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ENGINEERING PROGRESS AND THE SOCIAL ORDER[1]

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AT a time like the present, we all realize that something is on trial. Without perhaps being particularly aware of it, civilized man the world over is engaged in sifting and weighing evidence and will sooner or later reach certain conclusions. These conclusions are likely to be of fundamental significance as regards the future ordering of public judgment, and will differ no doubt in important respects from the basic tradition which, in the past, has been acceptable and accepted in guiding much of our action.

It would be very interesting to discover just what it is that stands before the bar. It may be fundamental science, it may be applied science, it may be science and technology in general, it may be religion, it may be domestic politics or world politics, or it may only be that old and primeval scapegoat, human nature, whom the bailiff never tires of bringing to book and who, we now begin to suspect, is quite incorrigible.

Here in brief is the setting for any contemporary discussion of science and technology and their repercussions on the social order. In attempting to identify what is here somewhat loosely designated as the culprit, it is perhaps well to recognize that the public at large will make up its mind irrespective of what any few individuals decide. However, a correct analysis is none the less important because every cor-

[1] Address delivered before the Section on Natural Sciences of the University of Pennsylvania Bicentennial Conference, Philadelphia, September 19, 1940.

rect analysis helps to establish for the future our assurance that we are not utterly creatures of chance, but that if, as a social group, we make the requisite effort we will be able to gauge our social and political environment and build and modify it consciously, as we now control much of our material environment.

Let us begin with the truism that the major problems and troubles of the day have, in considerable measure, a technological and therefore a scientific heritage. Both our civilization and our civilization-destroying engines are mechanistic. In business and in industry—even in that much more fundamental unit, the family—the daily round has become pretty firmly geared to the machine. In optimistic moments we declare that this has brought leisure and has raised the standard of living; but if so, can we also affirm that it has brought liberty and peace of mind? Quite the reverse, for out of it has grown a powerful compulsion that we coordinate our individual and collective actions with almost machinelike precision to the complex activities that go to make up the present-day life of society. To the extent that we fail in our efforts at coordination, the complex social machine of which we are a part goes awry, yielding not plenty and profit but conflict and confusion. Therefore, we might conclude that we are in danger of being plagued by our own knowledge of material things. It manifests itself as a web of exquisite subtlety which, unwittingly, we have been weaving about ourselves. And unfortunately there appears to be no way in which the web can be unraveled. Knowledge once available is destined to be a permanent possession; for all our inventive skill we can conceive of no method by which facts once understood can be forced back into the limbo of the mysterious and the unknown. The road of learning which the human race has been traveling permits of motion in only one direction. To go backward necessarily implies that the species were to become something less than human.

Constraints of Industrialization

A chief source of disquiet is that modern science in its own attainments and in its practical applications has emphasized as never before the gulf which separates the remarkable powers and the equally remarkable limitations of the human mind. In the face of such demonstrated limitations, we must all at times—and especially in the present crisis—have wished that they were not immutable so that something might be done to improve the breed, as it were. However, whatever the view we take toward eugenic programs and the uplifting influence of education, the only hope of prompt relief appears to lie elsewhere.

The mathematicians and physicists have a term which expresses precisely the change which accumulating knowledge seems to have made in our lives. There are in mechanics many problems which involve what are called constraints. The motion of the pendulum bob is a problem involving a very simple type of constraint. The string or wire which supports the pendulum weight converts the problem from that of a freely falling body to one which is compelled to oscillate to and fro indefinitely. The analogy is a good one, for our machines as they become hourly more complex and with more delicately balanced and interrelated parts, are constraining our lives to do likewise. Having created all manner of mechanical devices as aids to living we—as a people with instincts for gears and levers and close coordination—hesitate to sacrifice their marvelous efficiency by failing to meet the heightened standards of dexterity and cooperation on our part which their successful operation demands. The inevitable result is that our mode of living is becoming more and more determined by the presence of invisible but none the less compelling constraints.

What, then, is to be the antidote to our expanding knowledge of material things?

