TOFTOY

Dec
1966

II . 1

THE HISTORY OF ARMY MISSILE DEVELOPMENT

By Brigadier General H. N. Toftoy

Published as "Army Missile Development," Army Information Digest, XI (Dec 56), 10-34.

On 6 September 1944, the first tactical V-2, Hitler's celebrated vengeance weapon, was launched by German forces from the outskirts of The Hague, Netherlands. At 6:43 P.M., less than six minutes after it had been fired, the forty-six foot long rocket bearing its 2200 pounds of explosives detonated with a devastating effect at Chiswick-on-Thames, very near London.

Thus came the most dramatic application of military rockets known to the world. In the next ten days twenty-six V-2's were showered on London. Approaching its target at speeds greater than sound, the V-2 gave no advance warning. For seven months, until 27 March 1945, this bombardment continued. All told, about 1500 V-2's crossed the Channel, 1115 dropping in England. London recoiled under the impact of 518 of them. Nearly 3000 civilians were killed; thousands more were injured. Property damage was tremendous. The effects on English morale and prestige, intangible as those things are, were serious.

Recognizing the potential of the V-2, no less a military leader than General Dwight D. Eisenhower has written: "It seemed likely that, if the German had succeeded in perfecting and using these new weapons six months earlier than he did, our invasion of Europe would have proved exceedingly difficult, perhaps impossible."

The rockets of World War II represented the modernization of a very old weapon. As early as 1232 A.D. defenders of the Great Wall of China launched rockets against the invading hordes of Mongolia. The news spread around the world, and during the fourteenth century rockets were used in Europe as an incendiary and terror-provoking weapon. After 1500 A.D.

with the development of cannon, the military lost interest in rockets until late in the 18th Century when the Maharaja Mysore used them effectively against the British in India.

There is no quicker way to stimulate interest in a new weapon than to discover it in use by the enemy. It was not surprising that the British then tried to produce rockets of their own; but it took until 1805 before Sir William Congreve developed rockets considered satisfactory for military use -- just in time for the Napoleonic Wars.

During the War of 1812, Americans learned the effectiveness of Congreve's erratic rockets, when with flanking rocket fire the British demoralized the raw militiamen defending Washington and were able to enter and burn our National capitol. The expression "and the rocket's red glare" immortalized in our National Anthem was not a figment of a poet's imagination -- it was the real thing.

The U. S. Army organized its first rocket battery in 1846. At this time America made its first contribution to improved rocket design. William Hale first produced a spin-stabilized rocket by substituting canted fins for a stabilizing stick. These forerunners of the modern rockets were used by the thousands in the Mexican War; but in spite of a promising start, they could not compete with the accuracy of rifled cannon introduced in 1860, and once again rockets fell in disuse.

The United States Army's interest in rockets reappeared briefly in World War I when Dr. Robert H. Goddard of Clark University, the father of modern rocketry, undertook the development of military rockets. Dr. Goddard developed a number of test models and demonstrated them at the Aberdeen Proving Ground, Maryland on 10 November 1918 before representatives of the Ordnance Corps, Signal Corps, Air Service and others.

The demonstrations were considered quite successful, and interest was expressed in the continuation of the work. On the following day, however, the Armistice was announced, and official interest in military rockets lagged for more than 20 years.

Working under a $11,000 grant given to him by the Smithsonian Institution, Dr. Goddard is credited with developing many of the basic concepts in rocket and jet propulsion engineering. By 1920 he had obtained a Daniel Guggenheim grant, augmented by funds from the Carnegie Foundation, and proved his theories by successfully firing his liquid oxygen and gasoline propelled rocket to a height of 7,500 feet with a maximum velocity of 550 m.p.h. Goddard patented a number of fundamental principles which have subsequently been developed for use on present day guided missiles. Among these were the use of fuel to cool rocket motors, jet vanes and gyroscopic control for maintaining stability, and a plan for multi-stage rockets.

Thus the United States, contrary to popular belief, was the first to clearly outline the basic principles that were later applied to guided missile development. Germany's experiments with liquid propellant rockets in the early 1930's were generally unsuccessful, but ironically, the Germans developed the first long range tactical missile and used it against the Americans and their allies.

While Goddard was working on his rockets in 1917 the earliest recorded guided missile project was established. Under the direction of Charles F. Kettering of General Motors, the Army Air Service experimented with a remotely controlled pilotless aircraft type of "flying bomb". By 1924 a number of successful flights had been achieved and hits scored as far as ninety miles away.

