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WAR ACTIVITIES OF THE NATIONAL RESEARCH COUNCIL

BY GEORGE ELLERY HALE, chairman

IT is already a trite saying that this is a war of engineering and science. Yet it is a question whether the average person, or indeed whether even the technically qualified man whose work has been concentrated in a particular field, can realize in how large a sense these words are true. To do so he must survey the vast engineering achievements of the Entente and the Central Powers, and appreciate what countless details they involve and how far their ramifications extend into apparently unrelated fields. At the same time his view must embrace the wide expanse of medicine and hygiene, and the still wider operations of agriculture and the many industries without which the war could not go on. Nor must he be content with this sweeping view, comprehensive though it may seem. For inextricably united with the results achieved by men habitually concerned with the arts, he will find the no less important contributions of investigators in the mathematical, physical, and biological sciences, whose previous efforts have been devoted solely to the advancement of knowledge. Science and the arts have once more united their endeavors, to the advantage of the national defense and to the still greater advantage, let us hope of future national welfare.

In the vast fields of engineering, both military and industrial, the National Engineering Societies have played a truly national part. Merely to enumerate their contributions, in men and in activities of the most varied description, would occupy the entire time at my disposal. I must therefore confine myself to the barest mention of some of the most conspicuous of these activities the prominent part they have played in the work of the Naval Consulting Board, which has contributed in so many important ways to our progress in the war; the gallantry of their members on the western front, where they have proved that the engineer can fight no less effectively than he can build; the countless products, in munitions of war other necessities of national

defense, of the factories they operate; the railways, docks, cantonments, and fortifications they have erected, here and in France; the ships they have sped down the ways to overcome the submarines.

The National Research Council, of whose work I have been requested to speak tonight, has special reasons for gratitude to the engineers of the National Societies. Two years ago, when its organization had just been undertaken, the Research Council was essentially without funds. The Engineering Foundation, established by these societies on Mr. Swasey's endowment for the promotion of research, saw and appreciated the advantage of creating a body for the federation of research agencies, governmental, educational, separately endowed, and industrial. It accordingly placed its entire resources at the disposal of the Research Council, gave it the services of its Secretary and provided an office for the Councils' work in this building. Special contributions from Mr. Ambrose Swasey and Mr. Edward D. Adams enlarged the income available for this purpose, and thus the work of the Research Council was inaugurated. Today when ample funds from other sources have eliminated financial difficulties, the Research Council does not forget the indispensable aid it received from the Engineering Foundation at the most critical period in its existence.

Science in the Civil War

The experience through which we are passing recalls in many vivid particulars, the parallel events of the Civil war. This is true in the field of science, in spite of the popular conception that tends to associate the application of scientific methods in warfare with more modern times. One of the most striking pen portraits of President Lincoln that we possess depicts him on the great tower of the Smithsonian Institution,which he ascended night after night with Joseph Henry, first Secretary of the Institution and charter member of the National Academy of Sciences. From this vantage point lights were flashed to distant stations, in connection with tests of new methods of signalling. It was in such researches for military purposes that the National Academy had its origin.

The period of these experiments was an anxious one. Many months of war, marked by serious and unexpected reverses, had left small room for over-confidence, and taught the necessity of utilizing every promising means of strengthening the

northern arms. With one or two notable exceptions, the great scientific bureaus of the Government, now so powerful, had not come into existence. But the country was not without its leaders of science and engineering, both within and without the Government circle. Davis, fighting Admiral, Chief of the Bureau of Navigation, and founder of the Nautical Almanac; Bache, Superintendent of the Coast Survey, and designer of the defenses of Philadelphia; and Joseph Henry, of whom we have already spoken, clearly recognized the need of a national organization, embracing the whole range of science, to advise the Government on questions of science and art. Joining with them Louis Agassiz the great naturalist; Benjamin Peirce, mathematician and astronomer; and B. A. Gould, founder of the Observatory of the Argentine Republic, they planned the National Academy of Sciences. A bill to incorporate the Academy was introduced in in the Senate by Senator Wilson of Massachusetts on February 21, 1863. This passed the Senate and the House, and was signed by President Lincoln on March 3. This bill, which was subsequently amended to remove the limitation of membership, and to permit the Academy to receive bequests, is given below in its original form:

An Act to Incorporate the National Academy of Sciences.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That Louis Agassiz, Massachusetts; J. H. Alexander, Maryland; S. Alexander, New Jersey; A. D. Bache, at large; F. A. P. Barnard, at large; J. G. Barnard. United States army, Massachusetts; W. H. C. Bartlett, United States Military Academy, Missouri; U. A. William Boyden, Massachusetts; Alexis Caswell, Rhode Island; William Chauvenet, Missouri; J. H. C. Coffin, United States Naval Academy, Maine; J. A. Dahlgren, United States navy, Pennsylvania; J. D. Dana, Connecticut; Charles H. Davis, United States navy, Massachusetts; George Engelmann, St. Louis, Missouri; J. F. Frazer, Pennsylvania; Wolcott Gibbs, New York; J. M. Gilliss, United States navy, Kentucky A. A. Gould, Massachusetts; B. A. Gould, Massachusetts; Asa Gray, Massachusetts; A. Guyot, New Jersey; James Hall, New York; Joseph Henry, at large; J. E. Hilgard, at large; Illinois; Edward Hitchcock, Massachusetts; J. S. Hubbard, United States naval observatory, Connecticut; A. A. Humphreys, United States army, Pennsylvania; J. L. LeConte, United States army, Pennsylvania; J. Leidy, Pennsylvania; P. J. Lesley, Pennsylvania; M. F. Longstreth, Pennsylvania; D. H. Mahan, United States Military Academy, Virginia; J. S. Newberry, Ohio; H. A. Newton; Connecticut; Benjamin Peirce, Massachusetts; John Rogers, United States navy. Indiana; Fairman Rogers, Pennsylvania; R. E. Rogers, Pennsylvania; W. B. Rogers, Massachusetts; L. M. Rutherford, New York; Joseph Saxton, at large; Benjamin Silliman, Connecticut; Benjamin Silliman. junior, Connecticut; Theodore Strong, New

Jersey; John Torrey, New York; J. G. Totten, United States army, Connecticut; Joseph Winlock, United States Nautical Almanac, Kentucky; Jeffries Wyman, Massachusetts; J. D. Whitney, California, their associates and successors, duly chosen, are hereby incorporated, constituted and declared to be a body corporate, by the names of the National Academy of Sciences.

