HISTORY
OF THE
SHILLELAGH MISSILE SYSTEM
1958 - 1982

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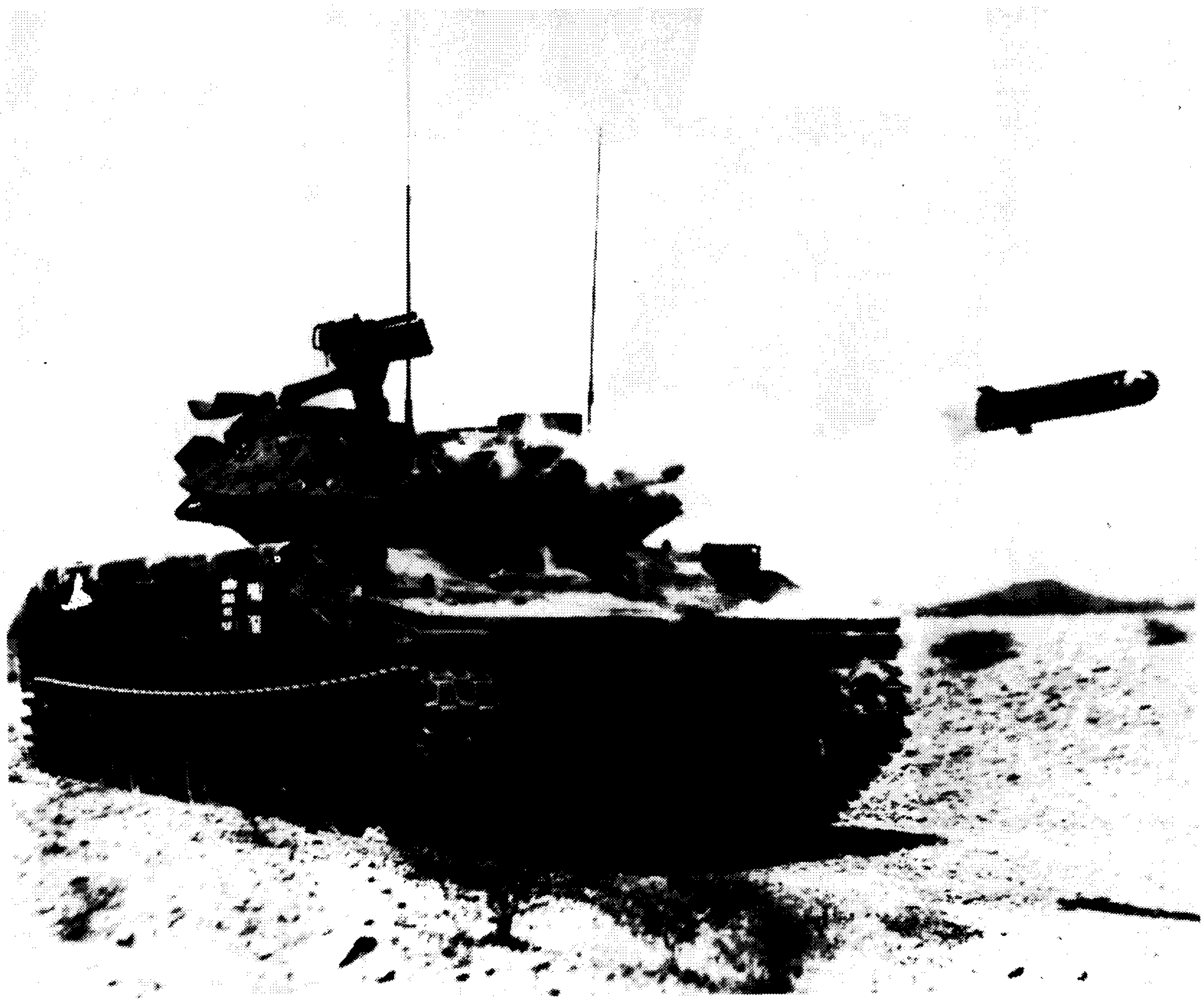

M551 SHERIDAN/SHILLELAGH Weapon System

PREFACE

The SHILLELAGH antiarmor missile system evolved from a requirement established in 1958 for the development of weapon systems for use in combat vehicles of the pentomic and future armies. The complete combat vehicle weapon system consisted of the SHILLELAGH direct-fire guided missile, 152mm gun/launcher, conventional ammunition, and guidance-fire control subsystems. The SHILLELAGH was the primary armament on the M551 SHERIDAN Armored Reconnaissance/Airborne Assault Vehicle and the M60A2 Main Battle Tank.

Overseas deployment of the SHILLELAGH missile subsystem was relatively short-lived, chiefly because of user dissatisfaction and problems with both the carrier vehicles and the missile. The M551 SHERIDAN/SHILLELAGH weapon system was assigned to overseas units from 1969 until 1980, when the M551 vehicles in armored cavalry units were replaced with improved M60 series main battle tanks armed only with conventional ammunition. The M60/SHILLELAGH weapon system was assigned to tank battalions in Europe from 1975 until 1981, when it was phased out of the Army inventory. As of FY 1982, the active inventory consisted of a small residual fleet of M551 SHERIDAN vehicles, which the Army planned to retain through the late 1980's.

This monograph traces the history of the SHILLELAGH missile subsystem from the inception of feasibility studies in 1958 through development, production, and deployment in the 1959-1979 timeframe, and system phasedown in 1980-81. Except for the chapter dealing with project management, the story of the SHILLELAGH is related in basically chronological sequence. Unless otherwise indicated, the documents cited in footnotes are in the Historical Division archives.

The monograph was a joint effort of Mrs. Elizabeth J. DeLong, Mr. James C. Barnhart, and the Chief Historian. Mrs. DeLong did the basic research and wrote the rough draft of the first five chapters. Mr. Barnhart prepared the last two chapters and rewrote portions of Chapters IV and V. The Chief Historian rewrote Chapter I and reviewed and refined the total manuscript to the extent that time permitted. In the coordination process, the classified portion of the text was modified to render the document unclassified. Time did not permit retyping of the manuscript to remove the unclassified markings.

17 August 1984

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(U) EVOLUTION OF ARMY ANTITANK REQUIREMENTS AND WEAPONS

(U) The present-day antitank requirements and weapons of the US Army evolved from the introduction of the armored tank in combat during World War I and subsequent advancements in tank and antitank weapon technology. Though only partially successful when first introduced in warfare in September 1916, the first crude tanks spurred further development and they were used with increasing success by the Allies and Central powers until the Armistice. Some armor-defeating weapons were also developed during World War I, but US military interest in both tanks and antitank weapons sharply declined with the signing of the Armistice. The US Army thus entered World War II with few and inadequate armored combat vehicles and weapons with which to counter the superior German tank forces. By the end of the war, however, the Army ground forces had a diversity of such weapons for specific tactical uses. Continued advancements in tank and antitank weapon technology during the postwar years led to the establishment of firm requirements for antitank guided missiles for use by infantry, armored, and airborne units. This chapter traces the evolution of antitank requirements and weapons from the inception of tank warfare in 1916 through initial antitank guided missile developments in the 1950's.

The Advent of Tank Warfare

(U) The British first developed the armored tank as a combination battering ram and assault weapon to penetrate enemy trench lines protected by barbed-wire entanglements and machineguns. The first British tanks were crude, ponderous armored combat vehicles developed by Colonel Ernest D. Swinton (later Major General Sir Ernest) and associates of the Royal Engineers, who had obtained some of their ideas from American caterpillar farm tractors. In the early morning hours of 15 September 1916, British tank D1, armed with cannon and machineguns, became the first armored fighting tank to go into combat as it led two companies of infantry who were to clear two trenches in Deville Wood on the Somme River. This initial deployment of the tank was premature and only partially successful. However, in their subsequent surprise attack on the German lines at Cambrai, France, on 20 November 1917, the British proved conclusively that tanks and trained infantry, with intelligent artillery support, could break through a well-built system of trenches.

(U) Recognizing the tactical advantage of the armored tank, the French and Germans developed tanks of their own, while the United States relied upon British and French tanks. Although the first armored tank in the field was British, the French had begun development of armored infantry carriers in December 1915 and deployed their first tanks in April 1917. The Germans, who discounted the tank as a significant weapon of war until the battle of Cambrai, concentrated their effort on large, unwieldy contraptions that were singularly ineffective, and on passive and active antitank measures that greatly diluted the effectiveness of Allied tank attacks. Like Germany, the United States almost entirely ignored the tactical significance of the tank until Cambrai, and by that time it was too late to produce designs of their own. A small number of French and British tanks were produced for the American Expeditionary Force, but they did not reach France until November 1918 and even then they were found to have defective armor.[1]

(U) Following World War I, US military interest in tanks and antitank weapons sharply declined, largely because of postwar retrenchment and financial stringency. It was not until the late 1920's that the first two postwar American tanks were built—the light T1 and medium T3. These tanks, however, were never released for production, leaving the troops with the aging British and French tanks left over from 1918. Meanwhile, the Germans and Russians proceeded with the development of armored tanks, using existing foreign designs as their basis. By the mid-1930's, both countries had a number of operational tanks of all shapes and sizes which saw action in the Spanish Civil War.[2]

World War II Developments

(U) At the outbreak of World War II, the Germans, whose tanks of the first world war had been failures, possessed vast numbers of improved tanks with which they overran Poland in 1939 and northern France in 1940. The mobility, armament, and armor of these tanks rendered obsolete the standard prewar antitank guns of the Allied armies. It was suddenly apparent that the failure to produce versatile and powerful antitank weapons was a glaring oversight that had to be speedily rectified if the Allied countries were to survive. It was equally apparent that the tank designs would have to be improved to increase their mobility, reliability, fire power, accuracy of fire, and armor protection.

(U) As the war progressed, many new antitank weapons and armor-defeating ammunition were developed and put into the field to counter the superior German tank forces. Among these were the rocket-firing bazooka; recoilless rifles; fast, heavily gunned motor carriages known as tank destroyers; towed antitank cannon; rifle grenades with shaped charges; antitank mines; high-velocity armor-piercing projectiles; and, late in the conflict, high-explosive antitank shells with shaped charges for penetrating armor by chemical (jet) action.

(U) The outbreak of war also spurred innovations in combat vehicle development. At the end of the war, the US Army, which entered the conflict with few and inadequate combat vehicles, had a wide variety of such weapons for specific tactical uses. These weapons included light, medium, and heavy tanks (then classified by weight rather than caliber of gun); gun, howitzer, and multiple gun (antiaircraft) motor carriages; armored utility vehicles; tank recovery vehicles; half-tracked personnel carriers; and amphibious cargo carriers. Tanks underwent a succession of design changes that continually increased their mobility, reliability, firepower, accuracy, and protection against enemy weapons.

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[1] Ian V. Hogg, *Armour in Conflict* (Jane's Publishing Inc., New York, 1980), pp. 9-10, 21-22, 26-28, 33-34, 42.

[2] Ibid., pp. 49, 53-55, 59, 62-65.

The US Army entered the war with only light and medium tanks, the former armed with a 37mm gun and the latter with 75mm and 37mm guns. By V-J Day, the M24 standard light tank mounted a 75mm gun, the M4 series of medium tanks was armed with either a 76mm gun or a 105mm howitzer, and the M26 (Pershing) heavy tank had a 90mm high-velocity gun.[3]

Postwar Requirements and Developments

(U) The return of peace in 1945 did not put an end to the development of combat vehicles and antitank weapons, although money was lacking for intensive pursuit of such programs immediately following the war. With the onset of the cold war in the late 1940's, and particularly after the start of the Korean conflict in 1950, the weapon development effort was no longer seriously circumscribed in this way. The trend of development after 1945 was determined by such interacting factors as combat experience, changes in tactical doctrine, and knowledge of Soviet equipment.

