, the vast majority of the technological applications of the physical sciences is either directly or indirectly concerned with the destruction of human life, and much of it has no prospective peacetime application.

All that we call "technology" is nothing but the application of fundamental science discoveries and the employment of scientific methods for useful or desirable purposes. Except incidentally, technology as such is not concerned in the production of new implements of knowledge. At all times, except during periods of active warfare, the scientific and technical world is divided roughly into two main groups. First, there are those who are concerned primarily with the exploration of the unknowns of science for the purpose of extending the boundaries of knowledge, developing new facts and learning more accurately the characteristics of old ones—all this without any particular thought as to their possible ultimate utility. For the most part this group is to be found in the colleges, universities and technical schools and in the great eleemosynary foundations. Incident to this work of pioneer exploration and as an integral part of it is the training of young men and women by indoctrinating them with the established learning of the past and with the methods of science by which it has been established. This is both to produce continuously a new group of investigators for the field of fundamental science or, as has been largely the case in the last two or three decades, to train men and women for a life in industrial research.

For this group it is a well-known fact that fundamental science flourishes best in a completely free intellectual world. In other words, a sine qua non in fundamental science is that there should be complete freedom of intercourse and discussion and the publication of results, so that all may have access to them. Men make discoveries; they publish their results; they meet together for discussion and argument, and they propound hypotheses and debate them. This freedom of intercourse is not merely freedom within a given nation but is a freedom among the scientific people of the whole world. It is all based on a common desire to know the truth about the things of nature; to extend that knowledge, and a realization that each individual's aspirations are helped by common group action.

The second division is that which we commonly designate as the sector of industrial research or technology. Here to a large extent the character and training of men, together with the implements and techniques which they employ, are the same or very similar to those in the fundamental science field. The objectives, however, are different, since they are concerned not with an extension of knowledge for its own sake, but in finding ways and means for new or better applications of fundamental science to the uses of mankind.

In this second group the modus operandi under normal conditions is likewise that of free intercourse and interchange of ideas. While this was not always the case, for the last thirty or forty years technologists have used the mechanisms of publication, scientific society meetings and free discussion in practically the same way as have those in the fundamental science fields. In addition to these agencies for spreading technological information there is in this field another form of publication, namely, that of patents, in which, while the publication spreads the knowledge to all who may care to read, it spreads it with limited property rights accorded by the state.

Now what happens to these two sectors when war enters the picture? Immediately there is a radical change in the whole situation. First, intercourse between the two contending parties ceases abruptly except for a small trickle of illicit and uncertain communication. Nor is this all. Within each nation the stark necessities of secrecy imposed by war impose great barriers of confidence for fear that items of importance to the enemy may leak out. For the time being complete freedom of interchange of information in any given field is taboo. Publication is circumscribed, patents are impounded, and men, whether in the field of fundamental or applied science, have largely to work in watertight compartments with intercourse only among those in the same compartment.

The result of course is that much unnecessary duplication of work ensues, much false work is done and all work is handicapped.

Further than this, fundamental science, which is the life blood not only of an expanding store of knowledge but likewise of an expanding technology, practically ceases for the time being. It ceases both because men and women have no heart for such work, but more because the trained scientist is immediately available for effective operation in the industrial field and is therefore drawn into the whirlpool of warfare.

We are prone to talk about this war as being a physicist's war in contrast to World War I, which was designated as a chemist's war. To a large extent it is not only a physicist's and chemist's war, but likewise a biologist's war, and most certainly an engineer's war.

Because of the nature of present-day warfare and the progress of science during the past two decades, it was inevitable that the field of physical science should be the one first affected. During the past two years, in this country, all production of new fundamental knowledge in the physical science field has substantially stopped because the men and women competent to work in those fields are for the moment engaged in the more urgent work of applying their knowledge and skills in the war effort. Gradually, but possibly not quite to the same extent, the same thing is happening in the field of the biological sciences. In these fields, in addition to a deflection of objective within the field itself, we have been witness to a large translation of biological scientists into the field of the physical sciences.

In both the physical and biological science fields there has been in addition a deflection away from those who would otherwise produce new knowledge to the field of intense instruction designed speedily to acquaint young men and women with highly specialized skills required in some phase of war activity.

The result of all this is that at the end of the war we are going to find ourselves with a frontier of fundamental knowledge which is not very much enlarged from that which existed at the beginning of the war. It will be somewhat different of course because the degradation in production has not been completely uniform around the periphery, it has not been completely stopped in some sectors, it has had some accretions of an incidental character supplied by our intense endeavor to expedite war developments, and because here and there, particularly in the field of the biological sciences, the mere necessities of war have made imperative a certain amount of fundamntal science research. By and large, however, I think it is safe to say that the period of active warfare is an almost complete stagnation of progress in the field of the fundamental sciences.