The secret of the flying bomb was almost revealed when one crashed. Local farmers were first on the scene and were mystified when they searched the wreckage and found no pilot. Upon the arrival of an Army flier, wearing flying togs, he managed to keep the Army secret by claiming he had "bailed out back yonder." The farmers did not know that the Army Air Service at that time had no parachutes!

Little was accomplished in the 1920's but in the 1930's European nations carried on secret development of solid propellant rockets in answer to its tactical needs. In the United States only Captain Leslie A. Skinner of the Army Ordnance Corps (now Colonel, Retired) held such a firm belief in military rockets that on his own initiative he carried on experiments in the basement of his quarters at Aberdeen Proving Ground. The Commanding General, fearful that Skinner would wreck the quarters, provided shop space and a few hundred dollars. This effort paved the way for the "bazooka," a weapon which for the first time enabled an infantryman to combat a tank singlehandedly.

Every major participant in World War II used rockets. The Russians pioneered in massed rocket barrages and the firing of air-to-ground rockets. The British first used rockets for air defense. The Japanese used them as artillery. The United States, too, developed and introduced rocket weapons. Not a service rocket was available at the time of the attack on Pearl Harbor, yet by V-J Day millions of rockets had been produced and fired by our soldiers, sailors, airmen and marines. The development job was difficult and time consuming because each project required development of fundamental knowledge which a continuing peace-time research program would have provided in advance. It is a tribute to the determination of our nation's Ordnance-Science-Industry team that, starting with such a handicap, they were able to produce a variety of free flight rockets which sank submarines, defeated tanks, spearheaded the air support for the Normandy breakthrough, and effected a deadly softening up barrage ahead of our forces invading Africa, Sicily, Italy, Normandy and Southern France. Rockets were also used in virtually every Pacific action from Arawe to Okinawa.

In August 1943 a radio controlled glide bomb launched from a German airplane struck a British ship in the Bay of Biscay. This marked the beginning of guidance for missiles in warfare. Guidance when combined with jet propulsion led to modern guided missiles.

The Germans were first to do this, bombarding British cities with the V-1 buzz bomb starting in June 1944 and with the V-2 missile in September of that year. The relatively slow V-1, a 400 m.p.h. pulse jet utilizing pre-set guidance, was effective enough to cause employment of heavy Allied air defense against it. On the other hand, there was no countermeasure against the 3,500 m.p.h. pre-set V-2 once it had left its launching site. Germany had demonstrated the V-2 was an all weather, day or night weapon effective without having air superiority.

By the spring of 1945, fifteen thousand V-1 buzz bombs and over 2,500 V-2 rockets had been fired in combat. An appreciable amount of Allied resources had to be diverted toward counteracting this threat. When the war ended the Germans were developing surface-to-air guided missiles that later might have seriously hampered Allied bomber operations. They were also busily engaged with improved versions of the V-2.

The Germans were years ahead in the development of modern guided missiles. However, by the time the V-1 and V-2 appeared on the scene, America already had recognized the great prospects for these weapons of the future and had a good start in research and development on guided weapons.

One phase of this activity was concerned with the development of a series of guided bombs. The Armed Services, the National Defense Research Committee and various industrial contractors collaborated in this work which included command type guidance systems incorporating heat, light, or radar seekers. There was one application of television equipment before TV became commercially available.

Best known of these weapons was the Army Air Forces AZON and RAZON and the Navy BAT. The AZON was a 1,000 lb. general purpose bomb which the bombardier could control to the right or left by radio. It got its name from the fact it was controlled in azimuth only. This guided weapon was used for special missions against long narrow targets in Europe such as the locks of the Danube, viaducts near Brenner Pass, and bridges over the Seine. Good results were also obtained in disrupting communications in Burma. The RAZON, which was designed to be controlled in both range and azimuth, was not perfected in time for operational use in World War II. The BAT, the world's first target seeking missile was pushed to completion and successfully employed against Japanese shipping before the cessation of hostilities. This weapon was a winged glide bomb utilizing radar techniques to home on its target.

As early as 1941 there had been agitation to develop a V-1 type of missile, but it was not until the buzz bomb attacks on England that the War Department initiated this project. Known as the JB-2, or LOON, this 450 m.p.h. pulse jet was similar to the German V-1. Heavy operational use had been planned and large scale production was well underway when V-E day led to cancellation of a large portion of the procurement order. The available JB-2's were then used for experimental work and for training purposes by the three services.