(U) Steady improvements in the armored vehicle design, particularly in the thickness and obliquities of armor in hulls and turrets, dictated the creation of better and more powerful weapon-ammunition combinations. The kinetic-energy and shaped-charge round of World War II vintage could not perforate the thick and acutely sloped frontal armor of the new tanks. It was, therefore, essential to develop weapons and ammunition that could nullify the steadily increasing protective characteristics of modern tanks. Two important influences on these developments were the requirement for greater accuracy, which affected the design of a weapon, its ammunition, and its fire control equipment; and the desirability that a projectile hitting a tank destroy it rather than inflict superficial damage that could be repaired. These and other considerations led to improvements of existing hardware and to the development of radically new weapon systems.

(U) Following the war, a number of equipment review boards studied the requirements for future wars and recommended the development of weapons and equipment to meet such requirements. One of the first to consider the problems of war readiness was the War Department Equipment Board (also called the Stilwell Board after its chairman, LTG Joseph W. Stilwell). The board's report, issued in May 1946, stated that the changes in tactics and strategy that the future would bring must be examined and clearly stated so that research and development could receive intelligent direction. It recommended that weapons be considered on a global basis, and that prototypes and developmental models be tested in areas with appropriate climates and terrain. In general, the weapons developed were to be simpler to operate and maintain; to have mechanical devices, if feasible, to reduce human error; to be constructed so that defective subassemblies could be replaced in minimum time and with minimum skill; and to be designed so as to reduce training time.

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[3](1) Technical Information Report CD-5, Office, Chief of Ordnance, Oct 60, subj: Development of Antitank Weapons, p. 3. (Hereafter cited as TIR CD-5.) RSIC. (2) Technical Information Report CD-2, Office, Chief of Ordnance, Jul 60, subj: Development of Combat Vehicles, p. 4. (Hereafter cited as TIR CD-2.)RSIC.

(U) The primary mission of armored forces, as stated by the Stilwell Board, was to assist the infantry in the assault and breakthrough by direct fire and movement. Artillery missions by armored forces were to be secondary. No more towed antitank guns would be developed. In the development of tanks, firepower and maneuverability were given priority over armor protection. The board classified tanks as light, medium, or heavy by the weight of the vehicle and called for an improved model of each type to meet the armor requirements of all branches. Light tanks, weighing under 25 tons, were to be used for reconnaissance and security; medium tanks, weighing no more than 40 tons, were to be the principal weapons of armored divisions for assault, exploitation, and breakthrough; and heavy tanks, weighing up to 75 tons, were intended also for assault and breakthrough.

(U) The Stilwell Board stated a requirement for tank-borne rocket launchers that would not interfere with other weapons on the tank and that could be loaded without exposing the crew. Additional requirements called for a swivel-type flame thrower and rocket to replace artillery cannon, as soon as rocket development reached the point where sufficient accuracy could be assured.

(U) In the ammunition field, the outstanding need was for smokeless, flashless propellants to increase the velocity of tank-gun projectiles. The shells were to have simple fuzes to insure uniformity in manufacture and to eliminate firing data corrections for different lots. The Stilwell Board recommended mass production of the proximity fuze in different wave lengths to prevent or reduce jamming. Radar was, the board felt, required for fire direction and control, target detection, and control of the shell in flight; however, several problems with radar remained unsolved, such as jamming problems and limitations of the line-of-sight characteristics of the beam.

(U) In October 1948, attendees at the Conference on Antitank Defense at Fort Monroe, Virginia, agreed that two new antitank guns were needed to counteract the threat of enemy armor to airborne operations. These weapons were a 90mm self-propelled gun, transportable in Phase I of airborne operations, and a 76mm towed gun, capable of being carried with its prime mover, crew, and ammunition in an 8,000-pound-capacity glider and of being dropped by parachute.

(U) Specific requirements for these and other weapons were established on an individual basis, then were consolidated and summarized in the Army Equipment Development Guides (AEDG's) of 1950 and 1954. The 1950 edition of the AEDG, which superseded the Stilwell Board Report, retained the recommendation for three basic types of tank, but deleted the weight requirements. Instead, the vehicles were listed as the light gun, medium gun, and heavy gun tanks, to be armed, respectively, with 76mm, 90mm, and 120mm guns, or guns of greater effectiveness. Each of the three types of tanks was to be capable of defeating the frontal armor of a comparable enemy tank and the sides of any tank at a range of 2,000 yards. Self-propelled and towed howitzers were to be lighter, but lethality, accuracy, mobility, and howitzer characteristics were to have priority in the order named. With exception of the requirement for a towed, lightweight, 105mm howitzer for airborne operations, which was later dropped, all of these requirements were repeated in the 1954 issue of the AEDG.

(U) The Continental Army Command subsequently rescinded its requirement for conventional towed artillery, and decided that a single main battle tank should replace both the medium and heavy gun tanks and that an armored reconnaissance/airborne assault vehicle should supersede both the 76mm (light) gun tank and the 90mm full-tracked self-propelled gun. As expressed in the new Combat Development Objectives Guide, the general purpose of the development of antitank weapons for the future was to improve the means of defeating enemy armored forces in order to release US tanks for increased employment for other purposes. The long range development plan called for a single main battle tank that would combine the features of an armored reconnaissance vehicle and an airborne assault weapon. Pending the achievement of this goal, a main battle tank and an armored reconnaissance/airborne assault vehicle were required, and the armored forces would use a group of special-purpose vehicles that were air-transportable and armored. Both the armored reconnaissance/airborne assault vehicle and the main battle tank were to be available in the midrange period extending through 1965.[4]

Requirements for an Antitank Guided Missile

(U) The increasing emphasis placed on the offensive capabilities of tanks, together with the introduction of more resistant armor, necessitated intensive efforts to improve their firepower. Once the guided missile was developed, its adoption as an antitank weapon was therefore logical and necessary. It was recognized that a properly controlled antitank guided missile would be an excellent weapon for use at ranges and under conditions that rendered conventional antitank fire either impracticable or ineffective. Despite steady improvements in conventional antitank weapons, they yet possessed a number of deficiencies that could only be overcome by the controlled or guided weapon.

(U) Although significant technological progress had been made in the development of guided missiles during the latter part of World War II, the possibility of front line troops using them against enemy armor was not seriously considered until early 1951, some 6 months after the Korean War started. Armor experiences early in the Korean War clearly demonstrated the need for an improved antitank weapon that would be capable of defeating the heaviest known enemy armor with pinpoint accuracy. There were a number of conventional weapons in combat use; however, their accurate range of application was limited to about 1,500 yards and their lethality was limited by projectile size. The most logical approach to overcoming these tactical deficiencies was the development of an antitank guided missile.[5]

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[4] (1) Ibid., pp. 6-8. (2) TIR CD-5, Oct 60, pp. 3, 12-15.

[5] (1) OrdC Report, Weapons for the Defeat of Armor, Vol. 4, - Aircraft Rockets and Guided Missiles, Antitank, Apr 53, pp. 6-7. RSIC. (2) Redstone Arsenal Technical Report, Ordnance Guided Missile and Rocket Programs, Vol. VII - DART Antitank Guided Missile System, Inception thru 30 Jun 55, p. 3. Hereafter cited as the DART Blue Book.

(U) Firm requirements for an antitank guided missile were initially established during a conference held at Fort Monroe, Virginia, in February 1951, to discuss land combat applications of infrared guidance techniques. The conferees concluded that infrared seekers had shown enough promise as homing devices for antitank guided missiles to warrant the establishment of a requirement for such a weapon. They recommended as a firm requirement a ground-launched antitank guided missile which would be of minimum size and weight, of very short range, and highly accurate, to attack armored tanks and other point targets, including artillery. The general characteristics outlined for the weapon called for a 6,000-yard effective range and a kill probability of 90 percent against the heaviest known enemy tank. These characteristics were based primarily on the potential tactical application of the AN/DAN-3 infrared seeker, which had already been developed and successfully tested by the General Tire and Rubber Company, parent company of the Aerojet Engineering Corporation.[6] The characteristics and potentialities of the homing device were further confirmed in March 1951, when Aerojet completed a preliminary study of an antitank guided missile called the AeroSWAT* which used a modified version of the AN/DAN-3 seeker.[7]

(U) In view of the foregoing findings and recommendations and the promising results of Aerojet's studies, the Chief of the Army Field Forces (AFF), in April 1951, directed the AFF Board No. 4 to prepare detailed military characteristics (MC's) for an antitank guided missile to supplement the conventional weapons then in use. Seven months later, in November 1951, the board submitted a proposed statement of MC's, together with a supporting staff study. The Chief, AFF, in January 1952, recommended that the proposed MC's as modified, be approved as the statement of Army requirements for an antitank guided missile, and that an investigative and design study project be initiated. The approved MC's, forwarded for action by the Ordnance Corps in May 1952, called for an antitank guided missile system with a maximum effective range of 6,000 yards (8,000 yards desired), a minimum range of 500 yards or less, and hit and kill probabilities of at least 90 percent against the heaviest known enemy tanks and other point targets. The missile was to be of minimum size

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*The code name originally suggested for this weapon was "SWAT," the acronym for Seeker Weapon Antitank; however, to distinguish it from other weapons of this type, it was called the AeroSWAT.

[6](1) Minutes of Conference on Infrared Applications in Land Combat, OCAFF, Ft. Monroe, VA, 15-16 Feb 51. (2) General Tire & Rubber Co. Report No. 2056, 22 Dec 50, subj: Final Engineering Summary Rept on the Development of Infrared Homing Set AN/DAN-3(XN-1). Both attached to Report of Study of Proj No. GM-451—MC's for an Antitank Guided Missile, AFF Bd. 4, Ft. Bliss, Tex, 20 Nov 51, RSIC.

[7]Aerojet Report No. 503, 16 Mar 51, subj: AeroSWAT - A Preliminary Study of an Antitank Weapon. RSIC.

and weight (not more than 100 pounds) and be guided to the target by an infrared seeker or other type guidance, preferably automatic.[8]

Initial Antitank Guided Missile Developments

(U) The state of guided missile technology in 1952 was not considered adequate to support the development of an antitank system meeting all performance requirements of the initial MC's. It was considered feasible, however, to develop an interim system that would substantially fulfill the MC's and pave the way for the ultimate weapon. The Ordnance Corps considered three guided missile concepts for potential antitank use: the D-40 which was under development by the Department of the Navy, the French SS-10, and the proposed DART which was similar in structure to the SS-10.

