WALTER G. BERL

IN DEFENSE OF FREEDOM — THE EARLY YEARS

This article describes the events that led to the founding of the Applied Physics Laboratory. It summarizes the development of a novel fuze for rotating antiaircraft ammunition and the organization that achieved it, continues with a discussion of the early stages of the development of a new technology for the delivery of warheads–the guided missile, and concludes with a brief sketch of Merle A. Tuve's career that led to his involvement with these programs.

INTRODUCTION

On 11 September 1939, only ten days after the German army invaded Poland and World War II began, President Franklin D. Roosevelt sent the first of many notes to Winston Churchill in which he proposed that Churchill reply with "anything you may want me to know about."[1] One such message, No. 831, from Churchill to President Roosevelt, dated 26 November 1944, read:

> Cherwell [Churchill's Science Advisor] has told me how very kind the US Army and Navy were in showing him their latest developments in many fields. . . . Perhaps, if you thought it well, you will transmit my thanks to them and especially to General Groves who went to so much trouble to show Cherwell the latest developments in his particular field.
>
> Perhaps you might also see fit to express gratitude to the Tuve establishment at Silver Springs [sic] whose work on the Proximity Fuze has proved so valuable in defending London against the robot [V-1] bombs.

For three months, from the dawn of 13 June, exactly a week after D-Day, to the end of August 1944, London had been subjected to the second blitz attack of World War II. More than 8000 unmanned flying machines, each carrying a 2000-lb explosive warhead, were launched from sites near the coast of the English Channel.

In midsummer 1944, the military situation for Germany had become desperate. In the east, the Russians were relentlessly hammering and breaking through the German lines near the old Polish border. In the west, "Operation Overlord," the massive Allied invasion into Normandy, was moving forward, albeit slowly at first. Hitler hoped that use of the new aerial assault weapon, the robot bomb, would divert some of the Allied forces to attack the launching sites in an effort to lessen the pressure on London.

But no such diversion took place. Instead, by combining the defenses offered by a network of barrage balloons, by fighter planes whose speed was sufficient to permit engagement in one-on-one combat, and, most successfully, by intense and accurate artillery fire, the damage to London was contained. Altogether, a quarter of the bombs penetrated the defenses. But once the triad defensive strategy was reorganized in July (8000 antiaircraft guns and 23,000 operators and support were moved in two days from near the city to the Channel coast where they could function more effectively) and proximity-fuzed shells were deployed for the first time in the European theater, only one in twenty of the flying bombs succeeded in their mission. In early September, the V-1 launching sites were captured by the advancing Allied forces and the V-1 attacks ceased.[2]

Halfway around the world, in the Pacific, a similar drama was unfolding. In October 1944, strong American forces appeared in the Leyte Gulf in the Philippines. The ensuing naval engagement went disastrously against the Japanese fleet, whose aircraft carriers and land-based air support were mortally stricken.

Extreme measures were called for. Suicide attacks by kamikaze aircraft armed with 250-kg bombs were improvised virtually on the spot, each plane crash-diving with its pilot, explosive load, and fuel into American ships. In a separate development and equally rushed into action, small, single-seated wooden craft (the Ohkas), rocket-propelled and guided to their goal by volunteer "human gunsight" pilots, were sent to the fighting fronts.[3]

The attacks caused substantial damage to surface ships until the end of the war in August 1945. But the growing competency of American fighter pilots at intercepting the attackers and the intensified use of proximity-fuzed antiaircraft shells that had been sent to the Pacific late in 1942 blunted the effects of the attacks.

Thus, in both the European and the Pacific theaters of operation, the timely availability and introduction of an effective defensive weapon proved to be of crucial importance in the outcome of the war.

THE STORM GATHERS

World War II can rightfully claim to have been the first war in history that was influenced, if not ultimately decided, by weapons virtually unknown at the outbreak of the hostilities, with its legacy of radar, rockets and jet engines, and nuclear ammunition. There is no space here to trace the deeper interactions between science, technology, and the arts of war or to comment on the nature of warfare that has absorbed the competencies of nations in its pursuit. No observer of the discovery of modern chemical high explosives and propellants, steel-hulled ships, motorized mass transportation and flight, and of the advances in the arts of communication would have failed to predict their incorporation into the military structures, thereby fundamentally modifying the nature of warfare.[4,5]

The world watched with dread as the European spectacle unfolded. The reoccupation of the Rhineland, the conversion of the small but intensively trained Wehrmacht into a large, well-equipped military machine, the takeovers in Austria, Czechoslovakia, and Danzig, coupled with a sudden pact with the Soviet Union and unremitting pressure on Poland brought on the declaration of war by the major western powers in 1939.

What had been the response to these thrusts and threats? The world economy had few resources for upgrading the state of the armed forces. In France, hopes were pinned on the massive Maginot Line defenses that were intended as an impregnable barrier to a German advance that was expected to be similar to the one of 1914. Britain, with its high population density and proximity to the mainland, was in the unenviable position of being an easy target from a superior air power.

