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THE MOBILIZATION OF SCIENCE IN NATIONAL DEFENSE[1]

By Dr. FRANK B. JEWETT

CHAIRMAN OF THE BOARD, BELL TELEPHONE LABORATORIES

There is perhaps no audience before which the role of science and engineering in modern warfare can more appropriately be discussed than one composed of members of the Institute of Radio Engineers. You are primarily communication engineers and of all the branches of applied science, that which has to do with the rapid transmission of intelligence is perhaps most vital to the successful use of the modern fighting instrumentalities. Rapid movement of troops and supplies over far-flung lines of action on sea and land and in the air are possible only on the basis of very effective systems of radio communication. In fact, more and more are means of communication assuming the function of a unifying influence which pervades the other arms of the military organization. They coordinate the movement of naval and aerial fleets. They enable infantry, tank columns and formations of planes to operate as a single effective unit. They shrink, as nothing else can, a 2,000-mile battleline to the compass of a single sector.

The telephone and telegraph and particularly the radio telephone and telegraph are, in effect, the keystone of the whole military arch. You members of the Institute of Radio Engineers are, therefore, exponents of a very vital department of technology, and I am particularly grateful to you for affording me

[1] Winter convention, Institute of Radio Engineers, Hotel Commodore, New York, N. Y., January 12.

the opportunity to speak here at this time to discuss the mobilization of science in the war program.

Further, it is not merely in the fields we ordinarily think of as communication that men who have devoted their lives to the problems of radio development are in position to render great service.

One of the striking things connected with the development of new military tools, both offensive and defensive, is the astounding extent to which the fundamental phenomena on which electrical communication is based are employed. In some cases it is application of established techniques in entirely new fields. More frequently it is the pushing of our frontiers of knowledge farther out, and then applying that knowledge to the problems of war in three-dimensional space. Basically, every military problem hinges on the rapid and exact location of an enemy objective and in transmitting and utilizing the knowledge acquired. This may be for the guidance of a commanding officer; the accurate pointing, fuse setting and firing of a gun; the release of an aerial bomb, or any one of a hundred similar things. Every single physical phenomenon which can be employed must be examined. Because modern science has changed the conditions of warfare from a slow-moving affair in localized areas to one of great rapidity over incredible distances of land, sea and air, it is imperative that those phenomena which have given us radio be developed and utilized to the full.

While the initial problem is one of intense research and development, each step forward involves great numbers of skilled technicians in design, manufacture, maintenance and operation of new implements. It seems clear that the demand for men trained in our art is bound to be enormous, not alone in the laboratory but in the services of supply and in the combat forces as well.

For fifteen years following the first World War there were frequent articles on the probable role of science in future warfare. While this was quite natural in view of the part played by the airplane, the tank and lethal gas in the titanic struggle of 1914–18, the articles in the main evoked interest rather than concerted action directed toward full employment of science in preparation for more wide-spread and more deadly warfare.

Despite the fact that the decade and a half following the war was a period of the most productive activity in fundamental science research and of intense effort to apply old and new knowledge promptly in industry, this *laissez-faire* attitude in the military sector was largely a reflection of men's attitude generally toward war. The weariness of the struggle and the distaste for carnage and destruction, coupled with a naive faith that men had learned finally the lesson of war's futility, gave rise to the era of small appropriations to the military, to disarmament conferences and to the League of Nations and similar efforts to organize the world for a settlement of international controversies by reasonable methods rather than by recourse to mass murder.

In the United States particularly, the decade of the 1920's saw this carried to the extreme. Warships were taken to sea and sunk or were laid up and the Army was reduced to the status of a moderate sized police force—a force so small and scattered that no really effective training or development of radically new implements could be had. Appropriations were cut to the irreducible minimum of maintaining a national agency which the country would have liked to abolish entirely had it quite dared. In this atmosphere and under these handicaps it is to the credit of the Army and Navy that they did as well as they did. There was little money to spend on development and less still for research to produce entirely new instruments of war.

When the storm clouds of another world war began to form in the middle 1930's, the volume of articles on the place and importance of modern science in warfare increased enormously in both the scientific and lay press. So, too, did discussion of the need for insuring that scientific and technical men should be utilized in the fields of their competence and not inducted indiscriminately into the combat services where men of less specialized training could serve equally well.