(U) Commonly known as the Cannonball missile, the D-40 was being developed by the Applied Physics Laboratory under a Navy contract with financial support from the Ordnance Corps. Unlike the torpedo-shaped bodies of its contemporaries, the D-40 was a spherical missile which measured about 24 inches in diameter. The principal disadvantages of the D-40 were its great weight (300 pounds) and the vulnerability of its radio control system to enemy countermeasures. A lightweight version weighing about 150 pounds and using wire guidance was later developed and tested, but the antitank phase of the program was eventually dropped.[9]

(U) The French SS-10 was an optically-guided, wire-controlled missile about 34 inches long with a 30-inch wing span. It had a gross weight of 34 pounds and an operational range of about 1,500 yards. Early in 1952, 500 SS-10 missiles and 3 sets of ground equipment were procured from the French Government for use in evaluation tests. The evaluation program began in December 1952 and continued until October 1953, when it was discontinued because of unfavorable test results. The evaluation team concluded that the SS-10 missile, in its current state of development, was unsuitable for use by the US Army, but recommended that future French development of the missile be carefully observed with a view of reconsideration of the weapon if an improved model should be produced before a comparable American weapon became available.[10]

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[8](1) Report of Study of Project No. GM-451—MC's for an Antitank Guided Missile, AFF Bd No. 4, Ft. Bliss, Tex, 20 Nov 51, & Appendix A thereto, Ltr, Chf, AFF, Ft. Monroe, VA, to President AFF Bd No. 4, Ft. Bliss, Tex, 14 Apr 51, subj: MC's for an Antitank Guided Missile. RSIC. (2) Ltr, Chf, AFF, to ACofS, G4, DA, 25 Jan 52, subj: Rept of Proj No. GM-451—MC's for an Antitank Guided Missile, w incl. RSIC. (3) MICOM Staff Study, "Examination of Antitank Development," 9 Aug 65, p. I-18. RSIC.

[9](1) DART Blue Book, pp. 1-2. (2) OrdC Report, Weapons for the Defeat of Armor, Vol. 4 - Aircraft Rockets and Guided Missiles, Antitank, Apr 53, p.14. RSIC.

[10]Redstone Arsenal Technical Report, Ordnance Guided Missile and Rocket Programs, Vol. IX - SS-10, Inception thru 30 Jun 55, p. 3. RSIC.

(U) While the foregoing evaluations were in progress, the Ordnance Corps began an investigation to determine the feasibility of the new DART missile system, the initial proposal for which had been submitted by the Aerophysics Development Corporation in November 1951. The DART system was envisioned as a ground-launched missile carrying a 20-pound shaped-charge warhead, which would be capable of penetrating 14 to 16 inches of armor within an effective range of 350 to 5,280 yards. Either a forward observer or the launching crew would be able to steer the missile into an enemy tank by a simple double-wire guidance link. The promising results of predevelopment studies, together with unfavorable results of the SS-10 evaluation, led to selection of the DART system to fulfill existing antitank requirements, and the missile was approved for development in August 1953. However, the DART contractor encountered serious development problems which could not be satisfactorily resolved, and the project was terminated in September 1958.

(U) Meanwhile, the French had developed an improved, highly reliable model of the SS-10 missile, which was successfully evaluated in US service tests in mid-1958. With cancellation of the DART project, the Department of Defense authorized the offshore procurement of sufficient SS-10 systems to meet interim antitank requirements of the US armed forces. The improved French SS-11 and ENTAC wire-guided missiles were subsequently procured for employment as helicopter-mounted and ground-launched antitank systems.[11]

(U) This successful application of a guided missile in an antitank role gave added impetus to antiarmor missile research. As technological advances were made in target acquisition, guidance, and control, antitank guided missiles were developed for infantry, armored, and airborne units. This study concentrates on the application of the antitank guided missile as armament for armored combat vehicles. Specifically, it traces the development, production, and deployment of the SHILLELAGH missile system, which was fielded as armament on the M551 (SHERIDAN) armored reconnaissance/airborne assault vehicle and on the M60A2 tank, a modified version of the M60 main battle tank.

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[11] (1) MICOM Staff Study, "Examination of Antitank Development," 9 Aug 65, pp. I-18, I-19. RSIC. (2) TIR CD-5, Oct 60, pp. 31-32, & Suppl I, Oct 61, pp. 3-4. RSIC. (3) For a comprehensive history of the DART, see Mary T. Cagle, *Development and Production of the DART Antitank Guided Missile System - 1952 - 1959* (ARGMA, 18 Jan 60).

CHAPTER II

(U) ORIGIN OF THE SHILLELAGH PROJECT (U)

(U) The SHILLELAGH combat vehicle weapon system was conceived as a combination of two major technologies (conventional tank cannon and guided missile) to produce a superior tank firepower system. It was an outgrowth of preliminary study programs in the mid-1950's and feasibility studies of the Combat Vehicle Weapon System (Pentomic) and the new Tank Main Armament System in 1958-59. The system was designed to fulfill the requirement for an armored combat vehicle weapon system capable of destroying the heaviest enemy armored vehicles and of providing a significant improvement in conventional gun-type tank armament in first round kill capability. This chapter traces the evolution of the military requirement for the SHILLELAGH system and the studies leading to initiation of the formal development program in mid-1959.

Preliminary Study Programs

(U) Beginning in the mid-1950's, the Department of the Army initiated various programs in attempts to fulfill existing tank and tank armament requirements. Two programs on the medium tank—Project Astron and the Airborne Assault Weapon System Project—were progenitors of the system which later became the SHILLELAGH.

Project Astron

(U) The Department of the Army initiated Project Astron early in 1954 to fulfill a requirement for long-range development leading to vastly improved types of medium tanks. The project directives indicated that emphasis should be placed on preliminary design of a complete end item. Activity on the project consisted of two contracts with commercial firms and design effort by the Detroit Arsenal. The project was terminated in 1956 because of unsatisfactory concept development and the inability to project sufficient improvement over existing developments.[1]

Airborne Assault Weapon System (Project WHIP)

(U) Another project to develop an improved medium gun tank began on 12 July 1956, when the Secretary of the Army approved a program to develop the Airborne Assault Weapon System. The objective of this program, code named Project WHIP, was to satisfy a requirement for a self-propelled, air-transportable weapon system after 1965 to perform most of the roles of the medium-gun tank without the high degree of armor protection afforded by the existing tank. The project was under direction of the Ordnance Tank-Automotive Command (OTAC).

[1] OTCM 36753, 10 Apr 58 (Appendix A).

(U) Project WHIP differed from Project Astron in that emphasis was to be placed on investigation in four subsystem areas: Chassis, power package, armament, and ballistic protection. The development of suitable armament was seen as a prerequisite to attaining the overall system requirements. Firepower was therefore accorded first priority among the characteristics for the system, followed by mobility, communicating ability, ease of maintenance, and physical protection. The lightweight weapon-ammunition-fire control systems under development in 1956 possessed one or more characteristics which made them unsatisfactory for use in the Airborne Assault Weapon System. The limitations of these weapons necessitated consideration of advanced concepts of continuous, intermittent, and/or terminal guidance, in conjunction with a suitable missile.

(U) Funds were allocated to the various commands and arsenals to conduct investigations and development in the ballistic protection and armament subsystem areas. No work was conducted in the other two subsystem areas under this specific project. The Frankford Arsenal began studies of the ballistic protection subsystem, while the Redstone Arsenal investigated various guidance techniques which would allow the system to meet the high accuracy requirement. The Redstone Arsenal study of command guidance was the major effort conducted under Project WHIP. This effort resulted in recommendations for further study of infrared television and automatic command guidance for use with the armor-defeating missile. In the study begun under Project WHIP, Redstone Arsenal scientists and engineers began accumulating background information and technical capabilities pertaining to infrared command guidance. This expertise led directly to the command guidance systems later adopted for the SHILLELAGH and the TOW* antitank guided missiles.[2]

DOD Study of Future Tank Armament

(U) While the Project WHIP studies were in progress, the Department of Defense (DOD) established an Ad Hoc Group on Armament for Future Tanks or Similar Combat Vehicles under the aegis of the Technical Advisor Panel on Ordnance. The mission of the group was to provide the best possible guidance on the direction of effort for the development of weapons and defensive measures for the period subsequent to 1965. The group's report, issued on 20 January 1958, stated that the ideal weapon for a combat vehicle should meet all the antitank and soft target military needs, yet be light and small enough and have sufficiently low recoil force to be usable in future combat vehicles. If the launching or guidance device for the projectile weighed less than 1,000 rounds, had low recoil force, and used ammunition having the general exterior physical characteristics of existing 90 to 120mm rounds, the vehicular characteristics

*Tube-launched, optically-tracked, wire-guided missile developed to fulfill the heavy assault weapon role. See Mary T. Cagle, *History of the TOW Missile System* (HQ MIRCOM, 20 Oct 77).

[2] (1) Ibid. (2) OTCM 36240, 12 Jul 56, subj: Airborne Assault Weapon System-Initiation of Department of Army Project No. 545-03-029, Ordnance Project TT2-829. RSIC. (3) The Role of ARGMA In-House Laboratories in Army Programs, DOD Study Project No. 97, 9 Aug 61, ARGMA/AOMC, p. II-7.

would be substantially independent of the main weapon. The armor, combat range, munition stowage, maneuverability, and means of transport could then be determined for each category of combat vehicles, depending upon its planned tactical employment. The group recommended that the principal emphasis and highest priority be given to the immediate development of a guided missile system for main battle tank use. They saw the greatest promise in a weapon system using a relatively high-launch-velocity rocket projectile which would receive command guidance along the line of sight for precise accuracy at ranges beyond the first 100 yards.[3]

Combat Vehicle Weapon System (Pentomic)

(U) On 10 April 1958, the Secretary of the Army officially approved the Combat Vehicle Weapon System (Pentomic*) project to provide for development of weapon systems (armament-ammunition-fire control combination) for use in combat vehicles of the Pentomic and future armies. The objective of the project was to fulfill an immediate requirement during the midrange period (1963) for a direct-fire guided missile weapon system for armored combat vehicles, and a long-range requirement for an advanced missile-type weapon system for combat vehicle installation and employment, which would be capable of rapidly engaging and destroying a wide variety of close and distant ground and subsonic air targets at ranges up to 5,000 meters. The latter differed from the midrange system to the extent that it imposed an additional requirement for a combat vehicle system capable of performing many of the offensive and defensive roles of the primary and secondary armament of the family of tanks.

System Requirements and Plans

(U) The midrange requirement called for a system capable of destroying the heaviest armored vehicles likely to be encountered on the battlefield and of attaining significant improvement over conventional gun-type tank armament in its hit probability and adaptability to vehicular installation and use. The midrange weapon system was required as expeditiously as feasible to offset the quantitative and perhaps qualitative superiority of Soviet armored vehicles. It would embody weapon development beyond the rifled and smooth-bore conventional tubes, which in 1958 were reaching the point of diminishing return, and would eventually replace the high-pressure light, medium, and heavy class of tank guns.

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*The term "Pentomic," a combination of penta (Greek for five) and atomic, denotes a short-lived Army organizational concept of the late 1950's, in which each division had five infantry battle groups and each battle group contained five companies. General Maxwell D. Taylor (then Army Chief of Staff) advocated the Pentomic concept as a means to streamline the Army to meet the challenge of nuclear operations. (John K. Mahon and Romana Danysh, *Infantry*, Part I: Regular Army, Army Lineage Series, [OCMH, US Army, Washington, DC, 1972], pp. 88-89, 91.)

[3](1) MICOM Staff Study, "Examination of Antitank Development," 9 Aug 65, p. I-20. (2) Memo History, SHERIDAN Weapon System, M551, 1954-1971, dtd 28 Apr 71, p. 2.