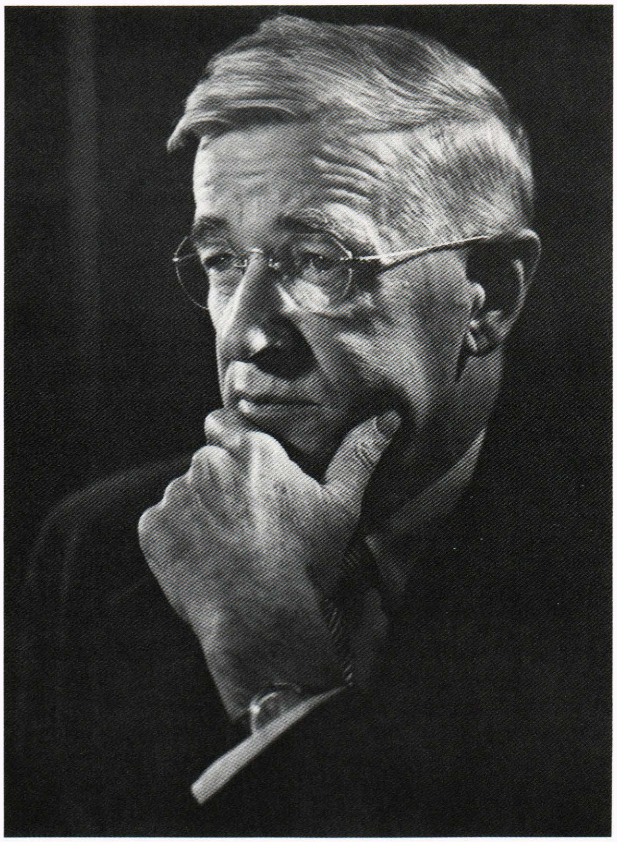
Detection of distant objects by reflection of radio waves was by no means a new idea, but during the 1930s little had been done to exploit this technology. In the obscurity of a few British R&D establishments and supported by a handful of farsighted technical committees, radio pulses as a means of detecting planes and ships and radio-controlled fuzes to improve the defense against air attacks began to be seriously studied. Perhaps of equal importance, the fashioning of an intimate relationship between the R&D community and senior officers in the armed services took hold to interpret military requirements on the one hand and the technically possible on the other, creating an atmosphere of mutual confidence and understanding between the scientific community and the military.

The upshot was that, with barely a month to spare, an effective radar network was installed in the south of England to detect invading planes, plot their course, and thereby help with the defense of the island. It was a technical achievement far superior to anything available elsewhere.[6,7]

THE RESPONSE OF THE UNITED STATES

In the latter half of the 1930s, the position of the United States was one of caution and neutrality, even though the sympathies of most of the population leaned strongly toward the Anglo–French alliance. Lend-lease, destroyer transfers, institution of the draft, and a substantial shift of production toward the tools of war—all were introduced with the general approval of the citizens.

In line with these preparations, on 27 June 1940, a vital step was taken toward the mobilization of the American scientific and technical community with the establishment of the National Defense Research Committee (NDRC).[8] Two years earlier, Vannevar Bush, the Dean of Engineering at MIT, had moved to Washington to accept the presidency of the Carnegie Institution of Washington, which ran a number of laboratories endowed at the turn of the century by Andrew Carnegie for the purpose of research in astronomy, geophysics, and other fundamental sciences. Bush was persuaded that an armed conflict with the totalitarian powers was inevitable and that the introduction of new tools into the armed services would require a large, sustained effort.


Vannevar Bush (1890–1974), President, Carnegie Institution of Washington; Chairman, National Defense Research Committee and Office of Scientific Research and Development.

Bush proposed to President Roosevelt—with the strong support of Roosevelt's advisor and confidante Harry Hopkins—the creation of the NDRC, whose purpose was to accelerate and improve "instrumentalities for the national defense" at a time when the general state of American military preparedness was precarious. It became an enormously successful venture, far surpassing the fractious organization fashioned by the Germans. By the end of 1944, more than half of the chemists and more than three-quarters of the physicists belonged to it.

The undertaking was directed by Vannevar Bush, James B. Conant (President, Harvard University), Karl T. Compton (President, MIT), Frank B. Jewett (President, National Academy of Sciences, and Chairman, Bell Telephone Company), Richard C. Tolman (Dean, California Institute of Technology), and representatives from the Army, Navy, and other government departments. It was divided at first into four divisions, each having a number of sections.

Speed and an emphasis on ideas that could quickly be turned into useful devices were primary considerations in accepting proposals. The committee had an initial "war chest" of $10,000,000 to fund projects proposed by the section chairmen, with the work to be carried out at the proposer's institution in order to interfere as little as possible with educational programs. When worthwhile projects requiring sizable investments in manpower and equipment could not be assigned to existing institutions, the NDRC could approve new research groups (such as the Radiation Laboratory in Cambridge, Massachusetts; the Sonar Laboratory in New London, Connecticut; two rocket research facilities at the Allegany Ballistics Laboratory in Maryland and at the California Institute of Technology).