So far as lay discussion was concerned, it was largely emotional, frequently ill-informed and sometimes fantastic. Naturally, discussion among technical people was more realistic, but on the whole was mainly related to applying newly acquired knowledge and techniques to the improvement of existing military implements. The idea of organizing scientific research on a huge industrial scale, where the ultimate end of "all out war" was the industry to be served, was slow to emerge.

Probably the most difficult hurdle every industry has had to get over in the effective introduction of scientific research as a powerful tool in its operation, has been to realize that the most profitable research is that which is carried on with the least restraint imposed by current practice. Practice can be adapted to radically new ideas, but radical ideas rarely, if ever, evolve from mere improvements in current practice.

Research in military matters is no exception. War being a very ancient art, military men are on the whole extremely conservative as to new tools. Like doctors, long experience has made them cautious and with possibly a more than ordinary tendency to impose on a research project requirements of current practice which, in fact, hamper rather than help. Against this tendency is the fact that they are quick to adopt the radically new once its utility is demonstrated. War more than any other of man's activities puts a high premium on being in the lead.

As soon as war in Europe on a vast scale was seen to be imminent, the nations there commenced frantically to mobilize and organize their scientific and technical men and resources, and to establish effective liaison between them and the combat services. For more than a year after this movement was in full swing across the Atlantic, our aloofness from the struggle and our ardent desire to keep from being sucked into the tragic maelstrom operated to prevent any effective steps in the direction of mobilizing our vast scientific resources for total war. The military services endeavored to strengthen their scientific branches and here and there enlisted the aid of civilian science. They were hampered by inadequate funds, by the pattern of years of a starved organization imposed by an anti-war philosophy, and by the fact that civilian sciences, both fundamental and applied, were built up on a basis of operation in a slow-moving peace economy. The latter had no machinery for marshalling its forces for war and, in the main, it knew little of war's requirements and frequently preferred to follow the courses it understood and liked.

But about two years ago, it became apparent to a few individuals that the *laissez-faire* approach to the mobilization of science ought to be abandoned in favor of a more direct and forceful organizational approach. At that time there existed certain technical groups and associations which, on the one hand, called for strengthening, and on the other were of suggestive value in the search for a suitable organizational set-up. I have already remarked upon the scattered technical groups and laboratories within the Army and Navy which over the years had been doing commendable work, but had been given insufficient funds and encouragement. It was, of course, obvious that as the tension of the emergency increased, the responsibilities placed upon these technical groups would mount with a resultant need to augment their personnel, but it was equally apparent that they could not be expected to carry the full load of scientific development and adaptation.

Civilian participation in one way or another in the solution of military problems has come to be taken for granted. It was first given official recognition in the United States when the National Academy of Sciences was incorporated in 1863 by an Act of Congress. The charter of the academy requires that whenever called upon by any department of the Government, it shall investigate, examine, experiment and report upon any subject of science or art, the actual expenses of such investigations, experiments and reports to be paid from appropriations which may be made for the purpose, but the academy shall receive no compensation whatever for any services to the Government. The academy is, therefore, recognized as a continuing official adviser to the Federal Government and it must attempt to answer such questions of a scientific or technical nature as are officially submitted to it by members of government departments. A permanent channel of communication was thus created, but power to initiate traffic over it resides with the Government and no auxiliary machinery was created whereby the academy or any other civilian agency might take the initiative in bringing before the Government matters of scientific importance.

Less than a year prior to the entry of the United States into the first World War, a significant step was taken designed to facilitate the use of the channel of communication between Government and the National Academy. In 1916 the National Research Council was created by President Wilson, and a little later was to play a part in focussing civilian effort on the military problems then arising. The National Research Council was, and is to-day, a subsidiary of the National Academy of Sciences and, like the academy, is largely an advisory body only and awaits the assignment of problems by one or another branch of the Government before it can go seriously to work. Moreover, the council, like the academy, is not in possession of free money, a corporate laboratory and other research facilities and is, therefore, not well constituted to conduct research work on any extensive scale.