(U) Three requirements were described for the midrange missile, along with several desired characteristics, all of which are outlined below:

Required	Desired
1. Guided missile be capable of destroying the heaviest armored vehicle likely to be encountered on the battlefield.	1. Missile be efficiently and effectively employable against other targets.
2. The probability of hitting a stationary or moving target with each guided missile be markedly better than that achievable with gun or rocket-type projectiles and be attained without either resulting in a rate of aimed fire unduly lower than that of existing medium gun tanks or requiring more than one on-vehicle controller-gunner.	2. a) This capability extend from near 0 to 5,000 meters, the approximate limits of direct fire associated with tanks. b) This capability be retained when the vehicle on which the missile system was mounted was moving, and when operating during hours of darkness and under conditions of poor visibility.
3. Loading and reloading be carried out by one man and the unassisted rate of loading not restrict the rate of aimed fire.	3. Weight, size, and configuration of the missile system and its components be such that the vehicle characteristics could be substantially independent of the physical characteristics of the missile.

To expedite achievement of the above mandatory requirements, it was accepted that:

- Defeat of 150mm of rolled homogeneous armor at 60° and associated equivalent targets with a shaped-charge warhead would provide a satisfactory level of terminal performance at the outset.

- Use of a guided missile against unarmored targets could prove inefficient from the standpoint of cost and supply. Therefore, during the initial concept study phase, consideration should be given to the feasibility of a weapon capable not only of launching a guided missile, but also of firing a relatively low-velocity unguided gun-type projectile. If attainment of this dual capability would unduly penalize the basic guided missile system or materially delay the fielding of the missile, companion free rockets or other conventional weapons would have to be used in the non-armor defeating roles.

- The direct fire range limits of near 0 to 5,000 meters might have to be reduced, and that a maximum range of 2,000 meters would be adequate initially.

(U) The project plan called for concept studies of the midrange armored combat vehicle missile system (including weapon, guided missile, weapon mount, fire control equipment, controls, and firing gear) to be completed by 31 December 1958. These studies would be evaluated to determine which concepts, if any, would be pursued. Upon selection of one or more promising concepts, development efforts would be concentrated on establishing the practicability of the basic weapon-missile-fire control combination, preparatory to developing ancillary equipment and fabricating prototypes of complete operational systems for armored combat vehicle applications.

(U) The long-range requirement was for a greatly refined and improved system with characteristics which could not be clearly foreseen in 1958 and which were doubtful of attainment with existing technological development. Feasibility studies of the long-range system were to begin in FY 1959, based on areas of profitable investigation revealed during the studies and development of the midrange system. Development of the long-range system would not be permitted to complicate development of the initial system. No operational availability date was forecast for either system.

(U) As with the Airborne Assault Weapon System project, primary management responsibility for the Combat Vehicle Weapon System (Pentomic) was assigned to OTAC. Other participating and/or coordinating agencies included Redstone Arsenal, Frankford Arsenal, Picatinny Arsenal, and the Ballistic Research Laboratories, each receiving specific task assignments from OTAC according to individual mission responsibilities.[4]

Feasibility Studies

(U) Using funds allocated under the Airborne Assault Weapon System program, Redstone Arsenal, in January 1958, had awarded four commercial firms 4-month feasibility study contracts for a direct-fire antitank guided missile. The companies selected for study contracts from 16 proposals were Aeronutronic Systems, Incorporated (a subsidiary of Ford Motor Company); Sperry Gyroscope Company (a division of Sperry Rand Corporation); Chrysler Corporation; and Gilfillan Brothers Corporation. In addition to these contracts, the Frankford Arsenal received funds for studies of its POLECAT system, which fell within the Continental Army Command's (CONARC's) definition of a guided missile type weapon system. In April 1958, the contractors received new CONARC guidance pertaining to the Combat Vehicle Weapon System (Pentomic) for use to the maximum extent practicable in the remaining portion of their studies. While these studies were under way, the Airborne Assault Weapon System program was terminated owing to the lack of significant improvement.[5]

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[4] OTCM 36753, 10 Apr 58 (Appendix A).

[5] (1) Ibid. (2) Memo History, SHERIDAN Weapon System, M551, 1954-1971, dtd 28 Apr 71, p. 3. (3) Final Report, Feasibility Study, Armored Combat Vehicle Weapon System, Report No. 5287-7371, Jul 58, Sperry Gyroscope Company, Division of Sperry Rand Corporation, pp. 1-2. RSIC. (4) Ltr, Cdr, OTAC, to CG, RSA, 15 Apr 58, subj: Transmittal of Minutes, w incl: Minutes of Combat Vehicle Weapon System (Pentomic) Conference, 3 Apr 58, RHA Box 12-659.

(U) The OTAC evaluation report of the feasibility studies, forwarded to the Office, Chief of Ordnance (OCO) in May 1958, recommended development of the system proposed by Aeronutronic Systems, Incorporated (ASI). The Ordnance Corps representative on the DA Tank Guided Missile Steering Committee concurred in this recommendation; however, the Chief of Research and Development, in June 1958, directed that contracts for further study be awarded to Aeronutronic and Sperry Gyroscope Company. Accordingly, Aeronutronic and Sperry received contracts in June 1958* for advanced feasibility studies and component experimentation to meet the combat vehicle weapon system requirements. Specific objectives of this phase of the program were to refine and advance the previous studies, to demonstrate experimentally some of the most critical hardware of the concepts proposed, and ultimately to provide a sound basis for selection of a development contractor.[6]

(U) In their feasibility studies, submitted to the OTAC evaluation committee in January 1959, both Aeronutronic and Sperry agreed that a closed breech concept for the missile system was feasible, and that the gun being developed by Watervliet Arsenal would, with some modification, be suitable for either launching the antiarmor missile or firing low muzzle velocity ballistic projectiles against soft targets. The missile size would directly affect the handling problems during the manual breech loading cycle, as well as determine the number of rounds that could be carried. The two proposed missiles would have a maximum diameter of 6 inches, but the Aeronutronic missile would be slightly longer and 7 pounds heavier. Although both missiles would use infrared trackers, the proposed method of transmitting commands from the tracker to the missile was different, one using a microwave radio link and the other using an infrared data link.

(U) The system proposed by Sperry consisted of a direct-fire missile with a shaped-charge warhead, guided on the line of sight to the target by a manually aimed sight with an infrared tracker. The tracker would detect missile errors and automatically send commands to the missile by a microwave radio link. The missile would have a launch weight of 32 pounds and a length of 38.1 inches.

(U) The proposed Aeronutronic system consisted of a rocket-boosted guided missile controlled to fly a line-of-sight trajectory from the launcher to the target. The line of sight would be established by the gunner, whose sole task would be to maintain the crosshairs of the optical sight on the target. An infrared tracker, boresighted to the optical sight, would automatically track the missile. The fire control system would automatically compute and transmit the necessary corrective commands by coded infrared data link to the missile. In their study report, Aeronutronic stated that completely acceptable infrared signal transmission characteristics (high signal to noise ratio) could be obtained by using double base propellants having flame temperatures in the

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*Contract DA-30-069-ORD-2448 to Sperry on 1 June 1958, and Contract DA-04-495-ORD-1329 to Aeronutronic on 26 June 1958.

[6](1) Memo History, SHERIDAN Weapon System, M551, 1954-1971, dtd 28 Apr 71, p. 4. (2) SHILLELAGH Monthly Progress Report, 30 Sep 59, ARGMA/AOMC, p. 6.

1,950 to 2,150° Kelvin range. The propellants that proved to be satisfactory were of a relatively standard variety and therefore were not expected to cause serious developmental, production, or cost problems. The study report further stated that test results showed that the gas jet control system could provide the required control moments without seriously degrading missile stability. The missile would have a launch weight of 39 pounds and a length of 39 inches.[7]

(U) At the end of the initial feasibility study in May 1958, the President of Aeronutronic had expressed confidence that the proposed system could be made operational in 54 months at a total cost of $33,922,000 (excluding facility costs)—$26,615,000 for the development phase and $7,307,000 for the training phase. Once developed, he estimated that the missile could be produced at a cost of $573 per unit in a total quantity of 50,000 over a 3-year period, and the launcher and turret, including associated fire control equipment, at $58,930 per unit in a total quantity of 1,000 over a 3-year period.[8]

(U) The OTAC evaluation report, forwarded to OCO on 21 November 1958, recommended that Aeronutronic be selected to proceed with development of its proposed midrange combat vehicle weapon system. This recommendation was then processed through the chain of command, receiving concurrences from the DA Chief of Research and Development and the Army Chief of Staff. On 2 April 1959, the Secretary of the Army approved the MC's for the Armored Combat Vehicle Weapon System (Midrange), accepted the proposed weapon system concept and development program in principle, and approved the selection of Aeronutronic as the prime development contractor.

(U) Accordingly, on 29 April 1959, OCO authorized the initiation of development of the Combat Vehicle Weapon System (Pentomic), assigned overall weapon system management responsibility to OTAC, and approved the popular name SHILLELAGH. The Ordnance Tank-Automotive Command then delegated responsibility for overall contractual supervision to the Army Ordnance Missile Command/Army Rocket and Guided Missile Agency (AOMC/ARGMA) and directed that a development contract be negotiated with Aeronutronic. On 11 June 1959, ARGMA awarded

[7](1) Final Report, Preliminary Experimental Development Armored Combat Vehicle Weapon System, Sperry Report No. EB-5287-0004, Jan 59, Sperry Gyroscope Company, Division of Sperry Rand Corporation. RSIC. (2) Armored Combat Vehicle Weapon System Preliminary Development Phase Final Report—Part I of II, Aeronutronic Publication No. S-334, 17 Jan 59, ASI Doc 4922-N, Pt I, Aeronutronic Systems, Inc., a Subsidiary of Ford Motor Co. RSIC.

[8]Ltr, Gerald J. Lynch, President, Aeronutronic Systems, Inc., to CG, ARGMA, 19 May 58, w incl: Report, Development of a Missile System, Armored Combat Vehicle - Revised Aeronutronic Publication No. S-208, Doc Control No. 3417-N, 19 May 58. RHA Box 12-665.

Aeronutronic a cost-plus-fixed-fee contract (DA-04-495-ORD-1599) in the amount of $3,303,704 for the initial phase of the SHILLELAGH development effort.[9]

The SHILLELAGH Weapon System

(U) The Combat Vehicle Weapon System (SHILLELAGH) was an outgrowth of the Combat Vehicle Weapon System (Pentomic) and the New Tank Main Armament System which was also under study in 1958-59. Feasibility studies of the conventional type ammunition and gun-launcher, initiated in August 1958, were based on a Ballistic Research Laboratories study of a new concept tank armament system for the main battle tank. The system recommended for development in March 1959 was a moderate pressure, lightweight, large caliber, short length gun capable of launching a spin-stabilized multipurpose projectile, as well as a direct-fire, wingless (or folding fin) guided missile. On 19 June 1959, the DA Chief of Research and Development approved the development program for the New Tank Main Armament System and directed that this program be integrated with the on-going antitank guided missile development effort. He officially identified the Combat Vehicle Weapon System (Pentomic) as the SHILLELAGH Weapon System and defined the SHILLELAGH as including the direct-fire guided missile, 152mm gun-launcher, conventional ammunition, and guidance-fire control subsystems.

(U) The SHILLELAGH weapon system would require a fire control system capable of firing and guiding the missile, as well as firing the conventional-type ammunition. The XM13 guided missile, the primary round for the weapon system, would be capable of defeating armored targets at all ranges up to 2,000 meters, with a very high probability of a first-round kill. The conventional ammunition would be the secondary antitank round, as well as the primary soft target round. The T95 tank chassis would be used as the initial development test bed for the SHILLELAGH. Plans were to use the midrange weapon system on the Armored Reconnaissance/Airborne Assault Vehicle (later designated as the M551 SHERIDAN), which was approved for development in September 1959, and on the future main battle tank. Feasibility studies of the long-range system were to be initiated in FY 1960, instead of FY 1959 as previously planned.[10]

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[9](1) Memo History, SHERIDAN Weapon System, M551, 1954-1971, dtd 28 Apr 71, pp. 5-7. (2) OTCM 37039, 2 Apr 59 (Appendix B). (3) SHILLELAGH Monthly Progress Report, 30 Sep 59, ARGMA/AOMC, pp. 6-7.