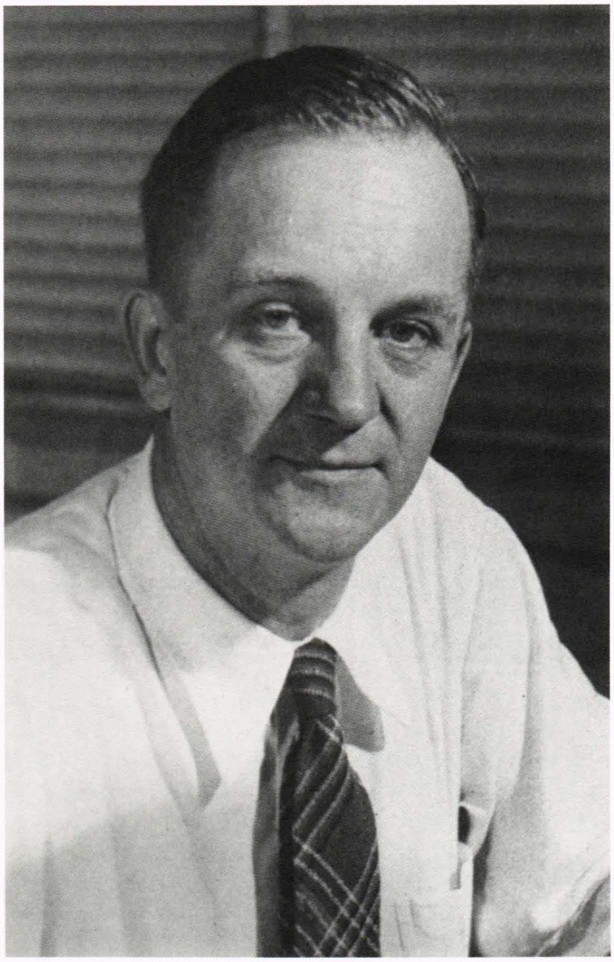
THE FIRST CHOICE—ANTIAIRCRAFT FUZES

One of the earliest, if not the first, NDRC contracts was with the Department of Terrestrial Magnetism (DTM), the most physics-oriented laboratory of Bush's Carnegie Institution of Washington. The chairman of the new section was Merle A. Tuve, its 39-year-old chief physicist. In accordance with identifying new sections by the surname initial of the chairman, it was called Section T of Division A (Armor and Ordnance). The duties of Section T were designated "Preliminary Investigations." Despite its cryptic title, the section's objective was the design of radio-controlled artillery shell fuzes. By sensing the approach to a radio wave-reflecting target, the fuze could be designed so that its triggering action would not depend on a direct impact with the target or on a preset time signal, but on a much more readily achievable proximity to the target, sufficiently close to inflict lethal or crippling damage.

The concept was straightforward and did not require the discovery or refinement of novel physical principles, as was the case, for example, with the development of nuclear devices. It required engineering development of a design that could be produced in quantities of hundreds of millions per year and that contained a reliable battery power supply, and, most importantly, a miniaturized radio set with tubes that could withstand the high acceleration forces of a gun-launched projectile.

There is now little evidence of how the decision was reached to select an artillery shell fuze project and assign it to Tuve as one of the first undertakings of the NDRC. The fuze was known in military circles in both the United States and abroad as a potentially useful device. It came to Tuve's attention in informal discussions with the technical staff of the Navy's Bureau of Ordnance. But its application to gun-launched shells, which required a rugged miniaturized design capable of withstanding a setback force of 20,000 g, had not been seriously pursued.[*,†]

In any event, it made eminently good sense to involve Tuve and, through him, the small and capable physics staff of DTM to take a fresh look at the problem. Within days it was demonstrated that several small, ruggedly built tubes could be packaged to withstand impact loads similar to what they might experience in gun launches and that, in principle at least, nothing stood in the way of a development effort.[10,11]



Merle A. Tuve (1901–1982), first Director, The Johns Hopkins University Applied Physics Laboratory.

The desire to tackle the fuze assignment was strengthened by the fortuitous arrival of the British "Tizard Mission." The Mission's objective was to have a frank interchange of technical information with the U.S. armed ser-vices and a sharing of a trove of blueprints, reports, and devices that had been under development in Britain dur-ing the past decade.[12]

In August 1940, Britain was fighting the crucial battle for control of the airfields in southern England. If the

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[*] From a letter from James B. Conant to D. Luke Hopkins, dated 29 February 1944: "Not the least merit of NDRC has resided in the fact that it is a young organization, created fresh to meet an emergency. All the important contributions that I can think of within the organization have been made by well-trained scientists and engineers who were not experts in the new fields into which they were forced as a result of the war effort. They, therefore, came with a fresh point of view and were able to do many things which the old timers either believed impossible or were too set in their ways to understand."

[†] "A radio influenced fuze was proposed as far back as 1931 and is now credited to William A. S. Butement of the Air Defense Experimental Establishment, Christchurch, England, who in a separate and independent undertaking also drew attention to the possibility of detecting and range finding of airplanes by the use of pulsed radio bursts. The fuze idea was taken to a breadboard design. In a complex patent infringement suit over the basic patent claims to the proximity fuze it was agreed in the end that Butement was the inventor of the original concept and that Tuve and his associates in the Section T program could claim prompt reduction of the concept to practice. Since the Butement rights had been assigned to the US Navy this decision, in effect, nullified large financial compensation claims by a third party."[9]

battle went badly, the Mission and the Churchill government hoped that the U.S. forces would benefit from the knowledge that Britain had so painfully acquired the preceding years. As it turned out, the British radars provided the small, vital advantage to the defensive forces. In October, the Luftwaffe air attacks were redirected away from the airfields to London and other cities, and, in place of an invasion of the British Isles, the Germans began to turn their attention to the fateful invasion of the Soviet Union in the following year.