Sec. 2. And be it further enacted, That the National Academy of Sciences shall consist of not more than fifty ordinary members, and the said corporation hereby constituted shall have power to make its own organization, including its constitution, by-laws, and rules and regulations; to fill all vacancies created by death, resignation, or otherwise; to provide for the election of foreign and domestic members, the division into classes, and all other matters needful or usual in such institutions, and to report the same to Congress.

Sec. 3. And be it further enacted, That the National Academy of Sciences shall hold an annual meeting at such place in the United States as may be designated, and the Academy shall, whenever called upon by any department of the Government, investigate, examine, experiment and report upon any subject of science or art, the actual expense of such investigations, examinations, 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 of the United States.

SOLOMON FOOTE,
President of the Senate pro tempore.
GALUSHA A. GROW,
Speaker of the House of Representatives.

Approved, March 23, 1863
ABRAHAM LINCOLN, President.

It will be noticed that the list of incorporators includes many well known names, and that both the Army and Navy are liberally represented. Among the engineers are Brigadier General J. G. Barnard, President of the Board of Engineers for Fortifications and River and Harbor Improvements; Colonel W. H. C. Bartlett, author of a treatise on rifled guns published in the Memoirs of the National Academy; Rear Admiral John Dahlgren, Chief of Ordnance, U. S. N., inventor of heavy guns; Brigadier General A. A. Humphreys, Chief of Engineers, U. S. A., reclaimer of lands inundated by the Mississippi River; Professor D. A. Mahan, Engineer Corps, author of standard treatises on civil and military engineering; Fairman Rogers, Professor of Civil Engineering in the University of Pennsylvania; and General J. G. Totten, Chief of Engineers, U. S. A., distinguished for his development of coast defences.*

*The National Academy of Sciences now elects fifteen new members annually. It has established a separate Section of Engineering, to which three new members were elected at the last Annual Meeting in April.

As the adviser of the Government on questions of science, the Academy was immediately called upon by the War and Navy Departments to report on various problems connected with the war. Among these reports the following may be mentioned:

On the Protection of Bottoms of Iron Vessels from Corrosion

On the Adjustment of Compasses to Correct Magnetic Deviation in Iron Ships.

On Wind and Current Charts and Sailing Directions.

On the Explosion on the United States steamer Chenango.

On Experiments on the Expansion of Steam.

On the Preservation of Paint on Army Knapsacks.

In addition to such formal reports from special committees many members of the Academy contributed individually to the study of war problems. Thus we find in the early records titles of such papers as the following:

F. A. P. Barnard: On the force of fired gun-powder and the pressure to which heavy guns are actually subjected in firing.

Joseph Henry: On materials for combustion of lamps in lighthouses.

J. E. Hilgard: On a chronograph for measuring the velocity of projectiles.

J. E. Hilgard: Note on the changes that have taken place in the bar of Charleston Harbor since the sinking of obstructions in the main channel.

B. A. Gould: Various papers on the stature, proportions, ages, and vision of American soldiers.

W. H. C. Bartlett: On rifle guns.

Most of the work of the members on war problems was, of course, not embodied in published papers, though it formed an important part of the activities of the Government.

This illustration of a national organization of science, including representatives of the Army, Navy and civil branches of the Government, cooperating closely with men of science in civil life, has an interesting parallel in the wars of Napoleon. As a member of the Paris Academy of Sciences, Napoleon fully appreciated the importance of science in connection with war. In organizing his military expedition to Egypt, he drew largely on the membership of the Academy of Sciences, taking with him a most brilliant company of scientific investigators, representing every field of research. While in Egypt, where he invariably signed himself "Le membre de l'Institut, général en chef," Napoleon organized the Institute of Egypt in Cairo, the complete records of which are fortunately preserved in a volume entitled, "Mémoires sur l'Egypte." (Paris An. VIII). From the minutes of the meetings we find that "le citoyen Bonaparte,"

who attended as a member without office, would frequently present requests for the formation of committees to report on such problems as the baking of bread for the armies, and the possibility of making gun powder in Egypt. Other phases of science did not escape his interest, as we recognize from the fact that one of the committees appointed at his request was for the purpose of reporting on the establishment of an astronomical observatory in Egypt. At the same time his architects and archeologists were carrying on extensive studies of the antiquities of Egypt, which are embodied in a superbly illustrated series of folio volumes and mark the first great step in Egyptian archeology, leading to the successful labors of Champollion, Mariette, and Maspero, and the dominance of the French school in Egypt under British administration.

If circumstances demanded, we might easily go still farther back in history to illustrate the connection between science and war, as Alexander the Great took with him on his famous campaigns men of science who determined the positions of captured territory by observations of the stars, and conducted other scientific work. But it is unnecessary to go further into details, since it is clear that any great leader of a state, with sufficient imagination to look at his problems in a large way, must appreciate the importance of utilizing the resources which science has placed at his disposal

Science in the Present War

One of the most striking results of the present war is the greatly increased emphasis which it has laid on the national importance of science and research. The sharp spur of necessity, felt by the Allies soon after the opening of hostilities, drove them to the instant utilization of scientific research—the policy that lies at the foundation of Germany's military and industrial strength. The superficial notion that science itself is to be condemned because of its barbarous misuse in German hands has no place in the minds of clear-thinking people, who perceive, more plainly than ever before, its significance as a fundamental factor in national progress. Statesmen ignorant of the bearing of science on the problems of war have given place to more enlightened men, and all governments that have felt the pressure of military and industrial necessity are now vying with one another in promoting scientific research.