[10](1) Ibid., p. 7. (2) Memo History, SHERIDAN Weapon System, M551, 1954-1971, dtd 28 Apr 71, pp. 7-8. (3) OTCM 37180, 17 Sep 59, subj: Armored Reconnaissance/Airborne Assault Vehicle, Initiation of Development and Recording of Military Characteristics (DA Project No. 545-02-003, Ordnance Project No. TW-429). RSIC. (4) OTCM 37245, 5 Nov 59 (Appendix C).

(U) The planned operational availability date for the midrange SHILLELAGH weapon system was December 1963. The estimated research and development (R&D) and test and evaluation (T&E) cost for the FY 1958-63 period totaled $62,738,000. Following is a breakdown of the cost estimates by fiscal year (in millions).[11]

Fiscal Year	R&D	T&E	Total
1958	$ .659	$ ---	$ .659
1959	3.029	1.500	4.529
1960	8.890	3.420	12.310
1961	9.675	2.750	12.425
1962	4.565	8.350	12.915
1963	7.550	12.350	19.900
TOTAL:	$34.368	$28.370	$62.738

[11] Ibid.

CHAPTER III

(U) MANAGEMENT OF THE SHILLELAGH MISSILE PROGRAM

(U) From 1959 until September 1964, the SHILLELAGH missile program was managed as a subsystem of various combat vehicle weapon systems under the overall supervision of managers at the Ordnance Tank-Automotive Command (OTAC), the Office, Chief of Ordnance (OCO), the Army Materiel Command (AMC), and the Army Weapons Command (WECOM). This fragmented management structure, in which the missile developer (AOMC/ARGMA/MICOM*) reported to another system manager at a distant location, complicated coordination efforts and adversely affected program progress during the critical years of SHILLELAGH missile development.

(U) In 1959, the policy of the Chief of Ordnance was to assign primary responsibility for a weapon system to a weapon system manager, usually the commander of the installation having a prominent role in fielding the complete system. The weapon system manager used the resources of other commodity commands in accordance with their assigned missions. And the commander of the supporting organization was responsible for complying with the directives of the weapon system manager and supplying him with the necessary technical and managerial reports. Since the SHILLELAGH missile was considered a subsystem of the complete system, ARGMA, as the commodity command responsible for guided missiles, supported the weapon system manager at OTAC. Under similar arrangements, AOMC supported the Ordnance Corps Project Manager at OCO, and MICOM supported the SHERIDAN/SHILLELAGH Project Manager located first at AMC and later at WECOM.[1]

(U) Under the overall weapon system management by OTAC, OCO, and AMC, the missile development team at Redstone Arsenal maintained authority and technical responsibility for the missile, although various coordination, scheduling, and funding problems were encountered. The transfer of the SHERIDAN/SHILLELAGH Project Manager from AMC to WECOM in April 1963 increased MICOM's management

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*The Army Ordnance Missile Command (AOMC) was established at Redstone Arsenal, on 31 March 1958. The Army Rocket and Guided Missile Agency (ARGMA), activated as a subordinate element of AOMC on 1 April 1958, was abolished on 11 December 1961 and its functions were merged with AOMC Headquarters. In the Army reorganization of 1962, the Chief of Ordnance was abolished as a statutory officer and most of the mission operations of the Ordnance Corps were transferred to the newly created US Army Materiel Command, which became operational on 1 August 1962. At the same time, AOMC was discontinued and the US Army Missile Command (MICOM) became operational as a major subordinate element of AMC. (Elizabeth C. Jolliff, *History of the United States Army Missile Command*, 1962-1977 [HQ MICOM, 20 Jul 79], pp. 1-16.)

[1](1) OrdC Orders 15-55, 1 Jun 55; 19-55, 1 Jun 55; 9-59, 25 Mar 59; 22-59, 10 Aug 59. (2) Ltr, CofOrd to CG, OTAC, 14 Aug 59, re Weapon System Management. (3) MICOMR 10-2, 21 Nov 62.

problems, because the project manager assigned responsibility for specific tasks, often in piecemeal fashion and without delegating the necessary authority to perform the functions satisfactorily. After some 18 months of working under this task order arrangement, the Commanding General of MICOM convinced AMC officials to separate the management of the SHERIDAN and SHILLELAGH. The SHILLELAGH Project Management Office was established at MICOM on 21 September 1964, less than 2 months before award of the initial missile production contract. This office continued to manage the SHILLELAGH program until 30 June 1971, when it was abolished and the SHILLELAGH functions were assigned to commodity-type management at MICOM.

(U) The summary which follows traces the management of the SHILLELAGH missile program during the 1959-1982 period, with primary emphasis on the problems and frustrations stemming from the fragmented management structure during the 1959-1964 timeframe.

Weapon System Management at OTAC

(U) When the Chief of Ordnance authorized development of the Combat Vehicle Weapon System in April 1959, he assigned overall weapon system responsibility to OTAC, in accordance with the Ordnance commodity command management concept. The OTAC, in turn, delegated to AOMC/ARGMA the overall contractual supervision authority over the missile development contract awarded to Aeronutronic on 11 June 1959.

(U) Shortly after award of the development contract, the Chief of Ordnance reoriented the Combat Vehicle Weapon System program to include four separate Ordnance projects and named the system the SHILLELAGH. The four subsystems were a direct-fire guided missile, a gun-launcher, a family of conventional weapons, and a fire control system. The OTAC retained overall weapon system responsibility, with development efforts on the subsystems divided among three other installations. Watervliet Arsenal would develop the 152mm gun-launcher cannon; Frankford Arsenal would develop the fire control unit for the final vehicle; and ARGMA would develop the missile and guidance subsystem, as well as fire control components for the T95 test vehicle to insure that the fire control would be capable of handling both the missile and conventional ammunition. The ARGMA would also coordinate with Watervliet to insure compatibility between the 152mm gun and the SHILLELAGH missile.

(U) Within ARGMA, the primary responsibility for the missile was assigned to the Research and Development Division, with the Industrial and Field Service Divisions providing secondary support to the program. The technical management process consisted of two phases: the placing of requirements with parallel guidance and the reviewing of effort as it progressed. The latter phase was a continuing process, only part of which involved the review of reports from the contractor. The majority of the review function was carried out through personal contacts, system demonstrations, and command reviews. To fulfill the unusual role of supporting a system assigned to another major command, MG John B. Medaris, the AOMC Commander, directed ARGMA to give OTAC the same support on this weapon system as this Command would expect if OTAC were doing this work for AOMC/ARGMA. To accomplish this, General Medaris encouraged direct contact between ARGMA and OTAC personnel within limitations of existing AOMC policy.[2]

(U) With the multiplicity of organizations and people involved in the management chain, some coordination and communications problems were inevitable. These problems, however, did not have as much of an impact on the program as the division of responsibility for the missile subsystem and the guidance and control package. In 1959, OTAC delegated to AOMC/ARGMA development responsibility for the missile and guidance subsystem, plus the fire control components for the T95 test vehicle, and indicated that the industrial and field service responsibilities would be assigned later. On 9 March 1960, OTAC formally assigned to ARGMA the industrial and field service responsibilities for the missile, but only a technical advisory role for the guidance components. In this framework, ARGMA would complete the R&D phase of the SHILLELAGH missile subsystem, then Frankford Arsenal would assume responsibility for adapting the guidance components to the final vehicle and for following through with the industrial and field service roles for the fire control components.

(U) The split of the guidance components from the missile developer was also reflected in an interim plan for the Armored Reconnaissance/Airborne Assault Vehicle (AR/AAV), which OTAC was developing as the basic vehicle for the SHILLELAGH missile subsystem. According to this plan, issued in May 1960, ARGMA's industrial and field service responsibilities, directly to OTAC, were limited to the XM13 guided missile. Frankford Arsenal had the R&D, industrial, and field service responsibilities for the AR/AAV fire control, and ARGMA was subordinate to Frankford for the vehicle-mounted guidance system (see Chart 1). Although the exact Frankford-ARGMA relationship was not detailed in the plan, previous correspondence had indicated that ARGMA would be limited to a technical advisory role.

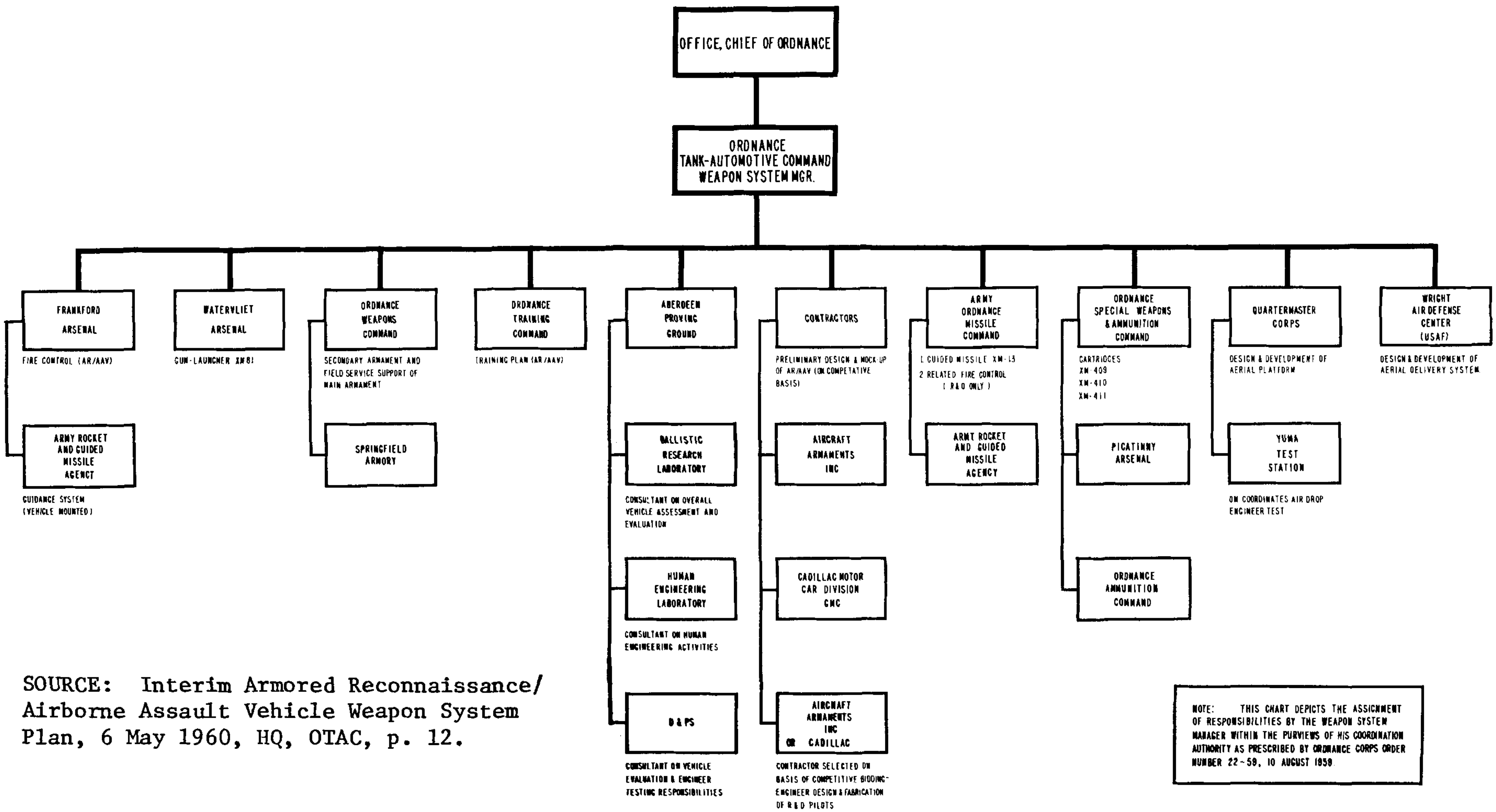
(U) Under the existing plan then, only the missile and the ammunition portion of the SHILLELAGH subsystem program could go beyond the R&D phase into the industrial and field service phases. The ARGMA R&D Division would release the XM13 missile to the ARGMA Industrial Division and the design data for installing the fire control and missile guidance equipment in the T95 turret would be released to Frankford Arsenal. Industrial engineering would begin on the missile, but the associated guidance equipment released to Frankford Arsenal would be used only as a basis for development of the AR/AAV fire control. Apparently, OTAC would assume responsibility for insuring compatibility of the missile and associated vehicular-mounted missile guidance equipment.