Alternatives Very Limited

This is not the place to discuss whether our association with the mechanisms of which the constraints are concomitants imparts adequate recompense for the resulting loss of freedom. Time alone will answer this question. But since most of mankind gives evidence of being fascinated by mechanism as well as welcoming the excitement of teamwork—that is, of being a cog in a machine provided only that the machine appears to be going somewhere or accomplishing something and is running rapidly enough—it seems reasonable to suppose that the growth of constraining influences will of itself scarcely be regarded as an unwelcome curtailment of action.

But whether this is so or not, we are faced with a startlingly limited array of alternatives. Recent events in Europe are of course the chief source of evidence in this regard. Should this nation or any western nation decide now or at some future time that the machine era has, so far as it is concerned, begun to display diminishing returns, there might be little that it could do to extricate itself, for the constraints of the machine are not alone of a kind which *counsel* conformity on our part, they include another kind which might very effectively *compel* it.

To be sure, history records that no dictatorship has long endured, having always proved the prey of disruptive forces working either from within or from without or both. But in this respect will history be able to repeat itself? We lack no evidence that through science and engineering the essential paraphernalia of dictatorship are much more effective than ever before. It is probably not wide of the truth to say that a few squads of men with modern tanks

are about as effective for purposes of offense as one of Caesar's entire armies. The unarmed mob, which in the past has so frequently been able to take matters into its own hands, is no longer a match for as much as a corporal's guard equipped with machine guns of recent design. And as a means of holding whole populations in submission, the airplane may prove itself to be a very decisive weapon. It has amply demonstrated that in densely peopled areas it can, unless strongly opposed, be the means of levying heavy toll upon civilian life and property, and apparently upon something even more vital, namely, civilian morale.

So it seems manifest that from the standpoint of the group—not alone the individual—we should regard very seriously the effort needed to overthrow authoritarian rule, once it becomes established; and this would be true even though it became utterly repugnant to its subjects. There is apparently something new to history—namely, the possibility that a minority can effectively secure control of a majority. We see not alone what can happen within national boundaries, as in each of the totalitarian states, but more significantly, we see an entrenched minority extend its sphere of conquest to much larger circles beyond its national boundaries.

While the full future consequences of these recent developments are not easy to gauge, it seems essential to attempt a re-evaluation of available political methods and instrumentalities, that we may thereby select those best suited to cope with the conditions obviously imposed by present-day technology. Our inherited social techniques give evidence of having lost an important measure of contact with reality. In an ideal sense one may still applaud Franklin when he said, "They that give up liberty to obtain a little temporary safety deserve neither liberty nor safety." But the vital fact to-day—and we see that it has but recently injected itself—is that a minority who are willing to sacrifice their own liberty, or who perhaps have been so unlucky as unintentionally to lose it, can compel a majority who cherish liberty to lose theirs. The most effective avenue of escape seems to be to find some way of preventing the minority from giving up their liberty. Failing this, little better than a Hobson's choice remains so far as the majority is concerned. They may elect either to lose their liberty by being worsted in a struggle for which they are improperly prepared, or if they act in time they may, by submitting in large measure to totalitarian methods, put themselves in condition to resist attack successfully. Now that mankind is in possession of the weapons made possible by modern technology, the planet has grown too small to support simultaneously the type of government which the modern dictators advocate and the type which we associate with liberalism. To combat the Nazi type of "total war" there is only one possibility—that of *total peace.*

The foregoing argument would only be strengthened were consideration given to such additional factors as wage, price and profit controls. Here again the liberal state as it now operates is at a distinct disadvantage. The authority necessary to establish such controls is entirely repugnant to the liberal way of life, except in so far as they can be worked out by voluntary acquiescence on the part of the individual. Yet the energetic waging of war—and in fact the energetic waging of commercial war in times of nominal peace—threatens to involve the equivalent of these authorities in the highly integrated modern industrial state and also in the world at large. In a word, unless the liberal nations, and those who would be liberal, have the world largely to themselves so that they can control the rules of the international game of give-and-take, they run a grave risk of proving but pawns in the hands of totalitarian powers.

Dangers in Planned Economy

Now it is proposed to discuss this situation not from the standpoint of the social sciences, but from that of the physical sciences and technology.