The activities of the National Academy of Sciences during the

Civil War, as well as the provisions of its charter, indicated its fitness for renewed service in support of the national defence. In April 1916, when the attack on the "Sussex" had greatly increased the tension of our relations with Germany, the Academy received from the President a call for immediate action. The rapid development of technical bureaus and laboratories in connection with the various branches of the Government left no demand for another scientific bureau. But the same function which the Academy had subserved during the Civil War—that of uniting the technical services of the Army, Navy and Civil Departments in close cooperation with scientific investigators from research laboratories all over the country—must, in the President's judgment again be fulfilled. He therefore expressed the desire that the Academy should bring into cooperation governmental, educational, industrial, and other research agencies, primarily in the interest of the national defense, but with full recognition of the duties that must be performed in the furtherance of scientific and industrial progress.

The Academy's connection with the Government, its inclusion of the whole range of science, and its many years of cooperation with the Royal Society of London, the Paris Academy of Sciences, and other similiar academies abroad, pointed to it as the only body in the United States in a position to comply with the President's request. It was clear, however, that membership in the desired organization should not be exclusively confined to the National Academy. Many technical bureaus of the Army and Navy, for example, should be represented by their chief's *ex-officiis*, and in other cases a changing membership, broadly representative of research in its numerous aspects, would also be desirable. The Organizing Committee accordingly recommended the establishment of a new body, resting legally upon the character of the Academy, sharing its privileges, both at home and abroad, and at the same time affording the wide freedom of selection desired

The National Research Council, comprising the chiefs of the technical bureaus of the Army and Navy, the heads of Government bureaus engages in scientific research, a group of investigators representing educational institutions and research foundations, and another group including representatives of industrial and engineering research, was accordingly constituted by the Academy with the active cooperation of the leading national scientific and engineering societies. On July 24, 1916, President

Wilson addressed a letter to the President of the National Academy expressing his approval of a preliminary report regarding the National Research Council, and promising his cooperation and that of the various departments of the Government. Since that time he has continued to give his support to the work of the Research Council, and has appointed various representatives of the Government to membership in it.

On February 28, 1917, the Council of National Defense passed a resolution expressing its recognition of the fact that the National Research Council, at the request of the President, had organized the scientific resources of the country in the interest of national defense and national welfare, and requesting the Research Council to cooperate with it in matters pertaining to scientific research for national defense. As a result of this action the Chairman of the Council opened offices in the Munsey Building in March, and entered into active cooperation with the Council of National Defense, which was then established in the same building.

Soon afterwards the Research Council was requested to act as the Department of Science and Research of the Council of National Defense, in which capacity it has continued to serve for the organization of investigations on military and industrial problems and, in harmony with the expressed wish of the President, as an agency for securing widespread cooperation in the field of science and research.

A further extension of the duties of the National Research Council occurred in July, when it was requested by the Chief Signal Officer to organize the Division of Science and Research of the Signal Corps. Major (now Lieutenant Colonel) Robert A. Millikan was placed in charge of this Division, which has remained in close contact with the Research Council, engaged in the solution of numerous problems of military importance.

Another important request on behalf of the Government, made by Assistant Secretary of War Stettinius, resulted in the appointment of a Committee of the Research Council to organize and direct extensive researches for the improvement of processes for the fixation of nitrogen, undertaken in cooperation with the Ordnance Department of the Army.

Before describing the war activities of the Research Council, it will be advantageous to consider the full scope of its duties, as set forth in an Executive Order issued by the President on May 11, 1918

Executive Order of President Wilson

The National Research Council was organized in 1916 at the request of the President by the National Academy of Sciences, under its congressional charter, as a measure of national preparedness. The work accomplished by the Council in organizing research and in securing cooperation of military and civilian agencies in the solution of military problems demonstrates its capacity for larger service. The National Academy of Sciences is therefore requested to perpetuate the National Research Council, the duties of which shall be as follows:

1. In general, to stimulate research in the mathematical, physical and biological sciences, and in the application of these sciences to engineering, agriculture, medicine and other useful arts, with the object of increasing knowledge, of strengthening the national defense, and of contributing in other ways to the public welfare.
2. To survey the larger possibilities of science, to formulate comprehensive projects of research, and to develop effective means of utilizing the scientific and technical resources of the country for dealing with these projects.
3. To promote cooperation in research, at home and abroad in order to secure concentration of effort, minimize duplication and stimulate progress; but in all cooperative undertakings to give encouragement to individual initiative, as fundamentally important to the advancement of science.
4. To serve as a means of bringing American and foreign investigators into active cooperation with the scientific and technical services of the War and Navy Departments and with those of civil branches of the Government.
5. To direct the attention of scientific and technical investigators to the present importance of military and industrial problems in connection with the war, and to aid in the solution of these problems by organizing specific researches.
6. To gather and collate scientific and technical information at home and abroad, in cooperation with Governmental and other agencies and to render such information available to duly accredited persons.

Effective prosecution of the Council's work requires the cordial collaboration of the scientific and technical branches of the Government, both military and civil. To this end representatives of the Government, upon the nomination of the National Academy of Sciences, will be designated by the President as members of the Council, as heretofore, and the heads of the departments immediately concerned will continue to cooperate in every way that may be required.

(signed) Woodrow Wilson

The White House
May 11, 1918

Three-fold Nature of the Council Work

If we consider any research problem bearing on the war, we are likely to find that it has a three-fold nature. Take, for example, the question of the supply of optical glass for periscopes, range-finders, field glasses, and other instruments. Obviously such glass, most of which has hitherto been obtained from Germany, is necessary from a military point of view and also in the industries. Therefore researches must be undertaken to determine how it can be made. Back of these lie the more funda-

mental researches on the nature of glasses, crystals, and minerals, undertaken for the purpose of advancing knowledge. Or take the problem of the fixation of nitrogen. Nitrates are needed for the manufacture of explosives and also for use as fertilizers. As we have obtained them in the past wholly from the nitrate bed of Chile, which are open to enemy interference, we must devise processes for their manufacture in the United States. Those involve researches for the direct purpose of accomplishing the necessary reactions, and back of these lie still more fundamental researches on the underlying scientific principles.