(U) Such an unwieldy management structure would not only require additional time and effort for interagency coordination, but also tend to lengthen the time required to field the system and invite incompatibility of missile subsystem and guidance components. For these reasons, MG August Schomburg, the AOMC Commander, recommended in June 1960 that responsibility for the entire

[2] (1) SHILLELAGH Guided Missile Sub-System Plan, ARGMA MSP-7, 31 Aug 59, AOMC/ARGMA, pp. B-2, B-3, D-5. (2) OTCM 37245, 5 Nov 59. RSIC. (3) 1st Ind, Cdr, AOMC, to Cdr, ARGMA, 16 Sep 59, on Ltr, CG, OTAC, to CG, AOMC, 26 Aug 59, subj: SHILLELAGH Weapon System.

CHART 1

ASSIGNMENT OF ARMORED RECONNAISSANCE/AIRBORNE ASSAULT VEHICLE WEAPON SYSTEM RESPONSIBILITIES



SOURCE: Interim Armored Reconnaissance/ Airborne Assault Vehicle Weapon System Plan, 6 May 1960, HQ, OTAC, p. 12.

missile subsystem, including the guidance and control package, be delegated to a single agency throughout the R&D, industrial, and field service phases of all programs planned to adapt the SHILLELAGH to military vehicles. Two months later, BG J. F. Thorlin, the Commander of OTAC, amended assignments in the fire control areas only, leaving all other delegated responsibilities the same as originally established in June 1959. Specifically, ARGMA would be responsible for life cycle management of all end items of missile guidance (i.e., the missile tracker, transmitter, computer, and power supply unit), while Frankford Arsenal would be responsible for all the conventional optical items, formerly considered the sum total of fire control for past combat vehicles. The ARGMA would also be responsible for the end item composed of hardware from both Frankford and ARGMA (i.e., the integrated articulated telescope required for the AR/AAV), with the stipulation that the optical telescope portion of this component be procured directly from Frankford Arsenal. The OTAC would retain complete system and vehicular installation responsibility for all fire control.[3]

(U) The interface problems stemming from the fragmented management structure were by no means confined to relationships among Government agencies, but also had a profound impact on the missile development contractor at a time when serious technical difficulties were being encountered.[*] Following a visit to the Aeronutronic plant in the fall of 1960, General Schomburg reported a contractor complaint that the communication channels were too long, complicated, and difficult. He found that Aeronutronic was indeed receiving technical instructions from too many sources—not only from two sources in ARGMA, but also from people in OCO and OTAC. Even though OTAC had overall weapon system management responsibility, General Schomburg emphasized that AOMC was responsible for the missile and the missile development contractor was responsible only to ARGMA for technical supervision and direction.[4] Evidence of the complicated communication channels surfaced in October 1960, when the Commanding General of OTAC complained to the ARGMA Commander that Aeronutronic had gone to AOMC/ARGMA rather than to OTAC about a problem with Picatinny Arsenal. The contractor, nevertheless, assured the ARGMA Commander that, from a contractual point of view, ARGMA was the only agency that could give them technical direction.[5]

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[*] See discussion of problems in the early years (1959-1961), pp. 41-57.

[3] (1) Ltr, CG, OTAC, to CG, ARGMA, 30 Jun 59, subj: Combat Vehicle Weapon System (SHILLELAGH). (2) Ltr, Cdr, ARGMA, to CG, OTAC, 11 Jan 60, subj: SHILLELAGH Weapon System Plan, w 1st Ind, CG, OTAC, to CG, AOMC, 9 Mar 60. (3) Interim Armored Reconnaissance-Airborne Assault Vehicle Weapon System Plan, OTAC HQS, 6 May 60. (4) Ltr, Cdr, ARGMA, to CG, OTAC, 15 Jun 60, subj: Comments to the Armored Reconnaissance Airborne Assault Vehicle Weapon System Plan. (5) Ltr, CG, AOMC, to CG, OTAC, 9 Jun 60, subj: SHILLELAGH Weapon System: Assignment of Responsibility, w 1st Ind, CG, OTAC, to CG, AOMC, 17 Aug 60, and 2d Ind, CofS, AOMC, to Cdr, ARGMA, 7 Sep 60.

[4] MFR, CG, AOMC, 19 Oct 60, subj: Trip Report for the Period 24 Sep 60-8 Oct 60.

[5] Journal Entries, COL John G. Zierdt, ARGMA Commander, 12 Oct 60, re telephone call from General Ghormley (CG of OTAC); discussion with Colonel Holmes and Mr. Normal; record of telephone conversation with Mr. Roy Jackson, Aeronutronic.

Project Management at OCO

(U) The SHILLELAGH management problems were carried over into the initial project management structure established at the Office, Chief of Ordnance in mid-1961. The year 1961 was a critical time for the SHILLELAGH missile subsystem, as technical problems remained unsolved and the program was beset with major changes in guidance from OTAC and higher headquarters. In May 1961, OTAC decided to expedite the program by using the M60 main battle tank as the basic vehicle for the system rather than the previously planned XM551 AR/AAV. The ARGMA plans for mounting the missile subsystem on the M60 were then complicated in July 1961, when the Department of the Army (DA) directed an earlier system readiness date than OTAC had requested. This resulted in two acceleration plans—the Directed Plan and the Reasonable Risk Plan—both of which were dropped when the Secretary of Defense decided, in September 1961, that the SHILLELAGH would be applied to the SHERIDAN* AR/AAV under an accelerated program. In December 1961, however, technical difficulties prompted the Chief of Ordnance to stop the accelerated program and put the missile into an applied research program. The importance of the SHILLELAGH weapon system in the defense structure and the problems which threatened to delay its fielding made the system a prime candidate for the intensive management concept called project management.

(U) In July 1961, Secretary of Defense Robert S. McNamara expressed a desire that project managers, with the rank of colonel or above, be appointed for significant Army programs. Secretary McNamara wanted to be able to call these people directly for immediate information on each major project. Accordingly, in August 1961, the DA selected nine major weapon systems for project management, one of which was the SHILLELAGH Armored Combat Vehicle Weapon System. The criteria for selection of the programs included the need for accelerating the decisionmaking process; significant interest in the weapon system by the Congress, the President, or the Secretary of Defense; the essentiality of the item to the Army mission; the high total dollar value of the system; or the presence of major technical and managerial problems. These criteria were very similar to those used later in selecting programs for the formal project management system established under the Army Materiel Command in 1962.

(U) COL Harold N. Brownson, the designated Ordnance Corps Project Manager for the SHILLELAGH Weapon System, was responsible for planning, directing, and controlling the work and associated resources involved in providing the weapon system to combat units. This task involved all phases of development, procurement, production, distribution, and support of a balanced program to insure that delivery and employment schedules were met. He exercised continuing monitorship over all project funds, evaluated progress, insured that quality standards were met, and served as the focal point for resolving problems related to this project among the military departments.[6]

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*On 4 August 1961, the Secretary of the Army had approved the popular name General Sheridan for the XM551 AR/AAV. (OTCM 37847, 21 Sep 61. RSIC.)

[6]Raymond J. Snodgrass, AMC Historical Studies No. 1, *The Concept of Project Management*, (USAMC, Washington, DC, 1964), pp. 92-95.

Project Management at AMC

(U) When the formal project management system became operational in the newly activated Army Materiel Command on 1 August 1962, the SHERIDAN/SHILLELAGH became 1 of the 30 project-managed systems. The AMC policy was to locate a project manager at the subordinate command that had the predominant interest in the project. However, when more than one command was involved, the funds were large, operational difficulties were foreseen, or urgency dictated, the project manager usually reported directly to AMC Headquarters. Such was the case for the SHERIDAN/SHILLELAGH Project Manager, LTC Wayne G. Higgins, who was located at AMC Headquarters and reported to the Commanding General of AMC.

(U) Under the AMC Project Manager, MICOM was assigned subsystem commodity management responsibility for the SHILLELAGH missile, warhead, rocket motor and gas generator propellants, fuze, safety and arming device, guidance and control equipment, and test and training equipment pertaining to these items. The AMC suballocated funds for the program to the major subordinate commands and encouraged direct communication between the commands in accomplishing their missions. Problems which could not be resolved by the subordinate commands would be immediately referred to the project manager for resolution.[7]

(U) During a visit to MICOM in August 1962, Colonel Higgins indorsed a vertical type management organization for the SHILLELAGH Project Manager's Staff Office (PMSO) at MICOM, as well as the PMSO's at other major commands. MG Francis J. McMorrow, the MICOM Commander, concurred in the concept of vertical type management for each project manager, but stated that the limited personnel spaces allotted to the Command precluded him from establishing this type of organization for the SHILLELAGH PMSO. Instead, he proposed a small management group as the PMSO, which would be completely responsible within MICOM for the direction, control, and management of the SHILLELAGH subsystem. The PMSO would use personnel in the functional directorates to accomplish the detailed management and direction of the program. To conserve scarce manpower resources and provide a greater depth of experience and knowledge upon which to base technical or managerial decisions, General McMorrow suggested that the functions and responsibilities of the SHILLELAGH PMSO be combined with those of the Antitank Product Manager. This proposed organizational concept would provide for efficient management of the SHILLELAGH program and at the same time relieve the PMSO/Product Manager of administrative-type responsibilities and permit him to devote full time to the technical aspects of the program.[8]

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[7](1) Raymond J. Snodgrass, AMC Historical Studies No. 1, *The Concept of Project Management* (USAMC, Washington, DC, 1964), pp. 133, 140-142. (2) Memo History, SHERIDAN Weapon System, M551, 1954-1971, dtd 28 Apr 71. (3) Msg, USAMC to CG, MICOM, et al., DTG 101730Z Jan 63, re SHERIDAN/SHILLELAGH Subsystem Commodity Management Assignments.

[8]Ltr, Cdr, MICOM, to CG, AMC, 11 Sep 62, subj: Missile Command Support of General Sheridan/SHILLELAGH Project Manager.