The purpose of the argument thus far has, of course, been to suggest that the free nations must alter in a fundamental fashion their methods of solving social and political problems. But let it be noted immediately that no planned economy will be advocated as the alternative. The gap which separates the planned economy from dictatorship is likely to be extremely narrow, if not in reality non-existent. It has frequently been pointed out that national planning, irrespective of the innocence with which it is launched or the beneficent ends held in view, will inevitably lead to dictatorship provided the political authority is created to enforce the plans when once they have been made. Time does not permit our retracing the argument to-day; suffice it that it has strong presumptive validity. As has already been noted, an increased complexity of function is being imparted to our social, industrial and political life by a growing technology; this demands a wider variety of specialized trainings and skills, and also calls for closer coordination between these specialized groups to the end that more rigidly guided and more narrowly confined spheres of action are imposed upon the individual. Since increasing emphasis upon specialization connotes planning while the increased need of guidance suggests dictatorship, we see that the two conditions are likely to merge *unless* great care is exercised to hold them apart.

Much depends upon that word "unless." What

procedures are at once compatible with preservation of the individual's freedom of action and yet with the need of circumscribing and directing his activities? There seems to be but one single practicable possibility, that of voluntary and educated guidance imposed by the individual himself, and consonant with enlightened public opinion. In other words, we can but base our policy upon the old political axiom that the source of all liberty is enlightened self-restraint. Before this audience it is not necessary to contrast the casual, not to say misinformed, methods frequently employed by representative governments in transacting their business, with the painstaking studies which underlie most operations of private business. Present-day evidence of faulty stewardship by representative government is swelling to such a volume that we are in some danger of being confused and misled by its very bulk. Haphazard political methods must go. The operation of government on the basis of uninformed popular hunch and whim, coupled with political self-interest, can only end in absurdity, if not in disaster.

Wider Knowledge Demanded

We are now at a stage where we possess "a little knowledge"—and are finding that it displays a peculiarly dangerous aspect. However, we will see clearly as we proceed that henceforth we must put our faith in the persistent and effective pursuit of broader knowledge, and at the same time give increased attention to its popular interpretation. This second point is as important as the first. Knowledge in the possession of a few who are without authority is powerless and useless, while knowledge in the possession of a few with authority to employ it is likely to be indistinguishable from totalitarianism. Final authority must be vested in the people if they are to retain their sovereignty, and understanding must be theirs too if the authority resting in them is to be used intelligently. Any other arrangement leads to concentrated control, since absence of control and likewise unwise control, under modern circumstances, are self-defeating alternatives.

Augmented knowledge seems, therefore, to be the sole key to liberalism's dilemma. The time has passed when, either in war or in peace, random and uninformed decisions in matters which at all vitally affect the body politic can be tolerated. Hence, what is now urgently needed is a new instrument of inquiry and investigation by which representative government, even in the face of novel circumstances, can educate itself "to act with vigor and economy," a phrase which you will recognize as borrowed from Henry Adams. It is his definition of an educated man, and it suggests precisely the status to which we must publicly attain.

In the search for an agency to be employed in the more effective pursuit of knowledge, we believe technology can offer a promising but as yet not widely recognized pattern.

It comes about in this way. To an increasing extent the larger problems of technology have become so involved that no single mind can cope with them adequately. As a concrete illustration—and no apology is made for the fact that it happens to be one with which the authors are especially acquainted—consider the dial telephone system as it now operates in a large metropolitan area. To any one at all familiar with the multitude of relays and opening and closing contacts, which must function to handle a single telephone call, the opinion will come as no surprise that it is one of the most complicated mechanisms yet devised. To comprehend it in all its ramifications, let alone to have developed, designed and built it, is a task probably beyond the capabilities of any single mind. Certainly, if its development and fabrication had waited upon the discovery of a sufficiently gifted individual who could have carried out the work himself, we might not have seen its completion for many a generation.