Before the battle was over, the vice-chairman of the Tizard Mission, Sir Charles Cockcroft, had an opportunity to meet with Tuve at his home and to discuss the proximity fuze work that had been done in England. The exchange of views between old friends made a significant impression on Tuve. He was persuaded that the electronic portion of a miniature fuze was well within the prevailing state of the art, that the design of proximity fuzes for all but gun-propelled ammunition was in hand, and that the fullest emphasis was to be placed on antiaircraft devices where the payoff would be great.

The DTM staff quickly carried out bench tests to ascertain that nothing stood in the way of the then-available radio tubes of appropriate mechanical design to survive the launch forces, that the entire electrical circuit could be shrunk in size to fit the space available to conventional fuzes, and that field testing of prototypes of these devices could be scheduled within a few weeks.

It was realized early that widespread use of the device could be accomplished only by a multipronged effort, where suitable components and systems were developed in parallel with the establishment of industrial production lines. Simultaneously, attention had to be given to the introduction of the device into the fleet, with the familiarization and training of the commanding officers and crews supplemented by vigorous quality-control and quality-improvement programs.

Much of 1941 was spent in testing and analyzing results from custom-built laboratory devices under increasingly more realistic conditions. Simultaneously, tube manufacturers were setting up assembly lines so that full-scale production could be undertaken as soon as there was assurance that the entire system (including battery power supplies, safety devices to prevent premature explosions, and miniature tubes) would perform satisfactorily. Toward the end of 1941, a threshold of 50% success rate was surpassed, and full-scale production was authorized by the Navy. Several months passed before a full-scale demonstration against drones proved highly successful.* Fuzes were rushed to the Pacific fleet, accompanied by Section T technical personnel who would deliver them to the senior officers and to gunnery officers and their crews. They would also bring back information about their effectiveness in combat.†

REALIGNMENT OF THE ORGANIZATION

The massive introduction of a successful system into Navy use required adjustments in the structure of the operation of Section T. When it became clear early in 1942 that a very large production and evaluation phase was likely, it was realized that the scale of operations was too extensive for the limited facilities of DTM. A decision was reached in March 1942 to shift the contract to a new contractor, The Johns Hopkins University, find substantially more space (at 8621 Georgia Avenue in Silver Spring, Maryland), and set up the Section T operation directly under Vannevar Bush rather than in Division A.

With the informality prevalent during the period, Bush called his old acquaintance Isaiah Bowman, President of Johns Hopkins, and requested that the University become the sponsor of the contract, to which Bowman readily assented. The Johns Hopkins University, in turn, appointed D. Luke Hopkins, a Baltimore banker and Vice Chairman of the Johns Hopkins Board of Trustees, as the liaison representative for the University. The Navy's Bureau of Ordnance, the most interested and supportive customer, designated Commander W. J. Parsons as the technical liaison between Vannevar Bush and the newly named "Applied Physics Laboratory," a name chosen by Tuve to be descriptive without revealing too much of its ongoing activities.

For the subsequent war years, the emphasis of the proximity fuze team moved toward reliability analysis of the output from the many mass-production lines set up throughout the United States, and to the design of fuzes that would meet the dimensions of a wide variety of ammunition for U.S. and British consumption. *In situ* performance analyses of ammunition effectiveness were

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*"The next day [12 August 1942] all was ready off Tangiers Island and a drone approached on a torpedo run. At about 5000 yards range the ship (USS *CLEVELAND*) opened fire with all of its 5" guns. Immediately, there were 2 hits and the drone plunged into the water. Commander [later Admiral] Parsons of Hiroshima fame called for another drone and out it came at about 11,000 feet altitude. Once again it came down promptly. Parsons called for another and then raised hell when the drone people said there were no more ready to use. The ship was ordered to the Pacific with no stops as the crew had seen too much."[13]

†From a taped interview of M. A. Tuve by A. B. Christman, American Institute of Physics, 4 May 1966: "He [Parsons] supervised personally the process of getting the first shipment of fuzes to the Pacific Fleet. During October 1942, 500 fuzes were produced a day and they were immediately flown to the Ammunition Depot at Mare Island, California, and inserted in the nose of 5" shells. Here, too, the careful testing and control was continued and 50 shells were flown back each day across the country to Dahlgren Proving Ground, Virginia, for testing. When 5,000 were accumulated Commander Parsons went to Mare Island to supervise the loading of the shells into the planes for their transport to Pearl Harbor. Parsons then flew ahead and three scientists working at the Applied Physics Laboratory, especially commissioned for this duty—Lts. N. E. Dilley, R. P. Peterson and J. A. van Allen—accompanied the ammunition. After arrival the shells were then loaded on the aircraft carrier *WRIGHT* for their destination at the naval base at Noumea, New Caledonia, where Parsons reported to Admiral Halsey. The new ammunition was distributed as rapidly as possible to the cruiser *HELENA* and the aircraft carriers, the *ENTERPRISE* and the *SARATOGA*. Parsons asked to be assigned to the ship that would most likely see action first. Without indicating whether or not the request was granted Halsey assigned Parsons to the *HELENA* and on January 5, 1943 Commander Parsons saw the first Japanese brought down by a proximity fuze. Undoubtedly Parsons indoctrinated the gunnery batteries on the *HELENA* in the use of the weapon. This was the beginning of the indoctrination of the personnel of the Pacific Fleet by Parsons and his three associates in the use of the proximity fuze during the following three months."