The Army's rocket activity assumed a new status in September 1943 when the Technical Division of the Office, Chief of Ordnance established the Rocket Branch. Ordnance had collaborated in some of the various wartime missile developments but the activities had been broken down and assigned to the most appropriate of the existing Ordnance agencies. This reorganization indicated that rockets and guided missiles were now considered new members in the Army's family of weapons which would be centrally managed in the same manner as small arms, artillery ammunition and tanks.

At the same time, Ordnance requested Jet Propulsion Laboratories (JPL) operated by California Institute of Technology to investigate the feasibility of developing long range surface-to-surface guided missiles. Also in September 1943, acting on a request of the Chief of Ordnance the Ballistic Research Laboratory (BRL) at Aberdeen Proving Ground prepared a feasibility study of long range rockets. Both the JPL and BRL reports were favorable. Impressed, Ordnance in May 1944 placed a $3,300,000 contract, known as the ORDCIT project, with JPL for general research on guided missiles, with emphasis on rocket propulsion and supersonic aerodynamics.

In less than a year, early experimental work at JPL confirmed the feasibility of guided missiles and two more contracts were negotiated. The first of these established the HERMES project with the General Electric Company. Its scope was broad, encompassing research and development leading to long range, surface-to-surface, and to high altitude anti-aircraft missiles. These original objectives were changed from time to time as the overall guided missile program developed. The other contract with Bell Telephone Laboratories of the Western Electric Company in February 1945, initiated the NIKE project for research, development and engineering work required to produce a suitable anti-aircraft missile system.

rdnance Corps was well qualified to conduct the Army guided missile program. It had years of aerodynamic work associated with development of projectiles in the BRL at Aberdeen Proving Ground, as well as long experience with complex fire control systems. Ordnance personnel recognized, however, that they would be pioneering in a considerably broader field than ever before, and that new development and test facilities were essential before much progress could be made.

There was no supersonic wind tunnel of useful size in the United States. Professor Theodore von Karman, a member of the Scientific Advisory Committee of BRL, had for some time urged the construction of such a facility. A study by a special National Academy of Sciences committee, headed by Dr. Frederick W. Durand, supported the reasoning advanced by von Karman: that such a tunnel was necessary for use in research in supersonic aerodynamics and the design of improved and more efficient ballistic shapes. In 1943 Ordnance obtained funds for its construction. Put into operation late in 1944, the BRL wind tunnel proved itself an essential element in the solution of supersonic flow problems and design of guided missiles for the Army, Navy and Air Force. For some time it was the only supersonic wind tunnel in the United States available for this work. Four years later a second Army Ordnance wind tunnel was placed in operation at the JPL. Meanwhile the Navy and the Air Force had also built new supersonic wind tunnels.

From the outset the Army was thinking in terms of guided missiles which would extend the range of artillery to 500 miles; in fact, our initial program included preliminary work on the 500-mile HERMES C-1. It was evident a much longer test range than any conceived to date had to be immediately established. In order to obtain all possible information and technical data pertaining to flight tests of these unmanned supersonic missiles, it would be necessary to devise and install a complex system of range instrumentation. Recovery of spent missiles for study during the development phases was also considered essential. An overland range, therefore, was decided upon. After an extensive survey in 1943, White Sands Proving Ground (WSPG) was established the following year in the New Mexico desert 28 miles from Las Cruces and adjacent to the Fort Bliss military reservation. The range extended north approximately 125 miles and was 45 miles wide.

Special facilities required by the contractors at their plants for component development and testing were also provided from Army funds.

The Army Ground Forces were quick to appreciate the lead time required to develop and evolve doctrine for the tactical employment of guided missiles. In order to be ready to place guided missiles in operational use as soon as they became available, the first guided missile batallion was activated in October 1945 at Fort Bliss. Personnel of this organization assisted in the missile launchings at WSPG, and gained valuable experience long before the first missile system was delivered to them. Concurrently the school at Fort Bliss developed guided missile courses and conducted intensive training of Ground Forces personnel to prepare them for what was to come.

Having established projects with highly qualified contractors, and provided them the necessary "tools of the trade," and a proving ground, the Army was now really in the guided missile business.