We turn our attention, therefore, to another agency contemporaneous with the National Research Council, which was created for the express purpose of establishing cooperative effort between military and civilian groups, and which was provided by Congress with funds necessary to create research facilities and to operate them when once created. This agency is the National Advisory Committee for Aeronautics, commonly known as the NACA. The law which created the committee provides that it shall "supervise and direct scientific study of the problems of flight, with a view to their practical solution," and also "direct and conduct research and experiment in aeronautics." The committee is composed of fifteen members, including two representatives each of the War and Navy Departments. Throughout its more than twenty-five years of existence, the NACA has given ample testimony of the fruitfulness of cooperation between military and civilian groups, and moreover has provided a prototype as to an organizational arrangement for effecting such cooperative effort successfully.

When, some two years ago, the group to whom I have already referred became convinced that broader participation by civilian scientists in the whole military program was likely to be essential, they regarded the NACA as typifying the sort of organization they would like to see created. A plan was therefore drawn up envisaging a committee composed in part of civilian scientists and in part of Army and Navy representatives. On the one hand, the committee was charged with a broad study of the materials of warfare and, on the other, it would recommend and, if possible, initiate such research as they believed to be in the national interest.

The NACA was created in 1915 by an Act of Congress. The somewhat duplicative plan just referred to was submitted to President Roosevelt about a year and a half ago for such action as he saw fit to take. The proposal appealed to him and he decided to create the committee by Executive Order. This order established the committee as a division under the Office for Emergency Management and confers upon them power to take the initiative in many scientific matters which they believed to have military significance. It also directed the committee to develop broad and coordinated plans for the conduct of scientific research in the defense program, in collaboration with the War and Navy Departments; to review existing scientific research programs formulated by these departments, as well as other agencies of the Government; and advise them with respect to the relationship of their proposed activities to the total research program. Moreover, and this is especially important, the order directs them to initiate and support scientific research on the mechanisms and devices of warfare with the object of improving present ones, and creating new ones.

The order contemplated that the committee would not operate in the field already assigned to NACA nor in the advisory field of the National Academy of Sciences and National Research Council. Parenthetically, it might be noted that in this latter field the academy and council are currently engaged on advisory work for Government for which the out-of-pocket expenses alone are at the rate of much more than $1,000,000 a year. A recent count shows that the present personnel of Academy and Research Council advisory committees runs to about 225. These figures will give an idea of the vital part which these fact-finding groups are playing in the present emergency. But to be a little more specific I might mention that one important committee of the National Academy is advising the Office of Production Management on the availability of strategic materials.

In order to formulate adequate rules for the utilization of materials of whatever sort, accurate knowledge as to their availability, as to new processes suggested for producing them, as to possible substitutes, and a thousand and one other basic questions must be answered. This can only be done by highly trained scientists and engineers. Only after they have answered can the urgent problems or proper utilization be handled. The academy has assembled a group of the most distinguished men in the United States to give OPM this basic information.

Other examples are to be found in the services which the National Academy of Sciences and National Research Council are giving in advising the military departments on highly confidential matters; in the fact that the Medical Division of the National Research Council is the operating arm of the Medical Research Committee mentioned later, and in the service the council is furnishing in selecting technical personnel.

Thus, in June, 1940, the National Defense Research Committee, more familiarly known as the NDRC, was born. It was constituted of eight members, two of these being high-ranking men from the Army and Navy, respectively, five more being civilians well known for their experience in organizing and directing both fundamental and applied scientific research, and as an eighth member, the Commissioner of Patents.

The Executive Order creating the NDRC omitted any reference to the biological sciences, and, in particular, to the medical sciences. However, during its first year of operation, experience accumulated to the effect that a broader program of attack would not only be useful but was, in reality, urgently demanded. This realization prompted a second approach to President Roosevelt, with the result that in June of last year he created two new functional groups. One of these was the Committee on Medical Research, to explore its indicated territory in the same manner that the NDRC had been exploring the physical sciences. Then, over and above both the NDRC and the Committee on Medical Research, there was placed the Office of Scientific Research and Development, usually referred to as OSRD. This latter office was placed in charge of Dr. Vannevar Bush, who until then had been chairman of the NDRC. President Conant of Harvard was then made chairman of the NDRC and Dr. Newton Richards, of the Medical School of the University of Pennsylvania, was made chairman of the CMR.