carried out whenever suitable data were available. The bulk of the technical development work, however, had been accomplished by the end of 1943.

THE SECOND CHOICE—GUIDED MISSILES

Toward the end of 1943 and early in 1944, a new concept began to occupy the thoughts of some members of the APL technical staff. Antiaircraft shells, no matter how precisely fuzed, are limited in effectiveness by the comparatively modest distances to which they can be propelled from conventional guns. Proximity fuzes were additionally handicapped by the inflexibility of the ballistic trajectory of the shell, and by the need of a gun director that would track a target and adjust the shell trajectory to bring about a conjunction of the two.

The Germans had been deploying ship-seeking, rocket-propelled bombs, released from high-flying planes, in the Mediterranean. Should such mother planes approach, launch their ship-seeking missiles, and turn back beyond antiaircraft range, a serious risk would ensue. It was clear that a system countering this threat had to be designed.

In a letter from Tuve to Bush, dated 19 July 1944, Tuve wrote:

> [A] new Navy tactical situation may arise if the enemy adopts guided missiles for attack against task forces from airplanes just beyond the limited range of anti-aircraft. . . . We have thought about this problem for several years, and only in the last eight months have reluctantly concluded that we may have to face it during this war, instead of the next one. . . . The problem must be faced before very long if we hope for real defense against future air attacks in this shrinking world.

A technical analysis of the problem during the summer of 1944 showed that a solution to the standoff missile-launching plane scenario (dubbed "Falcon") would require, in contrast to the fuze development, a very substantial adoption of technologies that were well beyond the then-current state of the art. It was to be maneuverable in flight, guided initially toward its target by a radio link with the launch platform, finally brought near to its target by an on-board terminal guidance system, fly at roughly twice the speed of the target so as to be able to overtake it in chase, and be small enough to be carried in adequately large numbers in naval vessels.

The general conclusions of the study and their implications were submitted to the Navy. Tuve wrote to Capt. C. L. Tyler on 24 October 1944:

> This discussion is limited to the "chaser" aspects of the problem and does not cover the broad aspects of the defense of the fleet against guided missiles. This chaser is further limited to the military objective of defense against guided projectiles by shooting down their mother planes at ranges of 20,000 to 40,000 yards.
>
> Discussions and analyses during the first six months of this year indicated the necessity for attack of this "chaser" problem, even if the probability of success were low, as the stakes involved are so large. . . .
>
> We have examined both subsonic and supersonic solutions. . . .
>
> The subsonic chaser can be made. . . . This weapon is not promising enough to be worth major emphasis.
>
> A supersonic chaser can very probably be made, although new experiments on propulsion and aerodynamics control are still needed before it can be stated with certainty that a supersonic ramjet missile can be made to fly under control. . . .
>
> The supersonic chaser missile should be made the objective of one sharply focussed single-goaled attack by a closely knit group. . . .
>
> An expenditure of about $10,000,000 in a period of two years by an experienced team will result either in a first type of chase missile actually usable to meet limited military requirements or in a rather extensive proof that no nation can bring such devices into use in any predictable length of time. Even a negative result of this kind would be extremely valuable, as the attack aspects of these devices are of at least as great significance as the chase (defense) aspects. Results of either type are highly necessary for the United States to possess as soon as possible, whether ready before the end of the war with Japan or not.
>
> The prospects of rapid and definitive progress of this problem are not great unless a very lively team is given the overall assignment promptly. . . . First-class technical civilians can be assembled for this now.
>
> The Chairman and senior staff of Section T. . . are exceedingly interested in this problem.

Nearly every aspect of the design required an advance in the state of the art. The missile's range should exceed 20 miles, and its speed had to be in the supersonic range. Neither a proved-in engine (a ramjet for the contemplated design, flying at twice the speed of sound or faster) nor supersonic aerodynamic controls existed as off-the-shelf items or in experimental prototypes. Acceleration to flight speeds where the ramjet engines could develop efficient propulsion thrust required solid propellant booster rockets that were well beyond the sizes produced in previous applications. Guidance systems that were immune to interference by deliberate jamming and that could deal with more than one missile at once had to be designed.

Despite these uncertainties, the Navy's Bureau of Ordnance was persuaded that such a system had great potential for the protection of ships and the defense of the fleet. In view of the developing kamikaze threat, there was hope that a simple design might prove beneficial, even though the end of the war in 1945 was widely expected. It also occurred to the eventual sponsor that scaleups in range, warhead size, and speed would lead to many more applications.