The Army recognized the achievements of the German scientists and engineers and the fact that they were the most experienced groups in the world. After their surrender to the United States forces, Ordnance Technical Intelligence personnel recommended transfer of the cream of the crop to the United States, in order that the American program could benefit by their knowledge and carry on where the Germans had left off. Ordnance obtained approval in June of 1945, and under the "Paperclip Program" an integrated team of 130 outstanding key specialists were voluntarily brought to the United States. The group was established at an Ordnance Sub-Office at Fort Bliss and organized to conduct studies and recommendations on the development of long range surface-to-surface guided missiles for the Army. In addition they rendered valuable service in indexing and translating large quanties of captured documents, identifying rocket materiel, and assisting with the assembly and firing of V-2's at White Sands. They were most cooperative in every way and provided excellent interrogation service, not only to the Army personnel and contractors but to those in the Navy and Air Force engaged in the American program. They were later transferred to Redstone Arsenal after it became the Ordnance center for rockets and guided missiles. Their work has been outstanding, and they are now highly respected citizens of their community and of the United States.

At the beginning of the Army Ordnance missile program it was realized that we would be pioneering in a field entirely new to U. S. technology. Brand new contributions representing real advances in several fields of science were required to solve the many problems associated with our present day guided missiles. The frontiers of science would have to be advanced -- and were -- at an unprecedented rate.

Consider what a guided missile is required to do -- fly at thousands of miles an hour speed, through the atmosphere and into the vacuum, navigate itself long distances with practically pinpoint accuracy, and stand up under tremendous extremes of acceleration, vibration, temperature and sudden forces of external disturbances.

No other single development to date has been as complex or as difficult as a guided missile system. It is not a one man job. Outstanding experts in electronics, aerodynamics, physics, chemistry, meteorology, mathematics and many other fields of science are required to collaborate as a team in the development of a guided missile system.

A carefully planned long range research and development program was initiated, with emphasis on research, in order to obtain the knowledge and experience which would insure successful development of guided missile weapons to meet the requirements of military service. We can refer to this period as one during which we "cast our bread upon the waters," and received many fold returns through this research. We knew practically nothing about supersonic aerodynamics, the sound barrier, or thermal barriers when we started. There were no text books on these subjects -- no courses in our educational institutions.

During the period Army was learning to walk before it ran, great technological progress was being made. Basic information of importance to missile designers was being developed at the various Army projects and proving grounds, and made available to all in the national program.

By the fall of 1945, JPL fired their first WAC CORPORAL at WSPG to an altitude of 43 miles. From this liquid propelled research rocket evolved several important applications. The Navy's AEROBEE upper-air sounding rocket was a scaled up version. Principles developed on the WAC CORPORAL were applied to the CORPORAL. But the most historic achievement of the WAC CORPORAL was the part it played in February 1949 as the business end of the BUMPER missile, which set altitude and velocity records which, at this writing, still stand.

The BUMPER came about from the need to check theories on multi-stage rocket flight. The primary objectives of this experiment were to obtain information on: (1) the separation and ignition of the second stage rocket in highly rarified air, (2) the stability of a second stage missile launched at extremely high velocities and altitudes, (3) the aerodynamic effects at higher Mach numbers obtainable in no other way at that time. Although it was recognized that the multi-stage principle offered the most effective means of obtaining great distance or altitudes, it had never been successfully accomplished. There were skeptics. The BUMPER missile, consisting of a V-2 with its nose modified to accommodate a WAC CORPORAL, was the result of the combined efforts of Ordnance, JPL, Douglas Aircraft and General Electric. The first full-powered flight at WSPG was entirely successful. The WAC CORPORAL traveled upward at a speed of 5,000 m.p.h. to a height of 250 miles. Army was credited with being the first to send a man-made object outside the earth's atmosphere. The flight lasted 12 minutes during which time the earth was rotating; this necessitated a directional correction amounting to several miles.

The V-2 program conducted at WSPG contributed much to rapid postwar progress in this country. Starting in May, 1946 a total of approximately 80 were fired. These were assembled from captured components with shortages supplied by the HERMES project. The V-2, which stands as a milestone in man's technological progress, was thoroughly researched; in the process it added to our background of scientific knowledge and expedited our experience in handling and firing large missiles of this type. Its use as a vehicle for flight testing various components being developed for our budding missiles, and for checking out the complex range instrumentation being developed for the proving ground, represented a great saving of time and money. An appreciable number were fired in collaboration with scientific institutions for research of the atmosphere. These V-2s, carrying heavy loads of instruments to altitudes exceeding 100 miles, gave scientists for the first time the means to study the properties of the upper atmosphere and the effects of cosmic radiation. In fact this phase became so important that the Navy was authorized to develop their VIKING missile to continue the work after the supply of V-2s was exhausted.