In these and many other similiar cases, we observe the three elements which are fundamentally important in the work of the National Research Council. It is clear that a nation unwilling to give place in the industrial world to better informed rivals must adopt every feasible means of promoting research in the industries. It is equally clear that so long as the security of the world is menaced by unscrupulous military powers, research methods must be effectively utilized in perfecting the means of national defense. Fundamental to both is the prime necessity, clearly appreciated and strongly emphasized by far-sighted leaders of American industry, of promoting research in all branches of science, without thought of any industrial application, for the sake of advancing knowledge. As Colonel Carty has said, the pioneers of industrial research are those who see and apply the discoveries of men of science, by whom new territories are opened and explored. Without the knowledge derived form such explorations, the investigator bent upon immediate industrial advantage could make little progress.

Thus any broad plan of promoting scientific and industrial research for national welfare must involve the cordial co-operation of the men, institutions and societies, interested in these three aspects of science: (1) its advancement as the source of new knowledge; (2) its development when applied in the fields of engineering, agriculture, medicine, and other useful arts; and (3) its utilization, so long as predatory military powers threaten national existence, as a means of strengthening the national defense

Our place in the industrial world, the development of our commerce, the health of our people, the output of our farms, the conditions under which the great majority of our population must labor, and the security of the nation, will thus depend, in large and increasing measure, on the attention we devote to the

promotion of scientific and industrial research. Anyone who doubts this statement would do well to study in detail the causes which account for the industrial and military strength of Germany.

Co-operation with the Government

The final clause in the Executive Order of the President, which provides for the closest co-operation of the National Research Council with the various departments of the Government, is of fundamental importance. Chiefs of Government bureaus, nominated to the President by the National Academy of Sciences, have been appointed members of the National Research Council, in which they constitute its Military Division. This Division consists of the Chief of Operations of the Navy, the President of the Army War College, the Chiefs of Ordnance of the Army and Navy, the Chief Signal Officer of the Army, the Chief Naval Constructor, the Surgeon General of the Army, the Engineer in Chief of the Navy, the Chief of Engineers of the Army, the Director of Naval Intelligence, and the Chief of the Military Intelligence Section, together with the Chief of the Weather Bureau, the Chief of the Bureau of Chemistry, the Director of the Bureau of Mines, the Director of the Geological Survey the Chief of the Bureau of Forestry, the Director of the Council of National Defense, the Director of the Bureau of Standards (Vice Chairman), and the Secretary of the Smithsonian Institution (Chairman).

One of the most valuable results of the cooperation effected through the Military Division is the organization of the Research Information Committees, with offices in Washington, London and Paris. The importance of this step, which should have direct influence upon international cooperation in scientific research, especially if the position of Scientific Attache of our embassies abroad is maintained after the war, is such as to warrant the following detailed statement regarding the organization and work of the Research Information Committee.

1. By joint action the Secretaries of War and Navy, with the approval of the Council of National Defense, have authorized and approved the organization, through the National Research Council, of a Research Information Committee in Washington, with branch Committees in Paris and London, which are intended to work in close cooperation with the offices of the Military and Naval Intelligence, and whose function shall be the securing, classifying, and disseminating of scientific, technical

and industrial research information, especially relating to war problems, and the interchange of such information between the Allies in Europe and the United States.

2. In Washington the Committee consists of, first, a civilian member representing the National Research Council, Dr. S. W. Stratton, Chairman; second, the Chief, Military Intelligence Section; third, the Director of Naval Intelligence; and fourth, a Technical Assistant, Dr. Graham Edgar. Similiar Committees are being organized in Paris and London.

3. The initial organization of the Committee in Paris is:

(a) The Scientific Attache, representing the Research Information Committee, Dr. W. F. Durand, Attache.

(b) The Military Attache or an officer deputed to act for him.

(c) The Naval Attache or an officer deputed to act for him.

(d) A Technical Assistant, Dr. K. T. Compton.

(e) A Military Assistant, Mr. Tod Ford.

4. The initial organization of the Committee in London is:

(a) The Scientific Attache representing the Research Information Committee, Dr. H. A. Bumstead, Attache.

(b) The Military Attache or an officer deputed to act for him.

(c) The Naval Attache or an officer deputed to act for him.

(d) A Technical Assistant, Mr. S. W. Farnsworth.

5. The chief functions of the foreign Committees thus organized are intended to be as follows:

(a) The development of contact with all important research laboratories or agencies, governmental or private; the compilation or problems and subjects under investigation; and the collection and compilation of the results obtained.

(b) The classification, organization and preparation of such information for transmission to the Research Information Committee in Washington.

(c) The maintenance of continuous contact with the work of the offices of Military and Naval Attaches, in order that all duplication of work or crossing of effort may be avoided, with the consequent waste of time and energy and the confusion resulting from crossed or duplicated effort.

(d) To serve as an immediate auxiliary to the offices of the Military and Naval Attaches in the collection, analysis, and compilation of scientific, technical, and industrial research information.

(e) To serve as an agency at the immediate service of the Commander-in-Chief of the Military and Naval forces in Europe for the collection and analysis of scientific and technical research information and as an auxiliary to such direct military and naval agencies as may be in use for the purpose.

(f) To serve as centers of distribution to the American Expeditionary Forces in France and to the American Naval Forces in European Waters of scientific and technical research information originating in the United States and transmitted through the Research Information Committee in Washington.

(g) To serve as centers of distribution to our Allies in Europe of scientific, technical and industrial research information originating in the United States and transmitted through the Research Information Committee in Washington.

(h) The maintenance of the necessary contact between the officer in Paris and London in order that provision may be made for the direct and prompt interchange of important scientific and technical information.

(i) To aid research workers or collectors of scientific, technical and industrial information from the United States, when properly accredited from the Research Information Committee in Washington, in best achieving their several and particular purposes.

6. The chief functions of the Washington office of the Committee are as follows:

(a) To provide means of ready cooperation with the Paris and London offices of the Committee by:

1. Receiving, collating and disseminating information forwarded from these offices.

2. Rendering available such evidence and documents as may be collected by the National Research Council relative to research in the United States, so as to formulate replies to inquiries sent from abroad.