In order to insure complete coordination of civilian and military research and development, Dr. Bush, as director of OSRD, was provided with an advisory council consisting of the chairmen of NDRC, CMR and NACA; the coordinator of naval research and the special assistant to the Secretary of War performing a somewhat similar function in that service.

The Executive Orders creating these various committees naturally had to leave indeterminate the question of financial support. They are all subsidiary to the Office for Emergency Management and, like this office, must look to Congress for the necessary operating appropriation. Thus far the appropriations, while not munificent, have been adequate. During its first year of existence the NDRC authorized research projects which totaled about ten million dollars. At the beginning of its second year, it was granted another ten millions and this was recently augmented by several millions more. To be more specific, the OSRD, during its first year of existence, will guide the expenditure of about twenty millions throughout the whole scientific field.

I should now like to take a few minutes of your time to explain the manner in which the expenditure of these funds is initiated and supervised. To begin with, let me point out that the work of the NDRC is divided into four major departments: Division A, of which Professor R. C. Tolman, of the California Institute of Technology, is chairman, deals with armor, bombs and ordnance, in general; Professor Roger Adams, of the University of Illinois, heads Division B on chemistry; Division C deals with transportation and communication and submarine warfare, and I am its chairman (this division operates the subsurface warfare laboratories); finally, Division D, which deals with instruments and numerous miscellaneous projects difficult to catalogue, is headed by President Compton, of the Massachusetts Institute of Technology. It is in this division that the micro-wave laboratory is organized.

To expedite discussions, surveys and the general handling of the work, a further breakdown has been found desirable, the result being that each division comprises several so-called sections. Division B on chemistry, under Professor Adams, is divided into thirty-one sections—which stands to date as a sort of record.

The work of a section is entrusted to a section chairman, who in turn calls to his aid certain individuals who become permanent members of his sectional committee and who are known technically as members. Then there are others who may be asked to render advice and assistance from time to time and hence are called consultants. Members and consultants are officially appointed by the chairman of the NDRC and are designated only after official clearance by the Army and Navy Intelligence and the FBI. Full consideration is therefore given to the basic requirements of the military services as regards the confidential handling of their problems. Because of its peculiar interest to you, I would note that the section dealing with communication problems is under the direction of Dr. Jolliffe, who is a vice-chairman of Division C.

Neither the five civilian members of the NDRC itself nor any of the section chairmen, members or consultants are paid from public funds. Without exception, they are loaned to the Government by their employing organizations and frequently the loan is complete, the work being so voluminous and detailed as to require a man's full time. Thus, when I tell you that about 500 of the leading scientists of the country are encompassed in the present NDRC organization, you will see that the Federal Government and even the forgotten taxpayer are getting a lot of valuable consulting talent free of charge.

So far as I have now outlined it, the functioning of the NDRC requires no public money except a very small amount for paid office assistants together with the traveling expenses of members and consultants. For the most part members and consultants do not carry on the research and development projects which the NDRC decides to promote—their duties are advisory and administrative. They formulate the problems which they believe it important to have undertaken, and then arrange with various scientific institutions to carry on the work. It is this last step which brings in the need for considerable sums of money. For instance, a project assigned to a particular university or industrial laboratory may require the full time of several of its faculty together with that of numerous younger men hired specifically for the work in hand.

The number of such projects now approved and, for the most part, contracted out to universities and industrial research laboratories stands around 600, while the number of contracting institutions is over 100; and when it is stated that the total value of the projects thus far determined upon is upwards of twenty million dollars, you will realize at once that the monetary resources of the scientific world would not be adequate to conduct the program on a gratuitous basis. The contracts vary all the way from those involving a few thousand dollars to those calling for two to three hundred thousand dollars per month. I have no doubt but that many of you here to-day are working either full or part time on one or more of these NDRC contracts.