With Navy acceptance of the APL technical and management proposal, Tuve could report to Bush in a letter dated 22 December 1944:

> The Bureau of Ordnance has determined to proceed with the development of jet-propelled guided anti-aircraft missiles. Admiral King has directed that this program be carried forward on an urgent basis.
>
> Captain C. L. Tyler, Director of Research and Development for the Bureau of Ordnance, asked me yesterday to organize and direct this work. The proposal made by Captain Tyler is that this is not to be an ordinary project, but that unified responsibility for the attack of this whole problem is to be assigned to a central technical group, preferably the Applied Physics Laboratory of Johns Hopkins, outside of the Navy. . . .

In a formal letter to APL, dated 11 January 1945, Admiral G. F. Hussey, Jr. (Chief, Bureau of Ordnance), assigned the following task:

> Task "F"—A comprehensive research and development program shall be undertaken, embracing all technical activities necessary to the development of one or more types of rocket-launched, jet-propelled, guided antiaircraft missiles. . . . This program shall include pertinent basic research, investigation and experiments, and the design, fabrication and testing of such missiles. . . .

He added the following comments:

> The Bureau of Ordnance does not expect in the immediate future to obtain an ideal or ultimate antiaircraft weapon, and is aware that the actual results of these efforts cannot be guaranteed or accurately predicted. The Bureau believes, nevertheless, that an immediate attack must be made on this problem, and expects that this will result at best in the production of an advanced antiaircraft weapon which may be available in the later stages of the war, and at the least in considerable valuable progress in research and development on jet propulsion techniques, self-guided techniques, and other technical matters of great importance to the future of ordnance.

A SECOND REALIGNMENT OF THE ORGANIZATION

Thus, APL embarked on its second major wartime assignment. The new and complex program provided an opportunity to negotiate a contract directly between the sponsoring Bureau of Ordnance and The Johns Hopkins University without going through the Office of Scientific Research and Development (OSRD) (the successor to the NDRC) with whom APL was still engaged contractually. The content of the contract was carefully summarized on 20 October 1944 in a memorandum from D. Luke Hopkins to the Trustees of Johns Hopkins who were wrestling with the implications of a break in sponsorship:

> Definite statements have been made by Dr. Bush, indicating that plans for demobilization of the OSRD be formulated to be effective shortly after the close of the German phase of the war. . . .
>
> The Navy Department requested that JHU consider entering into a contract with the Government to continue the activity at Silver Spring, at least during the Japanese phase of the war; and to this end and for the past several weeks, negotiations have been under way, which negotiations have evolved a form of contract very similar to the OSRD contract and giving a great deal of freedom and flexibility of operations. . . . We believe that this will evolve a pattern for handling contracts to carry on research and development similar to that now in existence. . . .
>
> Under the terms of the contract the University will be responsible for the technical direction and it is contemplated that Dr. Tuve, who has been the Technical Director of the entire activities of Section T for over four years will be appointed as Technical Director on the staff of the JHU. . . .
>
> It is of interest to know that not only the Bureau of Ordnance but also the other Bureaus of the Navy and various departments of the Army as well as private institutions are very anxious to see how this approach will work out. It is one step, at least in solving the most important problems of how to carry on the research and development of the Services for the prosecution of this war, the defense of the country, and an enduring peace.

Thus, Tuve was appointed the first Director of APL (but still on leave from DTM), relinquishing his title of Chairman of Section T. Virtually no changes in operation were needed. D. Luke Hopkins remained the contract representative of the University, while the Navy representative, previously assigned to work directly under Vannevar Bush, carried out his functions directly from within the Bureau of Ordnance. The APL operations, such as the contractual and technical interactions with a broadly based group of associate contractors, retained the Section T pattern that had been established in previous years during the OSRD phase.*

Even before the task assignment was formally received, Tuve plunged into the difficult but exhilarating task of setting up the new structure that would concern itself with the new guided missiles effort, without disowning the proximity fuze task that was reaching record levels of production. Groups dealing with propulsion, aerodynamics, guidance, control, launching, and analysis had to be organized. Test facilities had to be planned. New people had to be hired in areas that were unfamiliar to the people already on board. Associate contractors had to be found and persuaded to join the effort. All this was accomplished, and, after several weeks, test models were being built and program plans drawn up, discussed, and implemented.

When the war with Japan ended in 1945 and the time had arrived for a renewal of the contract with Johns Hopkins, enough had been accomplished to allow the then-Secretary of the Navy James Forrestal to write on 18 October 1945 to the President of The Johns Hopkins University, Isaiah Bowman:

> These activities are of the utmost importance to the security of the nation and this extension will afford an opportunity for those individuals who have the necessary technical background and experience to extend and consolidate the highly significant results already attained, and will allow time for adjusting the entire program into a peace-time framework.
>
> As you know, through the operations of the NOrd type contract at the Applied Physics Laboratory and at the various associated "Section T" contractors, a mechanism has been provided whereby technical direction of work in broad areas of scientific research and in the related applied fields, by groups outside the Navy establishments, can be carried on under the guidance of interested and qualified technical men who are associated with, but not directly a part of, the Navy. . . .