3. Communicating to foreign offices needs for additional information relating to problems originating in the United States.

(b) Classification, cataloging and filing of papers and reports received from various sources at the request of the National Research Council, and record of researches in progress concerning which detailed information may be obtained elsewhere.

(c) Issue of lists of available information and preparation of digests of such information for distribution to properly accredited persons.

(d) Maintenance of contact with various research agencies in the United States.

An appropriation of $38,400 has been made by the Council of National Defense to cover the expenses of the Research Information Committee for the current year.

Vice-Admiral Sims, in Command of the U. S. Naval Forces Operating in European Waters, has been particularly cordial in his welcome of the foreign representatives of the Research Council. Fully appreciating the possibilities of scientific cooperation, he has issued a circular letter to all naval officers and investigators in Europe, directing them to facilitate the work of the Scientific Attache in every possible way, to keep him fully informed of investigations in progress or needed, and to make every proper effort to see that all investigators, whether officers or civilians, shall consult the Scientific Attache in order to avoid unnecessary duplication of work and to utilize scientific and technical information obtained from any source. He has also created a Scientific Division of his staff, and placed Dr. Bumstead at its head. Major-General Biddle, in command at American Army Headquarters in England, has issued similiar orders to ordnance, engineer, gas, signal, aviation, medical and other officers in England. The British Government, on its part, has opened every source of information to Dr. Bumstead, and provided for the closest cooperation in research.

In France, Dr. Durand is also in close touch with our own Army and Navy, and with the French Government and men of science. He has also been appointed the representative of the United States on the Inter-Allied Board of Inventions.

The Ministry of Munitions in Rome has recently requested, through the Italian Ambassador in Washington, that a representative of the National Research Council be sent to Rome as Scientific Attache and head of an Italian branch of the Research Information Committee.

The natural development of the work of the Research Information Committee will lead to the concentration in the office of the National Research Council, where the Washington headquarters of the Committee is established, of all available information regarding research problems under investigation both in the United States and abroad. At the same time a service is being developed for the purpose of bringing properly accredited inquirers into touch with existing sources of scientific, technical, and engineering information in the United States. One of the

most valuable of these is the Information Service of the American Society of Mechanical Engineers, which is furnishing much important material to the National Research Council. A central office from which inquirers may be directed to Government bureaus and to such sources of information as that just mentioned has long been needed, and it is possible that the service of the Research Information Committee, once well organized, will be in increasing demand.

In this same field of supplying information on scientific and technical subjects, the work of the Research Council has already been developed in several different directions. For example, a sub-committee of the Geology Committee, consisting of one geologist and one highway engineer from each of nineteen states extending from Maine to Texas, has collected a very large body of information regarding materials for rapid highway construction along the Atlantic coast. The elaborate report of this Committee, bound in seven volumes, with three atlases, has already been of considerable service, not merely from the standpoint of those interested in highway construction for possible military purposes, but also to the Shipping Board in connection with the problem of building concrete ships, for which the stone quarries described in the report are often adapted. In another field the work of the Botanical Raw Products Committee has supplied extensive data relating to raw products required by industries, especially in cases where imports have been affected by the war. In still another field the Research Council has been called upon to cooperate with the Army War College in supplying information relating to topographical, geographical and related subjects. Without mentioning other cases in which the aid of the Research Council has been sought for the purpose of supplying technical information, it is clear that this section of its work, not only during the war but after its conclusion is likely to undergo extensive development.

How the Research Council Operates—International Operation in Research

When a scientific investigator undertakes any piece of research, his first act is invariably to ascertain just what work has already been accomplished in that field. It goes without saying therefore, that an organization composed of scientific investigators must proceed in the same way in attacking any large problem involving research. Moreover, it must lose no time in

arranging for close cooperation with the scientific men of other nations concerned with the same problem.

The writer, as chairman of the committee appointed by the National Academy to organize the Research Council, made a preliminary visit to England and France in August 1916, in order to learn how the scientific men of these countries were to be utilized in connection with the war. He found the investigators with whom he had cooperated for many years in astronomical and physical researches, actively engaged in the study of war problems. To the superficial observer it might seem strange that a physicist who has never before been engaged in so-called "practical" work, or an astronomer who had spent his life in the study of celestial phenomena, should be able to contribute effectively in time of war. But a moment's consideration of the nature of the problems to be solved, and a slight understanding of the methods in daily use by the physicist and the astronomer, would dispel any such impression. If I were free to betray military secrets, I could show that some of the most vital military questions have been solved by just such men. But enough will be said in the sequel to indicate how both the man of science and the engineer may render invaluable war service.

On the day preceding the entrance of the United States into the war, the following cablegram was sent by the Foreign Secretary of the National Academy of Sciences to the Royal Society of London, the Paris Academy of Sciences, the Accademia dei Lincei of Rome, and the Petrograd Academy of Sciences—leading scientific bodies with which the National Academy has cooperated for many years in the International Association of Academies:

> The entrance of the United States into the war unites our men of science with yours in a common cause. The National Academy of Sciences, acting through the National Research Council, which has been designated by President Wilson and the Council of National Defense to mobilize the research facilities of the country, would gladly cooperate in any scientific research still underlying the solution of military or industrial problems.
>
> HALE, Foreign Secretary.

Steps were also taken to despatch a group of seven scientific investigators, under the chairmanship of Dr. Joseph S. Ames, to France and England for the study of war problems and the arrangement of effective means of cooperation. The members of

the group sailed early in May, 1917, and were most cordially welcomed and given information of great value.

The response of our foreign colleagues to our offer of co-operation was immediate and effective. France sent to the United States an able group of investigators, headed by M. Fabry, the well known spectroscopist of Marseilles, with whom some of us has worked for years in the International Union for Cooperation in Solar Research. This group comprised such men as M. Abraham, able physicist and authority on wireless telegraphy, and the Duc de Gusche, who has no superior in his knowledge of the science of aeronautics. From England the Royal Society and the British Admiralty sent Sir Ernest Rutherford and Commander Cyprian Bridge, R. N., while Italy sent Lieutenant Giorgio Abetti, of the Osservatorio del Collegio Romano and the Italian Ministry of Munitions. The French members brought with them an invaluable collection of instruments and devices developed in France for military and naval purposes since the outbreak of the war.