In an interesting experiment in 1947 the Army cooperated with the Navy in firing a V-2 from the deck of the U. S. S. Midway. The missile, which had not been designed to counteract a ship's motion at launching, took off in an erratic manner and created considerable excitement and anxiety for all concerned. However, it did prove that large ballistic missiles could be successfully launched from ships at sea.

One V-2, in its role of a flying laboratory, also created a serious international incident. The experiment was a check on the effectiveness of the design of a ramjet diffusor under actual flying conditions. The V-2, with the ramjet component mounted on its nose, was programmed for a relatively short flight at low altitude. The missile took off, rising majestically and properly inclined into its trajectory, but the direction was south instead of north. Means had been provided to terminate its flight in case of trouble, but the man at the safety controls knew too much. He reasoned someone simply reversed the leads -- the programmed range is only half way to Fort Bliss. He let it fly. But it wasn't crossed leads, and the missile did not respond to its preset flight path. Radars lost it crossing the Mexican border! It passed over El Paso and over Juarez where a fiesta was in progress. It fortunately impacted on a barren hill, causing no damage or injuries except those resulting from traffic accidents in the rush to the scene. Enterprising Mexicans roped off the crater, charged admission, and sold bits of the V-2 for souvenirs. White Sands operations were suspended, by order, until the Chief of Ordnance was assured that missiles would never again cross the boundaries of the proving ground. As a result of this experience a complex and effective safety system was devised. This consisted essentially of a combination of radar tracking with automatic plotting boards, precise and continuous electronic impact prediction, backed up by visual observation through a sky screen on which safety limits were indicated. Operations resumed, witnessed by a large group of Mexican officials.

The new safety equipment paid off well. Malfunctioning missiles could now be permitted to fly the maximum distance before being cut down within the boundaries of the range. This provided more data on technical troubles encountered in flight. Judgment was still required on the part of the safety officer, however. For example, one day a CORPORAL took off normally, then hooked to the west. If cut down when the trouble developed the missile would have endangered the post of White Sands; beyond this was a ranch homestead, then traffic through the mountain pass, another ranch, and at greater distance the town of Las Cruces. This was the worst possible line on the map. The safety officer knew at all times where the missile was and where it would impact if the flight were terminated. He wisely let the missile fly over the inhabited area, over the boundary, terminating its flight safely in the desert between the last ranch and the city.

Very early in the game Army Ordnance established a policy of contracting with the most capable civilian scientific and industrial organizations available, so that the best talent in the country should be engaged in this work. Further, the development of an entire weapon system should be, whenever possible, placed with a single firm. A guided missile system involves a great many items in addition to the missile itself. There are launchers, radars, firing panels, test equipment, servicing vehicles, protective clothing, cold weather kits, drawings, specifications, instruction manuals and so forth.

Normally a prime contractor is selected, one not only willing and able to develop the system, but also capable of initial production. He is given the necessary responsibility and authority to go ahead within the limits prescribed and under the supervision of the military. This prime contractor is of course free to sub-contract as much as he determines necessary, but Ordnance has one man that can be held responsible -- one man to praise or blame. For complicated systems like this, a large number of sub-contractors are utilized because no single industry today includes all the fields required to produce a guided missile system.

A good example of the application of this philosophy was the development and production of the NIKE system. Western Electric Company was the prime contractor with Bell Telephone Laboratories their development agency. They were experts in electronics and experienced in complex weapon fire control systems, but knew little about aerodynamics and airframes. They wisely sub-contracted the missile with its problems to Douglas Aircraft Company rather than recruit their own aerodynamic group in competition with the air industry. The relationship between Bell Telephone Laboratories and their sub-contractor, Douglas, was a close partnership in the overall enterprise. It had to be thus because the various components of the guidance system and the missile are so inter-related that their design had to be fully integrated; a change in one component affected another. There was some concern that the 3,000 miles between Bell in New Jersey and Douglas in California would be a handicap, but it is interesting to note that the required coordination was readily accomplished through the principal commercial products of the two companies; namely, the telephone and the airplane.

In a normal program, the research and development people give a new piece of equipment extensive testing and after all "bugs" have been worked out, turn it over to the using service for field tests which usually result in subsequent modification tests. After all this, the production people take over and negotiate production contracts. The production items are then turned over to a third group who store and issue the items to troops as needed, and provide for the necessary maintenance service. Finally, special schools train the technical personnel who will service the equipment.