This is not the place to trace the fate of the Section T-type contracts after the war. The development of antiaircraft guided missiles was advanced with great speed and imagination. Indeed, workable systems were developed within a few years, together with an understanding of many of the scientific and engineering programs that

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*Memorandum dated 11 October 1944 from M. A. Tuve to Capt. C. L. Tyler: "A contract pattern has been worked out which permits a retention of the Section T pattern of using the central Laboratory (Johns Hopkins Applied Physics Laboratory) to guide the activities of various Associate Laboratories at other Universities and in industry. Each of these will have a direct Navy contract with technical guidance and control of their activities by the Johns Hopkins Laboratory, under broad tasks assigned directly by the Bureau. . . . This example of a shift of a major OSRD activity to a contract directly with one of the Services is being watched. . . ."

were only dimly known at the start of the program. Thus, the faith placed in the Section T approach was clearly vindicated by subsequent events.

THE LEGACY

What is Tuve's legacy for today? His activities as a scientist–soldier spanned less than five years. At a perilous time, he shifted his calling as a scientist at the peak of his creative years; he was joined by thousands who responded similarly.

He gathered around him a sizable team of capable collaborators who turned a concept into a prototype, transformed it into several hundred million fuzes, and pushed them to their timely use. Once the success of this venture was assured, he redirected the team toward a new task that is still of interest to the organization that he founded. In this, he was joined by only a handful.

But he was virtually unique in his persistence that the working relationship of the military and the civilian R&D community be one of mutual respect and trust and created a new pattern (the Section T pattern) for the management of complex development programs. He persuaded The Johns Hopkins University to support the Laboratory to which he gave its name and found its home in Silver Spring, Maryland, a support that has deepened since it began fifty years ago. He gave much thought to the future of APL. While not fully foreseeing the demands of the Cold War, he was never in doubt that a laboratory like APL would play an important role.

What is now the APL began as a small technical team assigned to do "preliminary investigations" within the DTM of the Carnegie Institution of Washington, initiating and pushing toward successful conclusion a development program that brought under its cognizance most of the electronic capacity of the United States. Because of the speed of its development and the rapidity of its acceptance, the program had a palpable effect on the outcome of World War II.

Fuze problems have ceased to be part of the APL assignment. What has remained is a legacy whereby a team of people with diverse technical backgrounds can harness their skills to reach technical solutions to problems that span the breadth of development from concept to application.

Interest in fleet defense by guided missiles remains a major APL task. Endeavors have expanded below the ocean surface and into outer space, but a staff member reporting to work fifty years ago in the Cyclotron Office Building of the DTM in northwest Washington, D.C., or in the Silver Spring Laboratory of APL would not feel greatly out of place in today's surroundings. The attitudes toward problem-solving first put into practice by Merle Tuve would still ring true.

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APPENDIX

MERLE ANTONY TUVE— THE STEPS THAT LED TO APL

Thomas D. Cornell is the author of a biography[A1] that covers Tuve's career up to 1939. He says

> Perhaps the most convenient way of introducing Tuve is to say that his experiences closely paralleled those of his friend, Ernest O. Lawrence. Both were born in Canton, South Dakota in 1901—Lawrence in August and Tuve in June. Both were the sons of educators and the grandsons of Norwegian immigrants. Both 'monkeyed with wireless' as teenagers, studied physics in college and developed particle accelerators during the years between the world wars. After World War II began both assumed important responsibilities, Lawrence with the atomic bomb project and Tuve with the proximity fuze. Finally, during the postwar era both led important research organizations—Lawrence at the Radiation Laboratory of the University of California and Tuve at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.
>
> . . . Both helped to create the technology-intensive, team-oriented approach to experimental physics that has emerged as one of the most distinctive features of science in the 20th century.[A2]

Tuve's experiments were beautifully transparent and always elicited warm applause from his colleagues. He probed the height and motion of the ionized Heaviside layer in the ionosphere with bursts of microwaves.

> The work of Breit and Tuve came close to winning a Nobel Prize. . . .[A3]

He measured the binding energy in simple nuclei by precise proton scattering. From a letter from Ernest Rutherford to Tuve, 17 November 1936:

> I have read with great interest your papers on the transmutation of the isotopes of lithium and your accurate determination of the scattering of protons, described in the last two numbers of the *Physical Review*. I congratulate you and your collaborators on two excellent pieces of work. . . . I am very pleased to see that as your papers show, results of real value can only be obtained by accurate and long-continued experiment . . . .

He probed the earth by following the propagation of explosion-induced shockwaves through the crust. A citation prepared by Maurice

Ewing for the Twenty-Fifth Award of the William Bowie Medal of the American Geophysical Union, given to Tuve in 1963 reads:

> Your research career might be characterized by the skill in applying electronics to almost any given job—whether the job was to probe the earth's ionosphere or the forces within the atomic nuclei—or to study radio waves from outer space or elastic vibrations from the earth's interior. . . .