As an example the dial telephone serves our present purpose very well, but bear in mind that it is no more than typical. The importance of the illustration lies in the fact that instead of being content with the sort of undertakings that the individual human mind could handle, science (at least as concerns many departments) has forged ahead in the domain of organization and has succeeded in creating a sort of super-being which is vastly more effective than the unit individual. Each modern, large industrial research laboratory, such as characterizes the electrical and chemical industries, is an instance of such a super-being. It is scarcely necessary to analyze the situation in detail. The basic fact is that more and more, due to his inherent limitations, the lone worker is being replaced by a carefully chosen corps whose various talents dovetail together and whose collective knowledge and collective analytical powers greatly exceed those of any single member of the group. When working as a unit, the capabilities of such a group, measured by results, are likely to exceed by a considerable margin the sum of any individual achievements possible to its members. In essence of course it is simply the division of labor applied in the intellectual field.

To make this fact a little more evident it might be mentioned that the laboratory with which the authors are associated comprises about 4,500 employees, one half of whom are skilled scientists and technicians, while the remainder include very essential laboratory assistants and service groups. Experience speaks so strongly that to-day no verbal argument is needed to

justify the existence of such a centralized research and development organization. No single individual, nor indeed a widely scattered but equal number of individuals, could hope to match the analytical and creative powers which such a laboratory, long accustomed to mutual effort, can focus upon its chosen field.

THE GERMAN METHOD

Thus the physical sciences display a prototype of the exploratory organization with which it ought to be possible to attack our larger social, economic and political problems such as give evidence of having outgrown the reach of former methods of solution. Moreover, at least one illustration may be cited that the method of the industrial laboratory is already proving effective when thus transplanted. It should come to no one as a surprise that Germany under Hitler has become none other than a vast laboratory dedicated to the perfection of the arts of war. It is not necessary to hypothesize any unusual skill at organization to explain the startling character of recent Nazi military achievements. The answer lies in the simple fact that the present German technique applies systematically and energetically to the affairs of a nation at war the precise methods which have characterized much of American industry for a generation or more.

It is well to recognize the type of human machine against which at any moment we may be pitted; we have here unimpugnable evidence that to wage a modern war successfully, and against a nation which has purposely set itself up as a war machine, involves detailed cooperation among all of a nation's population groups. Such a war machine may not actually rank in mechanical complexity with the dial telephone exchange, but it is clearly one of the more involved creations of modern science and industry. If a potential enemy, under dictatorship, chooses to focus all his powers upon its operation and coordinate its functioning by the same carefully drawn schedules that characterize industry, he leaves little choice but for other nations to adopt the same concerted methods as himself.

We are now witnessing a contest of strength between types of organization. In war the totalitarian state is proving itself a most potent adversary. It may in fact go further and succeed in proving also to have great survival power following war, unless perchance experience ultimately reveals that there is no branch of the human race—not even the Teutonic—so constituted as to submit indefinitely to the degree of dictation and regimentation that totalitarianism involves. Much as one might wish otherwise, there is little comforting evidence that a population working under the duress of dictatorship will lose significantly in efficiency. Certainly if any people were ever bludgeoned into submissiveness it has been the Germans under Nazi rule—in spite of which they continue to carry out orders of state with notable efficiency. It remains of course for the future to reveal whether such will be the case in peace as well as in war. If it should, then a new world situation indeed has been created.

DIFFICULT PROBLEMS OF PEACE

There are other reasons, however, and equally cogent ones, for believing that the time has come when a nation must institute a mass intellectual attack upon its social and political problems. For instance, was it not recent ways of peace which led to the present war? In other words, has the world yet learned to live at peace? Here it is that problems will arise whose calibre probably exceeds those presented by war, problems far exceeding the grasp of our present political methods of solution. Such problems become more and more the substratum of our daily lives in proportion as we base our livelihood upon the closely interrelated routine demanded by efficient operation of an industrial society. But the future prospect is certainly not one of unmitigated difficulty. Wise decisions and enlightened programs tend to induce a simplification of the political future. It is unwise and misguided national actions which lead us into political crises and morasses. Nevertheless, in the face of our growing involvement in the results of our own creative activity in the technological field, it behooves us to undertake a purposive improvement of those organizational forms which promise to be most effective knowledge-getters. Outstanding among these is the large research institution which assembles, in intimate association, a considerable number of experts whose professional knowledge and skills merge in harmonious cooperation.