But in the case of missiles, once the new systems started looking good on the proving ground there was great demand to get them into early production, and for good reasons. In the surface-to-surface category, need for new day and night, all weather weapons was clearly established during the Battle of the Bulge in Europe, the action at the Yalu River in Korea, and other engagements. In the anti-aircraft field more effective weapons were also required because jet engined aircraft were already outstripping our best anti-aircraft artillery.

As a result, the most urgently required of our missile systems were "crashed." This simply meant the successive steps of the normal program, outlined above, were telescoped, i.e., the steps which were normally done in series were now to be done concurrently as quickly as possible.

This of course presented new problems, but it was a challenge accepted by our Ordnance-Science-Industry team and the new weapons are now in operation considerably ahead of the original schedules.

Just after the war guided missiles rose to popularity overnight. The public's imagination had become fired by sensational stories in the press about pushbutton war, satellite stations, and space travel. With a sane approach the armed services concluded that guided missiles would become essential weapons of the future, and for their own good they had better get firmly established in the business. Army Ordnance had pointed the way through dynamic investigations and initiation of programs in the field. It was a natural then, that there developed jurisdictional controversy for the control of these new and sensational weapons. The ground forces were primarily interested in the type of guided missiles that Army was best qualified to produce --- namely, the supersonic rocket and ballistic types.

The ground forces considered that guided missiles which met its requirements were an extension of artillery. But the dual nature of these new weapons served as a basis for the Army Air Force (AAF) contention that guided missiles supplemented aircraft and therefore should come within their field of responsibility.

A series of opinions and directives supported the Army ground force views. The first delineation of Ordnance and AAF responsibilities was made by the New Developments Division of the General Staff in September 1944. By this decision the Ordnance Corps was assigned the wingless ballistic type missiles and the AAF the winged pilotless aircraft types. These responsibilities were formalized the following month by the McNarney (DC/S) directive assigning to the Army Services Forces research and development of guided or homing missiles launched from the ground and which depend for sustenance primarily on momentum, and to the AAF those missiles depending primarily on the lift of aerodynamic forces.

In 1946 the AAF reopened the subject, claiming Ordnance was infringing on their responsibilities because the Army missiles under development were supersonic pilotless aircraft not sustained in flight primarily by momentum of the missile.

The Guided Missile Committee of the Joint Committee on New Weapons which had been serving to coordinate the various service projects surveyed the situation. In its "Dewey Report" the Committee stated that the cognizance existing between the air and the Ordnance agencies of both the Army and Navy were not logical, but that research and development in the field of guided missiles must inevitably involve some competition, and that a certain amount of duplication was valuable. The report suggested a system of mutual agreement would be better than setting inflexible boundaries.

Many studies and proposals for an integrated program were then made, culminating in a War Department decision in October 1946 that within the Army the AAF be given overall cognizance for all guided missile development, but stipulating Ordnance Corps projects were to continue under the sponsorship of the agencies doing the work. Little was accomplished in complying with this directive because shortly thereafter the AAF was granted equal status with the Army and Navy, and relinquished its responsibility for the Army program. Army then assigned primary cognizance of its program to the Ordnance Corps and requested that the skills in all development agencies within the Army be utilized to effect maximum contribution to the national guided missile program. In this connection the Signal Corps felt it should be granted cognizance over the electronic portions of missile systems, but this bid was rejected because the close inter-relationship between the various elements of a missile system preclude a division of responsibilities. This settled, the Signal Corps, as well as the Corps of Engineers and Chemical Corps, continued to render valuable technical assistance to the Ordnance Corps.

Coordination of Army, Navy and Air Force programs was started by the Dewey Committee, taken over by the Joint Research and Development Board, and continued by its successor, the Research and Development Board (RDB). By 1948 the question of jurisdiction still had not been settled to everyone's satisfaction. RDB proposed that projects should be assigned on an individual basis with consideration of such factors as intended use, technical competence, and availability of manpower and facilities. The following year Army's Secretary Gordon Gray, recommended simply that each service develop the missiles it would use operationally, i.e., ground-launched to Army, ship-launched to Navy, and air-launched to the Air Force. Shortly thereafter General Omar Bradley, Chairman of the Joint Chiefs of Staff, laid down the policy that guided missiles would be employed by each armed service in a manner and to the extent required to accomplish its assigned missions. He wisely made no decision on the dividing line between short and long range missiles. Had the Joint Chiefs of Staff been required to settle the argument at that time, Army might have been limited to a miximum of 100 miles for its missiles because of strong representation that missiles of greater range were an extension of aircraft rather than an extension of artillery. For technical reasons assignment of fixed range limitations would be unwise. A hundred mile missile, for example, can be modified for effective use at much greater ranges by extending its length to accommodate more propellant and by substituting a lighter warhead. More important, however, is the fact that experience gained by a development team in producing a reliable missile system, and their application of proved principles and components to a new longer range missile of similar type, insures a much better chance of success and at a great saving of time and money.

