Lessons of World War II

From the War Reports of Fleet Admiral Ernest J. King

In December 1941 the United States faced seasoned enemies, who not only had long been preparing for war but who had actually been waging it for several years. Within the limited facilities and means available throughout the years of peace, the United States Navy had, however, equipped itself with weapons the equal of, or superior to, those of other navies and had laid the groundwork for still further development. During the war the science and industry of this country and our allies were mobilized to apply existing scientific knowledge to the perfection of these weapons and the development of new and more deadly means of waging war. As a result the United States Navy was able to maintain the technical advantage over the navies of our enemies, which contributed so materially to the outcome of World War II.

The means of accomplishing this were not so much directed towards making new discoveries, as towards the exploitation of the skills and techniques which civilian scientists had already cultivated in years of peace. When war appeared imminent, the War and Navy Departments and the National Academy of Sciences gave close attention to the most profitable manner of utilizing the strength of American science in military and naval research. It was decided to attempt a solution involving the maximum flexibility and initiative, in which the fundamental principle would be cooperation between science and the armed forces, rather than to bring the scientists into military and naval laboratories, as was done in England. The principle proved thoroughly sound. The arrangement adopted was the establishment by executive order of the Office of Scientific Research and Development, which had as its scientific and technical working bodies the National Defense Research Council, the Medical Research Council, and later the Office of Field Service. To assure full integration of the potentialities of these organizations with the Navy's own research and development program and the needs of the service, the late Secretary Knox, in July 1941, established the office of Coordinator of Research and Development. Throughout the war, the development of new weapons and devices has been accelerated by the teamwork between the users, the scientists, the engineer-designers and the producers.

The devices and weapons resulting from the research and development program have been put to use in every phase of naval warfare. Particular examples, cited because of their complexity and diversification, are amphibious warfare, carrier warfare, submarine and antisubmarine warfare. In each of these cases, our combat effectiveness has been materially increased by improvements in communications, navigational devices, fire control, detection equipment, firepower, aircraft performance (range, speed, armament, handling characteristics) and by advanced training methods and equipment.

Perhaps the greatest technological advances of the entire war have been made in the field of electronics, both within the naval laboratories and in collaboration with the Office of Scientific Research and Development. Pre-existing radar sets were developed and new models created for ship and air-borne search, fire control, and for accurate long-range navigation. Identification and recognition equipment were developed for use in conjunction with radar systems. New and highly efficient short-range radio telephones were used for tactical communication. In the successful antisubmarine campaign in the Atlantic, small radio-sonobuoys were used; these, when dropped from aircraft, listened for the noise made by a submarine and automatically relayed the information to the searching plane. Great strides have been made in electronic antisubmarine detection equipment. Underwater echo-ranging gear and listening equipment have been improved in quality and extended in function since the outbreak of the war. Countermeasures have been developed for jamming enemy radar and communication systems, disrupting the control signals for his guided missiles, and counteracting his measures to jam our own equipment.

The foundation for our shipboard radar systems had been laid before the war. The earliest observations of radio phenomena of the kind that are exploited by radar were made at the Naval Research Laboratory by groups working with Dr. A.H. Taylor and Dr. R.N. Page, and the military possibilities were immediately grasped by these scientists and by Rear Admiral H.G. Bowen, then Director of the Laboratory. Because of this, at the outset of the war, our Navy alone had on its ships a search radar specifically designed for shipboard use. We had already incorporated in these radars the technical development of using a single antenna for transmission and reception. Radar of this type contributed to the victories of the Coral Sea, Midway, and Guadalcanal. Over 26,000 sets of air-borne radar equipment were produced from the Naval Research Laboratory's redesign of British air-borne equipment. Ours was the first navy to install radar in submarines. Similarly, a highly efficient supersonic echo-ranging gear for submarine and antisubmarine warfare had been completely developed, and was installed before the war began. The success of all these electronic devices can be traced back to intensive early development of new types of vacuum tubes.

Initially, from want of experience against an enemy attacking with the persistence demonstrated by the Japanese, our antiaircraft batteries were inadequate.