Further than that, we will return to a peacetime condition with a paucity of young men and women broadly acquainted with established knowledge and rigorously trained in the methods of scientific investigation.

Against this, however, is the fact that in some sectors there has been an intense technological development, some of which will have substantial peacetime applications. Likewise, we will have a huge number of men and women who have become skilled technicians in limited fields, and above all, a population which has a quite different and enlarged understanding of science and technology. Both by reading, and more particularly by participation in the armed services or in industry, literally millions of people who would otherwise have gone through life quite unacquainted with science, except its obvious external applications, will have some real understanding of it.

This is the general outline of the picture as it appears to me, and because of my position on the National Defense Research Committee and as president of the National Academy of Sciences I presume I have about as good an opportunity as any one to obtain a general view of the whole vast field of science and technology. It is a picture of substantial stagnation in the fields of fundamental science and of a large sector of technology concerned with matters of little importance in active warfare. Likewise, it is a picture of intense activity and astounding technological results in a relatively small number of sectors, many of which results have little prospect of salvage in the postwar era.

The reason that we have made such enormous technological progress in certain directions is due to the fact, first, that we have concentrated the scientific and technical ability of the entire nation in these directions; and second, because the normal restraints of a peacetime economy do not obtain for the time being. Money is no longer a factor of controlling force. Time and success in the undertaking are the controlling essence of the job, and money as such is a very secondary consideration. Further, for the time being men and women are content to labor harder than they ever labored before and under conditions of restraint imposed by the necessities of war which they would not tolerate in normal times. For the moment every one in the field of science and technology has a single common objective which transcends in importance all other objectives, and which in addition they all desire to achieve in the shortest possible time.

Now what will happen when the armistice is signed? The minute that war is over, and particularly if the

prospective conditions of the peace are such as to indicate a long period of freedom from hostility, we are bound, I think, to see an immediate disintegration of the present machinery of science and technology. Men and women will yield to the deep-seated urge to return to their erstwhile modes of life, and in addition no one will wish longer to devote time and energy to objectives which have lost their reality. Scientific men will wish to return to life in a free intellectual world, there to pursue the quest for new knowledge. Industrial research men and technologists will hasten to take up again the things that once interested them and to expedite filling in the gaps made by the inroads of war and the forced laying aside of promising new applications of science. There will be a dearth of highly trained men for fundamental science research for general application, and a large number of men trained in specific applications. Much of what we have done during the war period will be of no peacetime value because it is concerned wholly with the things of war.

I have already mentioned the fact that the nature of this war is training millions of people to a different understanding of science and technology. Whether or not these men and women continue in some sector of fundamental or applied science, their number will be so great that their mass desire is bound to have a controlling effect on the things we do, and more particularly on the way we do them, especially in the field of technology. No one can say in advance just what this effect will be or how it will be evidenced either politically or economically.

Now I am almost through with my thirty minutes of talk. There are, however, one or two other things which I would like to lay before you as elements in the realm of uncertainty in which I think we are going to find ourselves in the beginning at least of the postwar era.

I mentioned earlier the uncertainties which would confront us of not knowing what kind of a world we are going to live in, or what the other fellow is going to do, which will force us, whether we like it or not, to do things which we might otherwise prefer not to do.

One thing which we do not and can not now know is the relation of political government to the development of technical applications of scientific knowledge. At the present time, in the midst of war, political government must of necessity control what we do and how we do it. It is the only way that a nation can wage war successfully. But coincident with the realization of this necessity we are all increasingly conscious of the limitations and deficiencies of attempting to control so vast a thing as a nation's technology in a single narrowly centralized government. It is too vast a thing to be administered effectively by any limited group having merely the clairvoyance with which God has seen fit to endow men.

On the other hand, there are certain applications of science which are of such a character that it is difficult to see how they can be carried on effectively except under some form of government support or control. If this is so, it would appear that in certain sectors at least government in the postwar era will play a bigger part in the development of science and technology than it has in the past.

An example of this is to be found in things like agriculture, where the problems are numerous and involved and where those to be benefited are a myriad of small units, each one of which can derive maximum benefit from the applications of fundamental science knowledge only through some form of cooperative effort, such as government or a government supported agency can afford.

In connection with the ultimate prospective place of political government in the field of science and technology, and in connection with a large part of current discussion about planned direction of research, there is a vast amount of popular misconception as to the role and part played by the director, whether he be a government official or an industrial research director. Any of us who have had wide experience as industrial research directors (and I have had nearly forty years of such experience) know that the director and his immediate subordinates do not direct the work of their laboratories or engineering departments in the way many people think they do. If they were wise enough to plan and direct the work in the detail which many assume, the size of the organization and character of its makeup would be drastically changed.