Immediately after the arrival of this party in Washington, the National Research Council organized a conference on submarine problems, in which the foreign representatives, with members of the Navy Department and the physicists and engineers who had already studied the subject in this country, participated.* As the result of a two-day's discussion, it became clear that a greatly intensified attack on the problem should be made. The Research Council accordingly brought to Washington about forty leady physicists and engineers, and a second conference, of three days' duration, was held with the foreign naval officers and men of science. This resulted in the selection of several groups of investigators, to take up the problem at the point in its development already attained here and abroad, and to continue its study in cooperation with a board of naval officers appointed by the Secretary of the Navy. While I am not at liberty to mention the results of the investigations thus initiated, I have thought it worth while to describe the mode of procedure in order to illustrate how the Research Council conducts its work.

*Three able groups of investigators were already to work on this problem in the United States under the Bureau of Steam Engineering of the Navy, and both the Naval Consulting Board and the National Research Council had taken an active part in promoting studies of the submarine problem.

Research Conference on Military and Naval Problems

The great value of research conference on war problems, in which representatives of the technical bureaus of the Army and Navy join with members of the scientific bureaus of the civil Departments and with representatives of university, industrial and other research laboratories, is too obvious to require demonstration. Such conference, organized under regulations prescribed by the Military Division of the National Research Council, are held weekly under the immediate auspices of the Engineering and Physics Divisions. The discussions are based upon reports of researches on military and naval problems in progress in the United States, supplemented by the reports received at short intervals from abroad through the Research Information Committee.

Such conferences not only serve to stimulate research in the most effective way, they also insure that principles and methods developed in one branch of the service shall be made available in every other branch. Thus every bureau, whether of the Army or the Navy, is sure to find points of interest and importance in the discussion held at these conferences.

War Problems Involving Scientific Research

It is evident that no detailed account of work on war problems involving scientific research can be given without affording information to the enemy. If you will permit us, however, to omit the most interesting part of what such an account should be, I may hope to afford some idea of the character of the chief work of the National Research Council.

The War Organization of the Council involves the grouping of its various Committees under a series of Divisions, each of which deals with related subjects. Thus the Physics Division comprises the work of committees of Physicists, mathematicians, astronomers and geophysics. This Division works in very close cooperation with the Engineering Division, in view of the impossibility of distinguishing sharply between the problems belonging in their respective fields. Under the Engineering Division, which represents the expansion of the work of our former Engineering Committee due to the rapidly increasing demands upon the Council from Government bureaus and other sources, there are Sections or Committees dealing with mechanical engineering, electrical engineering, metallurgy, and with various special fields of research. The National Advisory Committee for Aeronautics acts as the Aeronautics Section of the Engineer-

ing Division. Permit me to express here the appreciation of the National Research Council of the action of the Engineering Foundation and the National Engineering Societies, which have appointed representatives to serve as members of the Executive Committee of the Engineering Division. We have been fortunate enough to secure the services of Dr. Henry M. Howe as Chairman of this Division, while the Chairmanships of the Sections of Electrical Engineering, Metallurgy and Mechanical Engineering, are held by Professor Comfort A. Adams, Mr. S. L. G. Knox, and Professor Bradley Stoughton, respectively. Lieutenant Colonel Robert A. Millikan, who also heads the Division of Science and Research of the Signal Corps, is Chairman of the Physics Division.

Within the extensive field covered by these two Divisions, numerous problems are constantly presenting themselves. Take such a subject as naval range finders. Here we are dealing with an optical instrument of precision, involving methods employed by the physicist and by the astronomer concerned with the measurement of stellar parallaxes. As existing range finders are marked by several defects, a well-known physicist, who has had extensive experience in the development of new types of instruments, was requested to attack the problem. He has already constructed a new range finder which seems to offer important advantages.

Another problem in physics is the location of enemy guns by sound. As M. Painlevé has stated publicly that apparatus devised by the French physicists for this purpose has been captured by the Germans, there can be no harm in referring to it. Here it is a question of determining the exact time of arrival of the sound wave emitted by the discharge of an enemy gun at three or more points where automatic recording instruments are located. The research problem involved is therefore the development of simple and effective recording instruments and a rapid method of calculation which will permit the observations to be reduced and the position of the enemy gun located in the shortest possible space of time. The National Research Council initiated the sound ranging service of the Army under the Signal Corps (it was subsequently transferred to the Engineer Corps), and secured the development of new forms of recording apparatus.* Major Augustus Trowbridge of Princeton, who is in

*Captain Ernest Weibel, who took part at the Bureau of Standards in developing a new recording instrument, was killed at the front in France while applying the method.

charge of the service in France, is a well known physicist. The quickest method hitherto devised of reducing the observations is due to an equally well known Princeton astronomer, who is working under the auspices of the National Research Council.

Another field in which the experience of the astronomer in computing orbits is directly applicable is that connected with the dropping of bombs from aircraft and the calculation of the trajectories of projectiles. Here several physicists and astronomers have obtained new and interesting results, useful in military practise. Many submarine problems, the location of invisible aircraft, various questions connected with wireless communication, the visibility of objects on land and sea, and scores of other questions falling within the fields of acoustics, optics, electricity and other branches of physics, afford abundant opportunity for researches of the most varied character. Also lying within the field of the Physics Division is the work of the Committee on Navigation and Nautical Instruments, under the Chairmanship of Dr. L. A. Bauer, which has aided the Shipping Board in the selection and testing of compasses, chronometers, and other nautical instruments.