It will already have occurred to the reader that the analogy between the manner in which a modern corporation employs its laboratory and the manner in which an equally modern state might employ a similar investigative and advisory body, is startlingly close. Therefore the argument will not now be labored. The only outstanding difference, and it is one which would not appear to be significant, is that in the case of the state with representative government the public is served by a corporation around whose board it occupies all the directors' seats. This is precisely the allocation of powers and duties which is contemplated in the formula, "Government of the people, by the people and for the people." Whatever advisory and investigative bodies the management of the state—that is, government—is authorized to create, the public as its own board of directors will be in possession of

the findings of such bodies and, moreover, can demand that its chosen representatives properly employ them in their acts and policies.

Lack of Laboratory Control

In advocating that for the more effective pursuit of the knowledge which efficient public management presupposes, the industrial laboratory offers an admirable starting point, certain fundamental difficulties should not be overlooked. Thus, the methods of attack in regard to problems of state must differ in certain regards from those employed in technology. As is universally recognized, the basis of the experimental method in science is deliberate control of the factors and parameters which enter any problem. This is quite possible when dealing with the inanimate, but by and large there will be scant opportunity for the employment of such arbitrariness when studying the questions involving animate creations. This limitation assuredly makes the approach more difficult but does not rule out the attractiveness of the mass attack; if anything, it makes it more imperative.

And by the same token we must not be discouraged by the observation that while the problems of technology are in considerable measure quantitative and therefore susceptible of being stated in concrete and uncontrovertible terms, the problems of government, in proportion as they are difficult, defy reduction to simple methods of measurement. Here again as the challenge mounts, the need of organized study and analysis surely increases. Moreover the quantitative character of industrial problems is frequently more apparent than real.

In the social sciences, as in industry, there would be need to reduce findings to terms suited to general consumption. One of the commonest charges against the scientist is that while he may be very successful in discovering new facts, he is likely to fail or be indifferent to the description of them in terms which the so-called popular audience can comprehend. Whether the fundamental scientist who is primarily engaged in charting unexplored territory is justified in more or less disregarding the charge—and doubtless most would agree that in large measures he does disregard it—the problem is one which the successful industrial laboratory can not set aside. Its principal duty, in fact, is so to interpret its findings and conclusions that management, who while highly skilled in many essential ways is not likely to be skilled in scientific principles and terminologies, can make its decisions intelligently in so far as they ought to take the work of the laboratory into account.

And, finally, an additional comment will help to clarify the discussion. It resolves itself in brief into the question of who gives the orders in industry, management or the laboratory. It is obvious that in all matters primarily technological the laboratory is, or ought to be, supreme. Its purpose is clearly not to attempt to carry out the whims of management; its duty and prerogative are to develop and urge new instrumentalities and, in its expert capacities, to advise management as to what projects may be embarked upon with reasonable assurances of technological success. In a very real sense, therefore, orders go from the laboratory up to management. Nevertheless, the duties and responsibilities of management remain clearly defined. In the last analysis all decisions are within its province and are its proper function. Aside from the aspects of the business which the work of the laboratory does not touch, it is the duty of management to decide what products of research shall be introduced into circulation, and when, as well as what, in general, the future projects of the laboratory shall be. But in many such matters a management that is well advised will earnestly solicit the full cooperation of the laboratory before pronouncing final judgment.

Existing Political Analogies

Summing this up very briefly, the plan under which industry operates is seen to epitomize much of the republican form of government that our founding fathers intentionally created for the United States as a whole.

And in this connection it is well to bear in mind that there has been much loose talk in recent years regarding the identity of republican and democratic forms of government. Such is far from the truth. A republic is characterized by elected representatives who act in accordance with their own best judgment; in a pure democracy, each question is settled in accordance with the will of the majority. The former has proved workable and most of us devoutly hope that it will preserve this merit; the latter has never been workable, and there is less chance for it in the future than there ever has been in the past. The distinction between a republic and a democracy is one which the fathers of our Constitution had very clearly in mind; to quote one of them, James Madison, in the Federalist papers—"Democracies have ever been spectacles of turbulence and contention and have ever been found incompatible with personal security and the right of property, and have in general been as short in their lives as they have been violent in their deaths."