Actually what the director and his immediate subordinates do is to provide a proper setup in which men with creative ideas can work freely; to map out the general fields in which progress appears to lie, and finally to weigh the results of research work together with many other factors in deciding how to proceed. The real creative ideas originate hither and yon in the individual members of the staff and no one can tell in advance what they will be or where they will crop up. Every industrial research director has had the experience of having presented enthusiastically a radically new idea about the prospects of which he himself was skeptical. In such circumstances and unless the idea can be shown to be demonstrably impractical, there is only one safe thing that the director can do, namely, to afford opportunity to the originator to develop his idea, with the knowledge that if the individual is right and the director wrong good will result, and per contra, if the director is right and the

individual wrong, the latter will have satisfied himself and not have something which he thought a valuable thing discarded through an act of authority.

As an example of how impossible it is, even with simple things, to forecast the future, I have often thought of how infinitesimally small would have been the chance of any man or group of men, except the one who actually had the idea, planning to invent the common zipper.

In conclusion I should like to mention merely two or three more or less specific things which may be helpful in our later discussion as to fields where it appears that a considerable part of our war science and technology may find substantial postwar application.

I suspect that the field of aviation may be prominent in your minds. There is no question that because the airplane has shown itself to be a powerful military tool all sectors of aeronautical development have been pushed forward during the past three or four years infinitely faster than would have been the case without the impetus of war. This has been true not only as regards the airplane itself and its power plant, but likewise as regards a myriad of adjunct and incidental equipments which are needed for its safe and efficient operation. The same is true of development in those sectors of meteorology which are basically concerned with the character of the medium in which the airplane must operate.

Basically, however, the great bulk of the advances which have been made have not involved new fundamental science discoveries or even new techniques but merely a more intense utilization of existing knowledge and application of established techniques. What we have done in this field has been to concentrate a huge number of trained scientists and engineers on a relatively limited number of definite objectives and, with little or no regard for money cost, hammer out progress in the shortest possible time.

Much of what has been accomplished is with possible slight modification directly applicable to civil aviation, and many of those who have become skilled in the design, manufacture, maintenance and operation of military heavier-than-air vehicles can pass smoothly from the military to the civil sector.

Another and possibly the most spectacular of the wartime technologies is in the field of electronics. Here again, so far as I am aware, little that is fundamentally new has been produced, and yet because of the urgency of the military necessity perfectly astounding technical progress has been made. Here, as in the field of aeronautics, much of the effort has been directed to things of great importance in military operations but of minor importance in prospective civil usage. Much, however, is equally applicable. The much discussed radar devices are an illustration of this. As you know, these devices are an electrical means for detecting objects at a distance with great accuracy as to direction and distance and without regard to atmospheric conditions, such as would forestall the use of acoustical or optical phenomena. Fundamentally, radar does not involve principles which have long been recognized by science but, practically speaking, the application of such knowledge has compressed into two or three years what in normal times it might have taken a decade or two to do.

There is not the slightest reason to doubt that in the postwar era radar in various forms will serve civil needs in a multitude of ways. Collision of ships at sea in darkness, fog and rain should be a thing of the past. Likewise, collision of airplanes with mountains or structures should be uncommon rarities resulting merely from human neglect or the occasional unavoidable failure of mechanical and electrical things.

Finally, I would call your attention again to the fields of medicine and nutrition as fields in which scientific and technical progress under the mighty stimulus of war necessity will have a large direct beneficial application in the postwar era. As I pointed out, these fields, because they are concerned primarily with the saving rather than the destruction of life, have been able to develop during the war, under more nearly normal conditions of free intercourse than has been possible in the fields of the physical sciences. While some secrecy has had necessarily to be maintained in specific cases where the results were likely to have great military value, there has on the whole, I think, been a fair amount of free dissemination of progress in the biological sciences.

Added to this is the fact that war conditions present to the biological technician clinical benefits of a magnitude and kind which can not possibly be approached in normal times. Vast numbers of human beings are assembled together under the regimen of control not otherwise attainable and with opportunity for adequate clinical experimentation involving adequate control groups which not even the largest medical center can provide.

In peacetime the scientist or clinician is likely to be hampered by the desires of the subject. No such inhibition is present in a military organization.

A few new drugs may have been developed and more which had already given promise have been subjected to extensive trial and their merits or demerits largely determined. The present largely discussed penicillin is one of these, and vast preparations have been made for its quantity production from its original natural source. Even here, and in the allied field of possible synthetic production, the techniques which have been employed are not essentially the result of new knowledge but of old knowledge applied in new ways and on an enormous scale.