The Engineering Division has dealt with such problems as the design of two new types of gun, for one of which the Ordnance Department of the Army has made a special appropriation. It is making an extensive study, in cooperation with the Ordnance Bureau of the Navy, of the entire problem of gun-pointing, which involves a great variety of interesting questions and the cooperation of men who have derived the necessary experience from their work in engineering, physics and other branches of science. Another very interesting investigation conducted under the auspices of the Engineering Division has dealt with the best composition and design of helmets and protective body armor for troops. Dr. Bashford Dean, Chairman of this special Committee, and now a major in the Ordnance Department of the Army, is Curator of Arms and Armor at the Metropolitan Museum of Art. Dr. Henry M. Howe, the well known metallurgist, is another active member of this Committee.

It is unfortunate that I cannot go into the very interesting details of the work done under these related Divisions, as it would be so easy to illustrate the importance of securing such widespread cooperation in research as the National Research Council is especially intended to promote.

Passing on to the important Division of Chemistry and Chemical Technology, organized by Professor (now Lieutenant Col-

onel) Marston T. Bogert, and now under the Chairmanship of Dr. John Johnston, we enter a field of the first importance from a military and industrial standpoint. It is impossible here even to touch upon the extensive work of this Division, which includes thirty-four committees dealing with various phases of chemistry. Perhaps the most important work undertaken by the Division is the exhaustive study of processes for nitrogen fixation, conducted under its auspices. The first committee appointed by the National Research Council in May 1916 at the request of the Secretary of War, was charged with the duty of advising the Ordnance Department of the Army regarding the best processes to be adopted in its great nitrate plants. Dr. Arthur A. Noyes, Chairman of this Committee, is also Chairman of a new Committee, recently appointed by the Research Council at the request of Assistant Secretary of War Stettinius to survey the researches now in progress for the improvement of these processes, to plan further investigations relating to nitrogen-fixation, to arrange for the active prosecution of such investigations, and to exercise close oversight over their progress. Working in cooperation with the officers of the Ordnance Department, this Committee has initiated various researches for the purpose of improving existing processes, one of which has proved so successful that it will materially reduce the cost of nitrogen fixation.

It should be said here, once for all, that the policy of the National Research Council is now and has been from the outset invariably to recommend the immediate adoption and utilization for military and naval purposes of the best devices or methods known at the time, with the understanding that research for the purpose of improving such devices should not retard production demanded to meet pressing military needs.

Passing over, for lack of space, the many other activities of the Division of Chemistry, a word should be said regarding the Division of Geology and Geography, under the Chairmanship of Dr. John C. Merriam, which includes Committees on both of these subjects. The important work on road materials done under the supervision of the late Dr. William Bullock Clark, as a part of the work of the Geology Committee (Dr. John M. Clarke, Chairman), has already been mentioned. The Division is working in close cooperation with the Army War College, and has sent a geologist abroad to report on the best services of geologists in connection with the war. A valuable "Handbook of Northern France", prepared by Dr. William M. Davis, Chair-

man of the Geography Committee, has been widely circulated among American officers. The general information thus supplied is being supplemented by lectures on military geography given in the various contonments. In this connection special mention should be made of an important work prepared by Major Douglas W. Johnson, a member of the Geography Committee now in France, entitled "Topography and Strategy in the War."

The Division of Medicine and the Related Sciences, under the Chairmanship of Dr. R. M. Pearce, includes Committees on Anatomy, Physiology, Psychology, Anthropology, Medical Zoology, Toxicity of Preserved Foods, Psychiatry, and other special subjects, and is one of the most active Divisions ot the Research Council. Aided by an appropriation of $50,000 from the Rockefeller Foundation, and working in the closest cooperation with the Surgeon General of the Army (through Colonel Russell) and of the Navy (through Dr. Stitt), it has organized many researches of direct military value, assisted the Surgeons General of the Army and Navy in procuring trained investigators to enter the respective services, and initiated many other activities of importance. It is impossible within present limits to describe the numerous medical researches undertaken. About half of them are in the field of physiology alone, and deal with problems of shock, control of hemorrhage and similar subjects. The remaining half are divided, roughly, between problems concerning the acute infectious diseases, the control of vermin, food problems, and the diseases of munition workers.

A word should be said regarding the novel and important work in psychology, due to the initiative of Major Robert M. Yerkes, Chairman of the Psychology Committee of the Research Council. Perceiving the possibility of psychological examination as applied to the Army, and with the active aid of a strong committee, Dr. Yerkes prepared a scheme of psychological examination, and secured permission to test it with troops. Meanwhile a plan for applying tests on a large scale had been prepared and presented to the Surgeon General through the National Research Council. The preliminary tests impressed military officers so favorably that a new Division of the Surgeon General's Office was created, and Dr. Yerkes was commissioned a major in charge of the work. The psychological tests are now being applied to all troops in the Army, and the intellectual rating thus afforded has proved to be very useful in practise. This is one of the most interesting scientific innovations of the war

As the functions of the Committee on anthropology in connection with military needs might not be grasped without reflection, it should be remarked that this Committee then under the Chairmanship of Dr. William H. Holmes, was the first to point out that under the former height limit of enlistment (five feet, four inches) the taller native American would be discriminated against when compared with the shorter immigrants from many European nations. The figures presented by the Committee convinced the War Department, and the height limit was accordingly reduced to five feet, in accordance with the recommendations of the Committee. A further result of this Committee's activities is the organization of a Division of Anthropometric Measurements in the Surgeon General's office, under the charge of Dr. C. B. Davenport.

The field covered by the Division of Agriculture, Botany, Zoology, Forestry and Fisheries, under the Chairmanship of Dr. Vernon Kellogg, is a wide one, of fundamental importance in connection with the war. Working in close cooperation with the Department of Agriculture, the Bureau of Forestry and Fisheries, and the Food Administration, this Division is accomplishing much valuable work. The information collected by the Botanical Raw Products Committee, under the Chairmanship of Dr. E. M. East, has already been mentioned. The Agriculture Committee has initiated several large investigations involving the cooperation of members of the Department of Agriculture, State Experiment Stations, and investigators in the universities. The last piece of work organized by the Division was undertaken at the request of the Food Administration, which requested the Research Council to appoint a committee to investigate binder twine fibres with special reference to sisal and its substitutes.