Particularly was this true in the case of automatic weapon batteries, consisting at that time of the .50-caliber and 1.1-inch machine guns. The main antiaircraft batteries in the fleet, consisting of 5-inch and 3-inch main batteries were controlled by directors employing optical range information. Although antiaircraft fire-control radar was under development, no installations were operative in the fleet.

By the time Japan surrendered, our defenses had been revolutionized. The fleet was equipped with accurate antiaircraft fire-control radar. Our antiaircraft gun defenses consisted of multiple power-driven 40-millimeter mounts, 20-millimeter mounts, and 5-inch twin and single mounts, many of which were controlled by small intermediate range radar-fed gun directors. The VT, or proximity influence fuse, initially sponsored by the Navy and by the Office of Scientific Research and Development, marked a radical change from previous methods of detonating a projectile and vastly increased the effectiveness of antiaircraft defenses.

At the end of the war, the 8-inch rapid-fire turret had been developed and was ready for introduction to the fleet. Completely automatic in action, it can be used against ship, aircraft, or land targets. The guns are loaded from the handling rooms automatically and are automatically laid.

When the threat of the German magnetic mines became known in 1939, the Navy immediately mobilized scientific talent and industrial capacity to produce a countermeasure. Several methods of demagnetizing our ships were developed. These were applied before Pearl Harbor to all combatant vessels, and later to all other vessels, and were of material assistance in maintaining the safety of our vital shipping lanes. At the same time, acoustic and magnetic firing devices were developed and produced in quantity for our mines and depth charges. Electric torpedoes were developed to supplement the air-steam torpedo, which at the outbreak of war was our weapon of underwater attack.

Rockets and rocket launchers were developed, with the assistance of California Institute of Technology and other agencies, for use on board ships and aircraft. Appropriate types of rockets were developed for use against submarines, for the support of amphibious landings, and for aircraft. These allowed heavy firepower to be concentrated in light craft.

Fighter-plane speed was greatly increased during the war. At the end an experimental model ready for combat use had a speed of over 550 miles per hour.

This plane was powered with turbojet engines, little known before 1941. Development of the conventional aircraft engine had also progressed; whereas initially the maximum size was 1000 horsepower, improved types of 3000 horsepower are now in use. Torpedo bombers, scout bombers, patrol bombers, and scout observation planes have all been rapidly developed during the period. Carrier-borne aircraft with increased speed, range, and armament carried the battle to the Japanese homeland, and patrol aircraft with high speed, long range, and greater offensive power aided in supplying the information necessary to the success of those operations. Development of the arresting gear, launching catapults, and handling equipment of our surface ships kept pace with the increasing weights of planes, and allowed more planes per ship to be carried than had been possible in peacetime.

Our aircraft were a focus for developments in many fields. Radar opened new possibilities for search, night combat, and operations under poor visibility conditions. Aircraft guns were increased in size from the .30-caliber World War I weapon to 20-millimeter, 37-millimeter, and 75-millimeter guns. Air-borne rockets up to 11.75 inches in diameter radically increased the striking power of conventional aircraft, with little penalty on performance. Rocket power was also used on seaplanes for assistance in take-off with heavy loads and in high seas, making possible the rescue of many downed aviators and thereby reducing our combat losses. Development of the "fire bomb" further extended the tactical versatility of aircraft.

Training was enormously expedited by the introduction of a great variety of synthetic training devices. These endeavored to offer trainees an approximation of battle experience and to develop the reactions of a veteran before actual combat. As an example, it is now possible for the entire crew of a submarine to rehearse approaches and torpedo attacks against enemy task forces in trainers on dry land, which provide simulated visual observation of the enemy, simulated radar and sonar information, and in which all of the complex battle gear and fire-control mechanisms operate as they do in a real submarine.

Certain developments, whose progress was most promising, were not completed in time for extensive combat use. These are primarily guided missiles and pilotless aircraft, utilizing remote control by electronic apparatus. These new developments will play a major role in warfare of the future, carrying new explosives over greatly increased ranges.