The question is frequently asked as to how many technical people have been drawn into the civilian defense effort which the NDRC directs, but obviously this is quite difficult to estimate, let alone to enumerate in detail. I have already mentioned that there are about 500 scientists in the NDRC organization serving as members, consultants, etc. It seems likely that somewhere between two and three thousand scientists are at work on defense projects as employees of contractors with about an equal number of less highly skilled individuals assisting them as laboratory assistants, technicians, etc. Then, if the situation which

I know to exist at the Bell Telephone Laboratories is to be taken as a criterion, we must add to this scientific group another very considerable array of technical people who call themselves engineers as opposed to physicists and chemists—an array which if enumerated would no doubt total four to five thousand.

Recent figures from the Bell Telephone Laboratories might be of interest as perhaps typifying the situation found in a number of industrial laboratories which are fulfilling defense contracts, some for the NDRC and some directly for the Army and Navy. A rough count shows that about 600 of our technical staff are now engaged directly on a full-time basis on defense projects. When I say that they are "engaged directly" on defense projects, I am excluding those who by circumstances arising out of the defense program have been forced to devote themselves to such problems as the finding of substitute materials and the engineering of emergency telephone projects.

Another aspect of the NDRC plan of operation which I should like to stress is its "no profit" feature. This applies alike to contractors and to employees of contractors. Perhaps this point can be brought out most clearly by reference to a specific situation. The University of California is acting as a contractor to the NDRC on a large project which involves an annual expenditure of around one million dollars. Certain members of the California faculty are employed on a full-time basis on the project and in switching from teaching to defense work have incurred no change in rates of pay. The university has also hired from other faculties certain individuals to augment the defense staff and they, likewise, have gone over without changes of salary, although a payment is made to compensate for the cost of moving in the case of both single and married men. It is also stipulated explicitly that the university, as contractor, will derive no monetary profit from the work and the same requirement is exacted of industrial laboratories and other types of contractors.

The "no-profit no-loss" proposition has involved the adoption of certain more or less arbitrary but seemingly equitable rules of accounting. Thus, a university is usually allowed an overhead payment amounting to 50 per cent. of the salaries which it pays to its members employed on a defense project. Similarly, an industrial laboratory, by virtue of the fact that it has to operate with commercial capital and is subjected to a variety of forms of taxation from which the university is exempt as well as other expenses, is allowed an overhead of 100 per cent. of the salary item.

I suppose it depends upon one's point of view as to whether the effort I have just outlined appears large or small. On the one hand, it seems fairly certain that it is only a beginning and must expand further. On the other hand, it is certainly large already when contrasted with any civilian effort which was able to assert itself during the last war. And looking back to the situation which existed a quarter of a century ago, it is difficult to understand why the then available civilian agencies were not unleashed to an extent commensurate with their obvious capabilities. True, the National Research Council was created to assist with the solution of defense problems, but it was, as I have pointed out, in the position of a doctor waiting for clients; it could not adopt the attitude of an aggressive salesman and initiate attacks on what it regarded to be important military problems. Hence we can declare that as regards organization notable progress has been made.

As to future expansion of our civilian defense effort, it is becoming increasingly essential to bear in mind the potential shortage of trained personnel. Without insinuating anything as to guilt, the chemists declare that this is a physicist's war. With about equal justice one might say that it is a mathematician's war. The visible supply of both physicists and mathematicians has dwindled to near the vanishing point, consistent with the maintenance of anything like adequate teaching staffs in our universities. If this civilian defense effort is to expand, and such indeed now seems imperative, the limiting factor may therefore be a shortage of highly trained individuals and not a shortage of financial aid.

This leads me to state a few general observations concerning the past and future of our work. It is quite apparent that to date the burden of NDRC contracts bears much more heavily upon some institutions than upon others. At the outset this has necessarily been the case. While serious attention has at all times been given to the subdivision of projects so that they could be farmed out as widely as possible, a limit is frequently reached beyond which it isn't practicable to go in the matter of division. And in many cases, no division at all could be entertained, a situation that has given rise to a few large contractors, of which I cited the University of California as an example.