Today Army continues to press for longer ranges based on the necessity of a field commander having direct control of the weapons used in support of his operations in field army areas 600 miles in depth and airborne operations to greater distances.

No history of the U. S. guided missile effort would be complete without mention of the part K. T. Keller played between 1950 and 1953, while serving as Director of Guided Missiles for the Secretary of Defense. The Secretary of Defense, Mr. Johnson, was concerned that unnecessary duplication existed in the program and established the Special Inter-departmental Guided Missiles Board, consisting of the Army, Navy and Air Force secretaries and the Chairman of RDB, to study the problem and make recommendations. The Board found the National program was in no wise as bad as had been alleged and drew up a recommendation for either the continuance or elimination of each project. There was service agreement on a good many of these findings, but disagreement on others. Mr. Johnson then requested Mr. Keller to undertake monitorship of the program, but was succeeded by General Marshal while Mr. Keller was exploring the nature of the job. Keller accepted and, after careful study, selected the most promising Army, Navy and Air Force systems for production long before development had been completed. He recognized the need for far greater quantities of missiles for development and engineering tests, and he realized industry would require several years to develop the uniformly satisfactory production of these complex items. The courage and leadership of Mr. Keller in accelerating the most promising projects resulted in the availability of operational guided missiles far sooner than the normal procedures would have permitted.

From 1944 on, the Army program progressed amazingly well considering that through fiscal year 1950 Ordnance had available only 17 percent of the total funds expended on the Army, Navy, and Air Force guided missile effort. Nevertheless the ORD-CIT project at JPL and the HERMES project at General Electric established a great amount of fundamental technical information on which all missile designers could draw. The CORPORAL followed the WAC CORPORAL and PRIVATE series as a research test vehicle. General Electric was firing its 45 mile HERMES A-1 interim surface-to-surface missile, moving along with its 75 mile HERMES A-2, and working hard on the longer range, high performance and extremely accurate HERMES A-3.

LACROSSE, initiated at Cornell Aeronautical Laboratories by the Navy for use by the Marines against strong points, was transferred to the Army by Joint Chiefs of Staff action and progressed out of its study phase into experimental design.

As time went on reorientation of the program was necessary. The principal reasons for this were the rapid succession of the new atomic warheads and the limitation on funds available to the Army, as well as the unsettled international situation and the urgency of obtaining operational missiles. Project HERMES was affected the most. The HERMES A-1 was cancelled as a weapon, HERMES A-2 suspended with view to redesign as a solid propellant "work horse" missile after a large solid propellant rocket motor had been developed, leaving only the A-3 as a major effort at General Electric. Responsibility for the 500-mile HERMES C-1 study was transferred to Redstone Arsenal and became the REDSTONE project (in the interim it was called MAJOR). The requirement for a surface-to-surface missile became so urgent during the Korean action that the CORPORAL research vehicle was crashed as an interim weapon system on the basis it could be made operational considerably sooner than the more refined HERMES.

The Army's surface-to-surface requirements were by 1951 determined to be met by a family of guided missiles consisting of CORPORAL, HERMES A-3, and a proposed REDSTONE. These were to be the carriers of three different sizes of warheads; but again atomic warhead developments overtook the missiles and later when the two warheads satisfied the Army requirements, and funds became extremely short, the HERMES program was regretfully terminated.

Postwar developments of new and greatly improved solid propellants for rocket engines at JPL and Redstone Arsenal gradually placed them in a competitive position with liquid propellants for guided missile use, both as to performance and to size. First flight tests of a large solid propellant motor was made made in the HERMES RV-A-10 test vehicle.

This achievement paved the way for the SERGEANT project, which will give the Army a less complex, highly reliable, "work horse" missile after the CORPORAL becomes obsolete. Another solid propellant guided missile is the highly accurate anti-tank DART, recently announced in production.