In the early days of research leading towards the application of atomic energy for military purposes, the Naval Research Laboratory was the only government facility engaged in this type of work. At the Laboratory there was developed a liquid thermal diffusion process for separation of uranium isotopes. Enriched chemicals, as well as basic designs and operating practices, were later supplied to the Army and used in one of the Oak Ridge plants manufacturing the atomic bomb.

The complexity of modern warfare in both methods and means demands exacting analysis of the measures and countermeasures introduced at every stage by ourselves and the enemy. Scientific research can not only speed the invention and production of weapons, but also assist in insuring their correct use. The application, by qualified scientists, of the scientific method to the improvement of naval operating techniques and material, has come to be called operations research. Scientists engaged in operations research are experts who advise that part of the Navy which is using the weapons and craft--the fleets themselves. To function effectively they must work under the direction of, and have close personal contact with, the officers who plan and carry on the operations of war.

During the war we succeeded in enlisting the services of a group of competent scientists to carry out operations research. This group was set up as a flexible organization able to reassign personnel quickly when new critical problems arose. Fiscal and administrative control of the group was originally vested in the Office of Scientific Research and Development. The group as a whole was assigned to the Navy for functional control, and in the course of time was attached to my Headquarters.

The initial impulse toward the formation of such a group arose in April 1942, during the early days of the antisubmarine war. With the cooperation of the Antisubmarine Division of the National Defense Research Committee, seven scientists were recruited by Columbia University and assigned to the Antisubmarine Warfare Unit, Atlantic Fleet.

During the year 1942 the group was considerably increased in size, and in July 1943, at a strength of approximately forty members, it was incorporated into the staff of the Tenth Fleet as the Antisubmarine Warfare Operations Research Group. Subsequently the administrative responsibility for the group was transferred from Columbia University to the Office of Field Service, without alteration in relationships with the Navy. In October 1944, with the decline of the submarine menace, the group was transferred to the Readiness Division of my Headquarters and renamed

the Operations Research Group. At the close of the war it consisted of seventy-three scientists, drawn from a wide variety of backgrounds. Many of the members were attached, as the need arose, to the staffs of fleet and type commanders overseas, and at operating bases in war theaters. So far as possible they were afforded the opportunity of observing combat operations at first hand.

Operations research, as it developed, fell into two main categories: theoretical analysis of tactics, strategy and the equipment of war on the one hand; and statistical analysis of operations on the other. Each type of naval operation had to be analyzed theoretically to determine the maximum potentialities of the equipment involved, the probable reactions of the personnel, and the nature of the tactics which would combine equipment and personnel in an optimum manner. Action reports, giving the actual results obtained in this type of operation, were studied in a quantitative manner in order to amplify, correct, and correlate closely the theoretical analysis with what was actually happening on the field of battle. The knowledge resulting from this continued cross-check of theory with practice made it possible to work out improvements in tactics which sometimes increased the effectiveness of weapons by factors of three or five, to detect changes in the enemy's tactics in time to counter them before they became dangerous, and to calculate force requirements for future operations.

The late war, more than any other, involved the interplay of new technical measures and opposing countermeasures. For example, the German U-Boats had to revise their tactics and equipment when we began to use radar on our antisubmarine aircraft; and we, in turn had to modify our tactics and radar equipment to counter their changes. In this see-saw of techniques the side which countered quickly, before the opponent had time to perfect the new tactics and weapons, had a decided advantage. Operations research, bringing scientists in to analyze the technical import of the fluctuations between measure and countermeasure, made it possible to speed up our reaction rate in several critical cases.

Likewise, in their struggle to counteract our improved convoy escort tactics, the U-Boats introduced the acoustic torpedo, which steers for a ship by listening to the sound it makes under water. Our development of countermeasures was based on studies by the Operations Research Group into the pattern of sound produced in the sea by ships' propellers and on the probable reaction of the torpedo to various decoy devices. In this and other cases, information derived from intelligence sources was interpreted by the members of the group in the light of their own scientific knowledge and utilized to devise improved countermeasures.

Submarine and antisubmarine operations are closely complementary. Methods developed for attack have as a counterpart methods for defense based on the principles underlying both. In the subgroup devoted to submarine warfare, theoretical and operational studies were carried out on coordination of attack by groups of submarines; torpedo fire control; effectiveness of rescue of downed aviators; causes of loss of United States submarines; the relative merits of various types of torpedoes under differing circumstances; and enemy countermeasures to our radar search equipment.