In the assignment of the early contracts, it has been natural, in fact essential, to lean heavily upon those institutions, both academic and industrial, which for one reason or another have been peculiarly fitted to transfer quickly from peace-time to war-time problems. This has been done with a view to conserving time. But the stages of the program to follow will doubtless involve a broader survey of the situation to find locations where new problems can be lodged with a minimum of interference to essential defense work and teaching now in progress. In this survey a guiding principle will be to utilize men and facilities *in situ* whenever possible, thus preserving the "going value" of groups who are accustomed to working together. In the face of crises, the human tendency is usually to do the reverse, it being so easy for central agencies to ignore established but not well-known organizations, and attempt to cope with an emergency by calling workers from right and left to some new location. As a matter of fact, this tendency was beginning to make an appearance even as long as two years ago, when the fundamental plan of the NDRC was under discussion. Had the tide then setting in been allowed to run on for some months unimpeded, the result would inevitably have been a literal army of uprooted scientists in Washington and other central points, sitting around idly waiting for vast amounts of research equipment which had been placed on order, but was not much nearer materialization than that, to be installed in hastily constructed laboratories. This would have been the easy and disastrous way. Fortunately the creation of the NDRC came in time to stem such a tide.

Another present problem, and it is the last with which I shall trouble you, is one which by its existence supplies evidence that real progress has already been made in some of the research programs thus far initiated. It has to do with shortening the time gap between proven laboratory research results and the stage where mass production can be undertaken. Some of the laboratory results already achieved hold such promise that every day which intervenes before their wide-spread utilization becomes a serious matter. Obviously the problems to be met here cover a wide range of equipment and materials—as wide as that marked out by the scientific results themselves—and since they involve large-scale manufacture, the whole plan must be carefully worked out with other official agencies, particularly the Office of Production Management and the armed services. I am sure, however, that we are prepared to meet and solve these problems, and rather than be concerned with the difficulty of making progress along this avenue, I think all who are guiding the work of the NDRC would exclaim to the ranks of scientists and technicians, "Bring on your results, the more the better, and we will guarantee them a speedy passage to the firing line!"

In the foregoing, I have attempted merely to sketch the set-up of organized civilian research and development created for the war emergency. Obviously, it is only a part of the total effort which is being mobilized. It would be unfair to thousands of scientists and engineers to infer that the main results were dependent on the work of these agencies.

The scientific departments of the armed services are being greatly enlarged; industrial laboratories are turning more and more of their efforts to direct and indirect war work and engineers everywhere are active. Fundamental and applied science are on the march.

OBITUARY

HARRY WARD FOOTE

It is with real recognition of the responsibility which is placed upon the writer, a colleague of Harry Ward Foote in the department of chemistry in Yale University, that this report is made. This academic association covered a period of forty-two years of collegiate activity. Hundreds of graduates of the Sheffield Scientific School who enjoyed the privilege of studying chemistry under this inspiring teacher will be grieved to learn of his sudden death on January 14, 1942, in the New Haven Hospital. There were only eight days difference in the ages of Professor Foote and the writer, and we both grew up together in the atmosphere of Yale, and were taught by the same group of inspiring Yale teachers in chemistry: Professor Horace L. Wells, analytical chemistry, Professor William G. Mixter, general chemistry, and Professor Samuel G. Penfield, mineralogy.

Harry Ward Foote will be remembered as a most successful teacher in his special subjects, namely—general and analytical chemistry. He was the kind of a teacher that every American college boy should come in contact with during his academic or collegiate career. He endeared himself to his undergraduate students; he tried to understand each individual man in his class; he played fair with them, and the student was impressed with his spirit of fairness and square dealing. He was a sane thinker, not given to making snap decisions; his advice was sound and helpful. He exercised vigilance and conservatism in the trying days of Yale's reorganization of the university's departments of chemistry, and was recognized for his safe counsel and departmental coöperation.

Professor Foote's courses in chemistry laid an excellent and sound foundation for future growth; widened the student's knowledge and outlook, and encouraged many to get scientific training for themselves. Not only the student body suffers a real loss in the death of Professor Foote, but also the general faculty and departmental staff of the Sheffield Scientific School. He was recognized by his teaching associates as a good representative of democracy, a believer in freedom of speech, thought and action, as long as no infringement was made on the rights of others.