(U) In accordance with the approved McMorrow concept, the SHILLELAGH functions were merged with other antitank systems for about 7 months. When MICOM was activated in August 1962, the SHILLELAGH missile subsystem management functions were assigned to the Antitank and Field Artillery Product Office.[9] This office was split on 3 October 1962, and the SHILLELAGH functions went to the Antitank Product Management Office,[10] which was redesignated the Antitank Commodity Office on 22 October 1962.[11] The antitank and aircraft weapons were again combined in the Antitank/Aircraft Weapons Commodity Office, established on 19 November 1962.[12] Management responsibility for the SHILLELAGH was then transferred from that office to the SHILLELAGH Commodity Office which was established on 11 March 1963 with Mr. Lloyd L. Lively, Jr., as SHILLELAGH Commodity Manager.[13]

(U) The SHILLELAGH Commodity Office was a short-lived entity. It was abolished on 15 April 1963, when AMC transferred the SHERIDAN/SHILLELAGH Project Office from AMC Headquarters to the Army Weapons Command (WECOM) at Rock Island, Illinois.[14] The reasoning for this change was that, since the weapon system involved a self-propelled vehicle, the Weapons Command could provide the best technical support.[15]

Project Management at WECOM

(U) The transfer of the SHERIDAN/SHILLELAGH Project Manager from AMC to WECOM on 15 April 1963 compounded the SHILLELAGH management problems at a time when the missile was nearing transition from development to production and more Government agencies and contractors were becoming involved in the program. Under the overall management of OTAC, OCO, and AMC, the development team at Redstone Arsenal had maintained authority and responsibility for the missile subsystem and had managed to accomplish the program despite the attendant coordination and interface problems. But, under the management structure imposed by the SHERIDAN/SHILLELAGH Project Manager at WECOM, the Army Missile Command had virtually no authority and its responsibility was reduced to performing, on a task order basis, only that work specifically requested by the Project Manager.

(U) With transfer of the SHERIDAN/SHILLELAGH Project Office from AMC to WECOM on 15 April 1963, a Missile Engineering Division (later referred to as

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[9] (1) AOMC GO 87, 30 Jul 62. (2) MICOM GO 5, 30 Jul 62.

[10] MICOM GO 43, 3 Oct 62.

[11] MICOM GO 54, 5 Nov 62.

[12] MICOM GO 57, 19 Nov 62.

[13] (1) MICOM GO 19, 12 Mar 63. (2) MICOM GO 21, 18 Mar 63.

[14] (1) AMC GO 20, 1 Apr 63. (2) MICOM GO 61, 8 Jul 63.

[15] Raymond J. Snodgrass, AMC Historical Studies No. 1. *The Concept of Project Management* (USAMC, Washington, DC, 1964), pp. 141-142.

the Missile Division) was established at MICOM,* which took over the missions and functions of the SHILLELAGH Commodity Office and the SHILLELAGH Branch of the Development Division of the Research and Development Directorate. The Missile Engineering Division was under jurisdiction of the SHERIDAN/SHILLELAGH Project Manager at WECOM, with the Missile Command providing administrative, training, and logistical support and other support required by the Project Manager. The SHERIDAN/SHILLELAGH Project Manager desired to continue receiving the same type of support from MICOM that he had in the past, except for the engineering aspects of the SHILLELAGH missile. The Missile Engineering Division thus assumed full responsibility for development and product and production engineering, including those inherent disciplines required to insure maximum reliability, ease of maintenance, and field worthiness of the SHILLELAGH missile and its components.[16] Mr. Earl R. Edmondson served as chief of the division throughout its existence.

(U) Between April 1963 and December 1963, representatives of MICOM held many lengthy discussions with the SHERIDAN/SHILLELAGH Project Manager and his staff in an effort to establish specific operating relationships, roles, and responsibilities with respect to the SHILLELAGH missile subsystem. Throughout these discussions, the Missile Command took the position that complete functional missions—research and development (R&D), procurement and production (P&P), and supply and maintenance (S&M)—should be assigned by the Project Manager, who would exercise overall guidance and direction in the same way mission assignments had been handled under OTAC, OCO, and AMC. The Weapons Command insisted that the Project Manager would exercise full line authority for the planning, direction, and control of tasks and associated resources through his Missile Division at Redstone Arsenal. Under this concept, the Missile Command would perform, on a task order basis, whatever work the Project Manager requested—basically, that work which the Project Manager could not perform in his own organization. The Project Manager would make all decisions (except those internal to MICOM) and would be solely responsible for all contractual matters, including those involving schedules, delivery dates, technical performance, configuration control, etc. The Project Manager's Missile Division at Redstone Arsenal would direct, manage, and control all mission elements of the SHILLELAGH program; develop and issue directives, instructions, and policy guidance to all MICOM elements engaged in work on the SHILLELAGH system; and act as the primary point of contact within MICOM with respect to the SHILLELAGH program. Pending establishment of specific operating procedures and the necessary support arrangements, MICOM elements continued to perform work on the SHILLELAGH program under existing arrangements.

(U) The Missile Command agreed that the Project Manager should exercise responsibility and authority in depth, but pointed out the many pitfalls associated with fragmented assignments of tasks in a complex missile program.

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*At the same time, the Vehicle Engineering Division was established at the Army Tank-Automotive Center in Detroit, Michigan.

[16](1) MICOM Anl Hist Sum, 1 Jul 62 - 30 Jun 63, pp. 28, 146. (2) MICOM GO 61, 8 Jul 63. (3) Also see Ltr, CG, AMC, to CG, WECOM, 18 Mar 63, subj: Relocation of SHERIDAN/SHILLELAGH Project Manager's Office.

In a letter to the Commander of WECOM, in October 1963, BG John G. Zierdt, Commander of MICOM, declared that it would be extremely difficult, if not impossible, for the Project Manager to buy management responsibility from MICOM on a task order basis, while retaining the depth of authority proposed by WECOM. It was essential that the Project Manager provide adequate information on planned tasks far enough in advance to assure proper planning and availability of resources for their accomplishment. Moreover, it was imperative that all task orders clearly delineate the scope of work and timeframe for completion, since MICOM would be responsible only for the completion of requested tasks, with full responsibility for success of the program resting on WECOM and the Project Manager. The acceptance of individual task orders would be dependent upon the availability of resources and capability to perform the tasks as ordered.

(U) General Zierdt disagreed with the mission statement proposed for the Project Manager's Missile Division at Redstone Arsenal, saying that piecemeal day-to-day direction at the working level from the Project Manager could seriously disrupt other high priority projects and would soon result in confusion, inefficiency, and high overall costs. He maintained that normal command channels should be followed in issuing task orders and instructions, and that the proposed functional statement for the Missile Division should be changed accordingly. In view of the many problems inherent in the use of task orders, General Zierdt asserted that MICOM could accept only those orders falling within the common areas in which other MICOM project managers were supported, unless WECOM agreed to delegate additional authority and establish acceptable reporting channels. He again urged the Commander of WECOM to assign to MICOM integrated functional responsibility for P&P and S&M under the overall guidance and direction of the Project Manager.[17]

(U) The initial set of task orders, forwarded to MICOM on 17 October 1963, met some of the conditions set forth by General Zierdt, in that they did not reflect piecemeal day-to-day direction and they provided for the use of normal command channels. Other important conditions, however, were not met. The tasks were written to assign broad functional responsibility as exercised under the MICOM commodity management concept, but neither delegated the necessary authority to perform the functions satisfactorily nor provided the necessary reports or program authority to MICOM. Moreover, the task orders included functions not performed for MICOM project managers, did not give proper guidance,

[17](1) DF, Chf, Orgn & Msn Div, Mgt Science & Data Sys Ofc, MICOM, to Distr, 8 Jul 63, subj: Trip Report [TDY Visit to WECOM]. (2) Ltr, CG, WECOM, to CG, MICOM, 12 Sep 63, subj: Memorandum of Understanding of Operating Relationships for the Shillelagh Weapon System, w Proposed MOU and Mission Statement for Chf, Missile Division. (3) SS, AMSMI-WO-205-63, Chf, Mgt Science & Data Sys Ofc, MICOM, 27 Sep 63, subj: MOU of Operating Relationships for SHILLELAGH Weapon System. (4) Ltr, CG, MICOM, to CG, WECOM, 3 Oct 63, same subj. (5) DF, BG C. W. Eifler, DCG/Land Combat Systems, MICOM, to Distr, subj: Support to the SHILLELAGH Program, 31 Oct 63.

and did not adequately describe the exact effort required or the timeframe for accomplishment.[18]

(U) On 27 November 1963, after 40 days of negotiations, MICOM and the Project Manager's Missile Division agreed on a set of revised and clarified task orders. The Missile Command officially accepted the revised task order arrangement on 16 December 1963, placing the Command on a formal task order basis with respect to the SHILLELAGH missile subsystem.[19] The acceptance of this arrangement, however, did not alleviate the communication and interface problems between MICOM and WECOM. In fact, the problems grew more intense as the system neared production.

(U) For example, in February 1964—just 6 months from the scheduled date for the first production contract—Mr. P. K. Schaeppi, the Acting Director of Procurement and Production at MICOM, complained that the recent redirection of several elements of the SHILLELAGH procurement program was seriously affecting the directorate's ability to accomplish the functions assigned by task orders. The SHERIDAN/SHILLELAGH Project Manager, he said, had been continually informed of program plans and did not choose to take issue with them at the appropriate time. Specifically, the Project Manager had directed:

- That plans for the SHILLELAGH manufacturing facility be changed from a privately-owned privately-operated facility near the Aeronutronic plant at Newport Beach, California, to a Government-owned contractor-operated (GOCO) facility at an unspecified location.

- That the Iowa Army Ammunition Plant be considered as the site for the assembly and loading of SHILLELAGH missiles, instead of plans to use a GOCO facility at Redstone Arsenal, which had been approved by the Commander of WECOM on 9 December 1963.

- That plans for separate single contracts for procurement of SHILLELAGH hardware and engineering services be changed to require four contracts for hardware, with multiple contracts suggested for engineering and support services.

- That scopes of work be prepared for a multiyear buy on the missile, although multiyear buys had not been planned for any components.

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[18](1) Ltr, SHERIDAN/SHILLELAGH PM to CG, MICOM, 17 Oct 63, subj: Shillelagh Missile Sub-System Task Orders to MICOM. (2) DF, Dep Dir, D/P&P, to Mgt Science & Data Sys Ofc, 25 Oct 63, subj: SHILLELAGH Missile Sub-System Task Orders, w incls.

[19](1) SS, AMSMI-WO-265, Chf, Mgt Science & Data Sys Ofc, 16 Dec 63, subj: Shillelagh Missile Sub-System Task Orders to MICOM. (2) Ltr, BG C. W. Eifler, DCG/Land Combat Systems, MICOM, to SHERIDAN/SHILLELAGH PM, WECOM, 16 Dec 63, same subj. (3) DF, Act CofS, MICOM, to Distr, 24 Dec 63, same subj.

Such belated changes in procurement program plans not only meant the loss of a year's planning effort, but also placed the initial production contract in jeopardy.[20] (Award of the contract eventually slipped from 1 September 1964 to 9 November 1964.)