Research on air problems has been devoted in the main to perfection of tactics designed to minimize flak hazard to naval aircraft attacking gun defended targets, and to analysis of accuracy and effectiveness of aerial weapons, primarily against seaborne targets. Bombs, rockets, and torpedoes are designed for distinct uses, conditioned by the accuracy of launching and by their lethal effectiveness. Studies of the peculiarities of these weapons have led to recommendations for tactics and training procedures.

Studies were carried out by other subgroups on defense of task forces against suicide attacks, on the effectiveness of antiaircraft fire, and on problems of naval gunfire as a support for amphibious landings.

The Operations Research Group, to be renamed the Operations Evaluation Group as more closely descriptive of its function, will be continued as part of the naval organization at an appropriate peacetime strength.

The assistance and cooperation of industry and science have been indispensable. Without this assistance, many of the weapons which have come into being as the result of intensive wartime research and development otherwise never would have been completed and introduced into the fleet.

It had often been predicted that in a national emergency the totalitarian countries would have a great technical advantage over the democracies because of their ability to regiment scientific facilities and manpower at will. The results achieved by Germany, Italy and Japan do not bear out this contention. Studies made since the close of the war indicate that in none of these countries was the scientific effort as effectively handled as in the United States. The rapid, effective and original results obtained in bringing science into our effort are proof of the responsiveness of our form of government to meeting emergencies, the technical competence of American scientists, and the productive genius of American industry.

It would be unfair to others to single out by name individual scientists who made important scientific and technical contributions to the improvement of old or the development of new weapons. There were thousands of such contributions. It is generally conceded that with respect to originality of ideas and individual resourcefulness the scientists in the axis countries were as competent as our own. Where American science outdistanced the axis powers was in the superior administration of the over-all effort so that the available scientific manpower of the country could function with the maximum effectiveness. The leadership for what may be broadly termed the civilian emergency scientific effort was provided by the same individuals during the entire war period. These individuals deserve special mention among those responsible for the superb administrative efficiency which characterized the American conduct of the war throughout. Dr. Vannevar Bush as the Director of the Office of Scientific Research and Development carried the over-all administrative and technical responsibility for that organization. Under him Dr. James B. Conant as Chairman of the National Defense Research Committee; Dr. Alfred N. Richards as Chairman of the Committee on Medical Research, and Dr. Karl T. Compton as the head of the Office of Field Services administered the scientific and technical activities of the Office of Scientific Research and Development. Dr. Frank B. Jewett as the President of the National Academy of Sciences and of its working body the National Research Council, and Dr. Jerome C. Hunsaker as the Chairman of the National Advisory Committee for Aeronautics directed the activities of these organizations during this period. The coordination of the work of these groups with the Navy was handled by the Office of the Coordinator of Research and Development headed by Rear Admiral J.A. Furer.

I wish to pay particular tribute to the group of scientists, industrialists and officers of the Army and Navy who, under the direction of Major General L.R. Groves, USA achieved the final outstanding technical success of the war--the development of a practical atomic bomb and the method of using it from aircraft.

Sufficient progress in the technical development and use of improved weapons and associated equipment has been made during the war to emphasize the necessity for continued progress. Working under the stress of an emergency, the factor of primary importance was immediate effectiveness against the enemy. This resulted in "crash designs" and production that required considerably more personnel, weight and space, than the more seasoned designs that might have been produced had time been available. Thus, the rapid expansion and development of new weapons and devices during the war was often at the cost of factors of major importance, such as the reserve buoyancy and stability of the ships in which they were installed. Those wartime designs, while they have well served their purpose against the enemy, have nevertheless created problems of refinement and improvement in the ultimate design of equipment, which must be so resolved that a minimum of personnel, weight and space will be required to attain the desired effect. These problems must be energetically attacked in the coming years of peace. Only by continuing vigorous research and development can this country hope to be protected from any potential enemies and maintain the position which it now enjoys in possessing the greatest effective naval fighting force in history.