I might go on to describe other phases of the Research Council's work, including the activities of the Patent Office Committee, appointed at the request of the Commissioner of Patents; the Section on cooperation with state research committees and with the research committees established at the suggestion of the Research Council in seventy-two eductional institutions; the Committee which has undertaken a census of the investigators and research facilities of the country; etc. To do so, however, would greatly enlarge this paper, which is already too long. I will therefore close with a brief statement of the work inaugurated by the Council for the promotion of research in the industries.

Industrial Research and National Welfare

At the outbreak of the war the average statesman of the Allied powers was but little concerned with the interests of research. Necessity, however, soon opened his eyes. He began to perceive the enormous advantages derived by Germany from the utilization of science, and sought to offset them by the creation of appropriate agencies. Thus arose throughout the British Empire a group of Councils for Scientific and Industrial Research. The first of these was established in England by an order in council issued in 1915. Subsequently, Canada, Australia and South Africa followed the example of the mother country, and New Zealand proposes to do likewise. The world-wide movement swept across the Empire, and its benefits will be felt in every country under the British flag. A similar awakening was experienced in France and Italy, but in both of these countries the pressure of the war concentrated attention for the moment upon military problems. At present, the needs of industry are also under consideration, and research organizations are being developed to meet them.

Without entering here into a detailed discussion of these Councils, we may mention certain typical illustrations of their activities from the report of the British Advisory Council for Scientific and Industrial Research for the year 1916-17.

The British Advisory Council has devoted itself during the year mainly to the organization of industrial research, partly because of the prime importance of stimulating and fixing the interest of manufacture in the development of industry through research, and partly because the effect of the war has been to render industrial leaders more susceptible than ever before to the growth of new ideas. In pure science, on the contrary, the war has seriously affected the prosecution of research, because so many investigators have been drawn into military and industrial activities. Thus, while the Advisory Council strongly emphasizes the fundamental importance of pure science, it has been forced to postpone its activities in this field until the arrival of more favorable conditions.

Research for the development of the industries may be conducted in several different ways. In this country a stimulating example has been set by such great corporations as the American Telephone and Telegraph Company, the General Electric Company, the Eastman Kodak Company, and the Westinghouse Company, all of which have established large research

laboratories. The value of this example has been enhanced by the remarkable success achieved by these laboratories in matters affecting public welfare, such as the reduction in cost of electric lighting caused by the development of the Mazda lamp and the possibility of transcontinental telephony, not to mention the latest advances in the field of wireless telephony.

Self-interest will sooner or later induce many other corporations to adopt similar methods of improving their products, but the heavy expense of establishing independent research laboratories will sometimes prove an insurmountable obstacle. Other means must then be resorted to. A useful example is that afforded by the American Canners' Association, which has established central research laboratory in Washington, where any member of the Association can send his problems for solution and where extensive investigations, the results of which are important to the entire industry, are also conducted.

The British Advisory Council, aided by a Government appropriation of one million pounds, is actively promoting the organization of Trade Research Associations for the mutual benefit of the members of the great industries. Thus a Provisional Committee representative of the British cotton industry has proposed the establishment of a cooperative Association for Research in Cotton, to include in its membership cotton spinning, doubling and thread making firms, cloth, lace and hoisery manufacturers, bleachers, dyers, printers and finishers, which will conduct researches extending from the study of the cotton plant to the "finishing" of the manufactured article. So long ago as 1835 Baine wrote in his "History of the Cotton Manufacture" —"The manufactory, the laboratory and the study of the natural philosopher, are in close practical conjunction; without the aid of science, the arts would be contemptible; without practical application, science would consist only of barren theories, which men would have no motive to pursue." This spirit, clearly shown in the early cotton industry, is now to be revived for the common benefit.

The woolen and worsted manufacturers of Great Britain are also drafting the constitution of a Research Association, and the Irish flax spinners and weavers are about to do likewise. Research Associations will be established by the Scottish shale oil industry and the photographic manufacturers, while various other British industries are looking in the same direction. Thus a national movement for research, directly resulting from the

war, has already made marked headway. The Research Councils in various parts of the British Empire, actuated by the same spirit, are rapidly extending the advantages which an appreciation of the national importance of research will afford.

The National Research Council, joining with its valued ally and supporter, the Engineering Foundation, is just entering upon an extensive campaign for the promotion of industrial research. In addition to a strong active committee, comprising the heads of leading industrial research laboratories and others prominently identified with scientific methods of developing American industries, an Advisory Committee has been formed to back the movement. This already comprises the following gentlemen: Honcrable Elihu Root; Mr. Theodore N. Vail President of the American Telephone and Telegraph Company; Dr. Henry S. Pritchett, President of the Carnegie Foundation for the Advancement cf Teaching; Mr. Edwin Wilbur Rice, Jr., President of the General Electric Company; Mr. George Eastman, President of the Eastman Kodak Company, Mr. Pierre S. duPont, President cf the E. I. duPont de Nemours Powder Company; Mr. A. W. Mellon, Founder of the Mellon Institute for Industrial Research; Judge E. H. Gary, President of the United States Steel Corporation; Mr. Cleveland H. Dodge, of the Phelps-Dodge Corporation, and Mr. Ambrose Swasey, of The Warner and Swasey Company.

We are indeed fortunate to have the aid of men whose experience and standing are so certain to command public recognition of the claims of scientific and industrial research.

Science is in the air, keen competition is in prospect, and the industries are more favorably inclined than ever before to the widespread use cf research methods. Their greatest leaders, moreover, are unanimous in their appreciation of the necessity of promoting research for the sake cf advancing knowledge, as well as for immediate commercial advantages. Only thus can the most fundamental and unexpected advances be rendered possible, and continued progress in all directions assured.

In preparing to continue and extend its work in the interest of national defense, industrial development, and the advancement of science, the National Research Council wishes me to assure the Engineering Foundation and the National Engineering Societies of its cordial appreciation of their invaluable assistance in the past and of its sincere desire to utilize every possible means of promoting even closer cooperation in the future.