Without entering upon a discussion of the relative practical merits of a republic versus a democracy, it is nevertheless reassuring in view of Madison's observation, that the suggested use by government of organizations of technical experts whose existence is a continuing one and whose function is advisory to the elected representatives of the people is in every respect a republican institution. The proposal does not imply that the people as a whole must weigh detailed

and involved evidence. It asks only recognition of the fact that over the years public respect for informed opinion has developed surprisingly, and hence will probably continue to rise. This in itself is a singularly notable phenomenon. No longer is the expert, and particularly the expert in science, the object of disdain or suspicion. Rather he is the medicine man of the present epoch and his word is usually accepted as authoritative. In other words the pragmatic success to which science and organized knowledge have attained has established a tradition that what counts in the world to-day is accuracy and truth, not guessing. This represents progress of the highest order. It means that the public mind is ready to accept a wider application of the scientific method—or the nearest approach to this method which is practicable in the affairs of state—and would bestow upon the information and conclusions thus provided the same high regard that it metes out to the more ordinary applications of logical investigation. In a word, that all-important person, the man-in-the-street, has become intuitively aware of a golden truth attributed to Marcus Aurelius, namely "To change thy mind and follow him who sets thee right is to be, nonetheless, the free agent that thou wast before."

However, it should be emphasized that there is still much room for progress in this respect. The many methods of inculcating a popular understanding and respect for the value of unbiased inquiry should receive even more earnest support than heretofore, and doubtless outstanding among these are the science columns of the daily press, the popular science journals and the science museums.

The Machinery for Political Investigation

It is not the present intention—nor indeed would space permit—to venture any detailed suggestion as to the various organizational mechanisms which might be set up to procure the knowledge which must be procured if the liberal form of government is to maintain its workability. At the same time nothing said here is intended to imply that the practical problem which must be solved is anything short of extremely difficult. Its solution will quite obviously call for a very high order of statesmanship and political invention.

Let us note, however, that suggestive models and experience are already available. As regards certain fields of science, routines are now in existence whereby an independent and highly competent group of experts may render advice to the Federal Government. These routines had their origin in problems arising during the Civil War, and with certain additions the routines have remained in effect. The body of talent which is on call for consultation is the membership of the National Academy of Sciences or such other experts as the Academy may choose to select. During 1917 the pressure of war work became such that need of closer advisory routines led to the creation of the National Research Council, a body subsidiary to the National Academy and one which has had a continuing existence. Finally, as a result of the present crisis, the machinery of cooperation between the Federal Government and the nation's scientists has been further enlarged by an Executive Order creating the National Defense Research Committee. It is interesting, but perhaps not overly significant, that it has been war or the threat of war which has led to the creation and the elaboration of this machinery as well as to the periods of its extensive use.

In conclusion, it seems likely that we are well launched upon an era during which all the existing advisory aids to the government, as well as others still to be created, will have to function with increasing vigor. Such an arrangement need not savor of bureaucracy. The sovereign people will still remain sovereign. But belated and constructive recognition will have been given to the fact, now abundantly clear, that the day is gone, and probably forever, when a successful state can base its policies upon clamor of pressure groups or upon the uninformed beliefs of the majority, even though measured numerically by tens of millions.

OBITUARY

FRANCIS HOBART HERRICK[1]

Francis Hobart Herrick was born in Woodstock, Vermont, November 19, 1858, the son of the Reverend Marcellus Aurelius and Hannah Andrews (Putnam) Herrick. He attended St. Paul's School at Concord, New Hampshire, was graduated from Dartmouth College in 1881, earned the degree of doctor of philosophy at the Johns Hopkins University in 1888, and received the honorary degree of doctor of science from Western University of Pennsylvania in 1897 and from Western Reserve University in 1936. Immediately after having received his doctorate at the Johns Hopkins University he came to Western Reserve University as instructor in biology, to found what has since become a great university department of biology, including zoology, physiology and botany with their allied specialties. In 1891 he was appointed professor, and assumed permanent directorship of the laboratory. He retired from active service in 1929, becoming professor emeritus.

[1] From a tribute at memorial services in Amasa Stone Chapel, Western Reserve University, September 14, 1940.