The 762mm HONEST JOHN, developed in a little over two years by Douglas Aircraft Company and Redstone Arsenal was a new concept in rocket weapons. It was simply an unguided solid propellant rocket, aimed and fired from its mobile launcher like artillery, and capable of carrying both atomic and conventional warheads. Before the test firing of the first 762mm rocket, there was controversy in the Pentagon as to its worth. In fact, there was serious consideration in the General Staff of cancellation on the grounds that such a large unguided rocket could not possibly have the accuracy to justify further expenditure of funds. At this time a Texan was overheard making statements hard to believe. When his veracity was questioned, he exclaimed, "Why around these parts I'm called 'Honest John'"! Feeling somewhat like a Texan at the time, the writer felt HONEST JOHN would be an appropriate nickname.

In the anti-aircraft field NIKE took form, and from the beginning looked so promising that GE was relieved of any surface-to-air responsibility. Although Army never lost confidence in the successful conclusion of NIKE I, Navy time scales indicated their TERRIER would be operational some time before NIKE. Based on urgency Army decided to use TERRIER as an interim weapon, and Ordnance was directed to develop a suitable ground control system for this ship-launched missile. Before the ground system had been completed Navy schedules had slipped to the point NIKE would become available for operational use first, and Army's TERRIER ground equipment was transferred to the Marine Corps.

Advances in the art, particularly in the field of electronics, resulted in the present Army family of surface-to-air projects consisting of the NIKE B, NIKE II, and HAWK guided missile systems.

By 1949 the Army Ordnance program had grown to the point that it was necessary to decentralize the management of the research and development, procurement, and field service activities from the Pentagon to a field installation. Accordingly two adjacent wartime ammunition manufacturing installations hear Huntsville, Alabama, were reactivated as Redstone Arsenal and designated as the permanent Ordnance Corps commodity arsenal for rockets and guided missiles. In addition to planning, directing, and supervising the nationwide Ordnance missile activities, the arsenal was charged with operating facilities for research and development work in solid propellants, free flight rockets, and guided missiles. Two highly competent contractors, the Rohm and Haas Company and the Thiokol Chemical Corporation, agreed to operate the arsenal's solid propellant laboratories. Experienced Ordnance rocket personnel were moved in from other installations to staff the Rocket Development Laboratory and the testing facilities. The German team was transferred to the arsenal and became the nucleus of the Guided Missile Development Division of the Ordnance Missile Laboratories. The Ordnance Guided Missile School was also established at Redstone to train civilian and military personnel in the handling and maintenance of these new weapons. Both individual and unit training is conducted to provide proper Ordnance support for the using troops. Thus Redstone Arsenal built up highly qualified and experienced teams which can carry a rocket or guided missile project through from preliminary design, component development, fabrication, and final test in specialized and integrated facilities; then manage the procurement and the storage, issue, and maintenance of these weapon systems as well as conduct the necessary training.

The Ordnance Corps' foresight in the integration and utilization of the former German scientists into its organization gave the Army a unique guided missile team having the most advance development and operational experience in the world.

The arsenal's Guided Missile Development Division, under the direction of Dr. von Braun, gained national recognition for its competence in developing the REDSTONE Missile. In February 1956 the personnel and facilities of this division became the backbone of the new Army Ballistic Missile Agency, established for the expedited prosecution of a program to place on the intermediate range ballistic missile, JUPITER, and the shorter range REDSTONE missile in operational status as rapidly as possible.

In spite of jurisdictional problems and limited funds, the Army program maintained a position of technical leadership in its fields of interest and contributed much to the National program.

At the working levels of all three services, there was excellent liaison between the various projects -- no "working behind the barn" so to speak. Cooperation and a full free exchange of technical information was the rule rather than the exception. Examples of this cooperation have already been mentioned in this article. In addition, Army developed and delivered rocket motors used on the Air Force's air-to-air missile, FALCON, and in turn utilized an Air Force power plant for its REDSTONE missile. A Navy solid propellant was used in the HONEST JOHN rocket. Many more cases could be cited.

Among its contributions to the National effort was Army's pioneering work in establishing the feasibility of an earth satellite program.

Ordnance personnel at Redstone Arsenal made extensive studies into the problems involved and was largely responsible for clearing the way for the current U. S. satellite project established under the cognizance of the Navy.

We can all be proud of the technical achievements of the Ordnance-Science-Industry team which pioneered in the art of rocketry and produced this country's first supersonic guided missile weapons in a relatively short period of time. An equally progressive development effort is continuing on a family of new guided missiles which will better meet the various requirements of our modern Army.

Science is forging ahead -- there is no time to rest on our laurels. The present state of the guided missile art indicates that any place on the surface of the earth may be reached with a reasonable degree of reliability and accuracy by these vehicles in the near future. Our research and development people are dedicated to maintaining the peace by staying ahead of any potential enemy.

###