Tuve began his scientific career at the Department of Terrestrial Magnetism in Washington in 1925 at age 24. He fully lived up to the challenge of the Carnegie Institution of Washington's credo that it would buy the time of a creative research man and then give it back to him so that he could pursue pathways of his own choosing. He fashioned a world-class nuclear physics laboratory at a time when the rich harvest of studies of nuclei, of their transformations, and structures was only dimly perceived.

He responded to a flattering offer in 1937 from J. Slepian of the Westinghouse Research Laboratory in Pittsburgh.

> I am happy here and I am satisfied the future will provide an even greater opportunity for creative contribution to our work.

But, as he said at a later occasion "Important things are always basically simple." So he gave up nuclear physics research when the other pressing tasks seemed more appropriate. From a taped interview of Tuve by A. B. Christman, American Institute of Physics, 1967:

> War was declared in 1939. In February 1940 I had just plain quit any scientific work in the laboratory and I led my immediate colleagues . . . in the same direction. I said 'Let's not do any more research if the Germans are going to inherit it. I think we have got to find out what we can contribute to stopping this conflagration.' The problem was how to mobilize the scientific and technical capabilities of this country and get ready for what we felt was bound to come.

And in 1948, receiving the John Scott Award at Girard College, Philadelphia, he would say

> We are still ready to drop whatever we are doing and meet the call for the defense of freedom if it comes again.

To probe more deeply into Tuve's relationship with what was eventually to become APL, we need to pay attention to the crucial events of 1939 and 1940. As noted by his young colleague, Richard B. Roberts in 1979,

> It was a relief to find that Tuve had been active during the summer [1940] and we were about to shift our activities to something more relevant than building cyclotrons for biology. . . .

Tuve had been restless. In September 1939, he had written to Ernest Lawrence

> There is a tremendous public sentiment in these parts favoring repeal of the Neutrality Act to permit arms shipments, cash and carry, to England and France. . . . I'll go to war as soon as it becomes proper for US citizens to contribute that way. . . .

And in July 1940 he would write to his old friend E. C. Stevenson:

> We are very much in the same position as you with regard to being anxious to do something for defense. I have been in touch with Bush in connections with the National Defense Research Committee [NDRC]. . . .

The opportunity to participate was not far off. In the weeks immediately preceding the establishment of the National Defense Research Committee (NDRC) (June 1940), Tuve was asked to help with the preparation of an assessment of people who should be considered for top positions as NDRC Section Chairmen, whose assignment was to organize a viable countrywide research effort that might quickly lead to useful military devices. Tuve was well-connected in the physics community, having vigorously supported an active Washington Physics Colloquium for years, having been instrumental in bringing Edward Teller and George Gamow to the George Washington University, and, most importantly, in organizing an annual summer Discussion Meeting on Important Fundamental Physics Problems that attracted the most vigorous physics practitioners in the United States and abroad (Bethe, Dirac, Szilard, Goudsmith, Condon, Lawrence, Uhlenbeck, Fermi, Bohr, and others).

In early September 1940 he was informed by Vannevar Bush that

> The National Defense Research Committee established by order of the Council on National Defense to handle research on instruments of war in the present national emergency has appointed you Chairman of Section T of Division A.
>
> May I assure you of the Committee's deep appreciation of your willingness to assist in these vital matters of national defense. The fact that so many scientific workers have indicated their willingness to put their immediate problems to one side and sacrifice their own personal interests to those of the country in this hour of need is a heartening sign of the country's unity in the face of danger.

Only four years later, President Harry Truman awarded the Medal of Merit to

> Dr. Merle A. Tuve, for exceptionally meritorious conduct in the performance of outstanding services to the United States. Dr. Tuve, by his outstanding devotion to duty, scientific leadership, perseverance and enthusiasm was primarily responsible for the development of a major improvement in ordnance which has proved to be a determining factor in defensive antiaircraft action by the United States Navy and resulted in a material increase in the efficiency of offensive action by the United States Navy against enemy air power.

When in 1946 Tuve returned as Director to the Laboratory from whence he came in 1942, he plunged, once again, into the work in science from which he would glean deep satisfaction and much pleasure.

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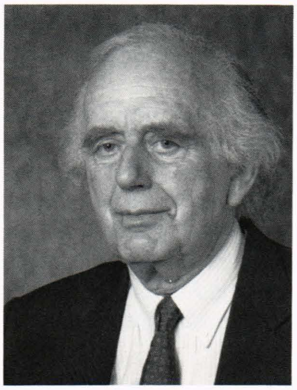

WALTER G. BERL joined APL in 1945 and is a member of the Principal Professional Staff. In 1937, he received a B.S. degree in chemical engineering from the Carnegie Institute of Technology, followed by an M.S. from Harvard in 1939 and a Ph.D. from Carnegie in 1941 in physical chemistry. After a distinguished career in combustion and fire research and their applications to practice, he was Editor of the *Johns Hopkins APL Technical Digest* (1980–87) and the *APL Technical Review* (1988–89). A member of numerous professional societies and advisory boards, he is the author of more than 40 technical papers. He was recently the William F. Parsons Professor at the Paul H. Nitze School of Advanced International Studies of The Johns Hopkins University, where he was involved with the introduction of an expanded curriculum in the role of science and technology in international affairs.