(U) On 15 May 1964, MICOM received confirmation of the Project Manager's decision to use the Iowa Army Ammunition Plant for SHILLELAGH loading and assembly.[21] Following a review of the facility evaluation report, prepared by the Mason and Hanger Silas Mason Company, Inc., Mr. Paul W. Hancock of the MICOM Installations and Services Office declared: "I am shocked to have such a document thrust upon the Government and can only hope that the Army has more basis for making a decision on Assembly Facilities than the information contained in the . . . document. . . . This is about the weakest presentation of facilities requirements I have ever reviewed for such an important undertaking."[22]

(U) The Missile Command continued to request the "doing" job for SHILLELAGH, while assuring the Project Manager that he would retain management and control in sufficient depth to manage the program. The Commander of WECOM submitted an alternate plan which in essence offered MICOM the total "doing" job, less engineering, under conditions of very strict control. The Missile Command concluded, however, that WECOM's alternate plan provided no significant overall improvement over the existing arrangement.

(U) The Missile Command had been assigned a multitude of very detailed jobs under 70 task orders. Each task was isolated from related tasks, making integrated operation across the task structure most difficult. Such a vast quantity of tasks, with all of the words contained therein, contributed to a lack of understanding as to specifically who was to do what, which resulted in duplication or, more importantly, voids when each thought the other was performing the job. With even the minor decisionmaking aspects reserved for the Project Manager and his staff, the more experienced top level people at MICOM contributed very little to the program. Both the Project Manager and MICOM had experienced personnel in most functional areas, causing duplication of effort, confusion, and inefficiency. For example, in performing tasks in the contractor's plant or elsewhere, MICOM personnel were accompanied by Project Manager counterparts. Moreover, in the implementation of the task orders, changing situations occurred to such an appreciable degree that the Project Manager felt constrained to violate the task order agreement by actually performing a part of the work within his staff. Most of these cases of overlap were discovered after-the-fact and after MICOM had been working under a different concept of operations. Because of the independent effort on the part of the Project Manager, MICOM

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[20] DF, Act Dir/P&P to DCG/Land Cbt Sys, MICOM, 26 Feb 64, subj: SHILLELAGH Management Problems.

[21] MFR, Gustavus N. Brown, Installations & Services Ofc, MICOM, 15 May 64, subj: Telephone Conversation between Mr. Leonard, Facilities & Resources Ofc, P&P Drte, and Mr. Brown of this Office.

[22] MFR, Chf, Construction Br, Facilities & Construction Div, I&S Ofc, 3 Apr 64, subj: Preliminary Facility Evaluation for Final Assembly of Shillelagh.

personnel were not completely knowledgeable on all aspects of their assigned tasks and therefore were not in a position to do the most effective job.[23]

(U) In July 1964, after months of discussions, proposals, and counter-proposals failed to produce compromises acceptable to both commands, MG John G. Zierdt, the Commander of MICOM, brought the foregoing management problems to the attention of the AMC Chief of Staff. He summarized the problem by stating that the missile system management team, which had been developed over the years at tremendous expense, was not being used effectively in the SHILLELAGH subsystem program. "It conflicts with my understanding of my mission," he declared, "in that the Sheridan/Shillelagh Project Manager exercises his own discretion as to what actions on the Shillelagh subsystem the Missile Command will take, reserving for himself any actions he so chooses, with the net result that the Missile Command mission . . . is to furnish personal services to the Project Manager." The handicap imposed on MICOM by detailed task orders rather than a mission assignment, the necessity to consult the Project Manager on the most minute details, the delays in obtaining decisions from the Project Manager, and the uncertainty as to when and how the Project Manager would use MICOM, together with the morale problem created by these factors, rendered the Missile Command's effectiveness in the program much less than desirable. General Zierdt expressed concern that, as the SHILLELAGH approached production, the problems stemming from the fragmented management structure would be magnified to the point where the total program might very well be adversely affected. In view of the prevailing management problems, plus plans to use the SHILLELAGH in multiple modes in addition to the SHERIDAN, General Zierdt strongly recommended that AMC separate the SHILLELAGH from the SHERIDAN/SHILLELAGH Project Manager and establish a separate SHILLELAGH Project Management Office at MICOM.[24]

(U) In a follow-up letter to MG W. B. Bunker, Deputy Commanding General of AMC, on 17 August 1964, General Zierdt emphasized his concern and strong convictions about the management of the SHILLELAGH subsystem. Recognizing that his letter of 7 July covered only the highlights of the problem, he furnished General Bunker a written briefing elaborating on the details. "I am convinced," he said, "that the current arrangement, which in essence uses my people as a technical management labor pool, is not working and will not work satisfactorily, even as modified by a recent proposal by General Anderson." General Zierdt again requested that total responsibility for the missile, including development engineering, be assigned to MICOM. While the recommendation that the SHILLELAGH be projectized was considered to be of secondary importance, he expressed the belief that such action would place the whole matter in the best perspective with respect to clarity, simplicity, efficiency, and effectiveness.[25]

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[23] Ltr, MG John G. Zierdt, CG, MICOM, to MG Selwyn D. Smith, Jr., AMC CofS, 7 Jul 64, re Management of the SHILLELAGH Subsystem.

[24] Ibid.

[25] Ltr, CG, MICOM, to DCG, AMC, 17 Aug 64, re Management of the SHILLELAGH Subsystem, w incl: MICOM Briefing on SHILLELAGH Subsystem. (See Appendix D.)

SHILLELAGH Project Management at MICOM

(U) General Zierdt's last appeal brought prompt results. Effective 21 September 1964—shortly before award of the initial SHILLELAGH production contract early in November 1964—AMC Headquarters established the Office of the SHILLELAGH Project Manager at MICOM and redesignated the SHERIDAN/SHILLELAGH Project Manager at WECOM as the SHERIDAN Weapon System Project Manager. The directive establishing the new project office transferred 25 manpower spaces and appropriate personnel from the SHERIDAN/SHILLELAGH Project Office to the SHILLELAGH Project Office. These personnel formed the nucleus of the SHILLEALGH Project Manager's staff. LTC Robert M. Pearce was assigned as the first SHILLELAGH Project Manager.[26]

(U) The SHILLELAGH Project Manager, who would report to the Commanding General of AMC through the Commanding General of MICOM, was delegated full line authority and responsibility for the development of his program and all planning, direction, and control of work and allocated resources. This included, as applicable, all phases of research, development, procurement, distribution, and logistical support to provide a balanced, expedited, economical, and effective system consistent with established objectives. Programming and funding of the SHILLELAGH would be through other project managers having a requirement for the SHILLELAGH to the SHILLELAGH Project Manager.

(U) The SHILLELAGH system would consist of the missile, including the missile test set and container; the guidance and control group, including the transmitter alignment fixture, but excluding the telescope and mount; and other items which could, from time to time, be specifically designated by the project managers of using systems. Since the SHILLELAGH was not in itself a complete weapon system, but had utlimate value only in conjunction with other elements (vehicles), it was essential that the Project Manager be responsive to the needs and requirements of project managers or others responsible for using systems. To assure effective coordination between the SHILLELAGH and using systems, the SHILLELAGH Project Manager assigned liaison representatives to WECOM and AMC Headquarters. He also stationed liaison representatives with the US-German Main Battle Tank Program and maintained a field office at the prime contractor's plant.[27]

(U) The SHILLELAGH Project Office was organized according to the refined MICOM project management concept, which was approved in FY 1965 and implemented on a command-wide basis in FY 1966. Under the refined concept, the project

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[26](1) Msg, CG, AMC, to CG, MICOM, DTG 171347Z Sep 64, re Establishment of the SHILLELAGH Missile System Project Manager's Office. (2) MICOM GO 77, 21 Sep 64. (3) AMC GO 66, 1 Oct 64. (4) Msg, CG, MICOM, to Aeronutronic Div, Philco Corp., DTG 301400Z Sep 64, subj: Change in Office Status.

[27](1) Msg, CG, AMC, to CG, MICOM, DTG 171347Z Sep 64, re Establishment of the SHILLELAGH Missile System Project Manager's Office. (2) Project Charter for the SHILLELAGH Missile System, approved by GEN Frank S. Besson, Jr., 10 May 65.

manager had the minimum possible staff required to manage, direct, control, and monitor his project. He had reasonable depth in systems engineering and project management skilled personnel, but relied to the maximum extent on the functional directorates in other areas. In the command-wide implementation of the refined concept, personnel spaces excess to the needs of the older projects (such as the NIKE HERCULES, PERSHING, and SERGEANT) were assigned to the newer projects (such as the SHILLELAGH, REDEYE, TOW, and CHAPARRAL), and certain functions, spaces, and personnel were reassigned from the project offices to the functional directorates. In this reshaping exercise, the SHILLELAGH Project Office gained 40 civilian personnel spaces.[28]

(U) As stated earlier, the SHILLELAGH Project Office was established on 21 September 1964 with a nucleus of 25 personnel spaces transferred from the SHERIDAN/SHILLELAGH Project Office. By 31 December 1964, the office's manpower authorization had increased to 57 spaces, but only 32 of them were filled. The 40 civilian spaces gained during implementation of the refined project management concept brought the 30 June 1966 personnel authorization to 101. The authorized manpower resources reached a peak of 104 with initial deployment of the SHILLELAGH system in June 1967, and gradually dropped thereafter to a low of 67 in June 1970. The following table depicts the SHILLELAGH Project Office's authorized and assigned personnel strength at 6-month intervals from 31 December 1964 through 31 December 1970.[29]

	MILITARY		CIVILIAN		TOTAL	
	Auth	Act	Auth	Act	Auth	Act
31 Dec 64	6	5	51	28	57	32
30 Jun 65	7	8	52	45	59	53
31 Dec 65	9	7	52	51	61	58
30 Jun 66	9	10	92	74	101	84
31 Dec 66	9	9	92	82	101	91
30 Jun 67	9	7	95	85	104	92
31 Dec 67	9	27*	91	84	100	111
30 Jun 68	9	13**	94	85	103	98
31 Dec 68	8	7	88	83	95	90
30 Jun 69	9	9	94	85	103	94
31 Dec 69	9	8	85	81	94	89
30 Jun 70	5	7	62	61	67	68
31 Dec 70	5	8	62	56	67	64

*Includes 19 enlisted men assigned but not authorized.

**Includes 6 enlisted men assigned but not authorized.

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[28](1) MICOM Anl Hist Sum, FY 65, pp. 10-14. (2) MICOM Anl Hist Sum, FY 66, pp. 20-23. (3) DF, CG, MICOM, to Distr, 18 Jun 65, subj: Implementation of MICOM Policy on Project Management, w incls.

[29]MICOM Personnel Status Reports, 31 Dec 64 - 31 Dec 70.

(U) The SHILLELAGH missile system remained under project management through the production and deployment phases of the program. The project office was abolished on 30 June 1971, shortly after completion of the missile production deliveries. LTC Robert M. Pearce served as the SHILLELAGH Project Manager from 21 September 1964 to 23 August 1965. He was succeeded by LTC Spencer R. Baen, who held the post until 31 May 1968. Mr. Earl R. Edmondson, the Deputy Project Manager, filled in as Acting Project Manager until the arrival of LTC Robert J. Proudfoot on 21 June 1968. Colonel Proudfoot saw the project through the final stages of production and transition to the commodity management concept on 30 June 1971.[30]

Commodity Management at MICOM

(U) With the inactivation of the SHILLELAGH Project Office on 30 June 1971, the SHILLELAGH missile functions were assigned to commodity-type management in the Land Combat Special Items Management Office (LCSIMO). As a management concept, commodity management fell between project management and functional management; i.e., it was less intensive and less expensive than the former but more systems-oriented than the latter. The LCSIMO Manager had full line authority within MICOM for managing his assigned materiel, the same relative authority as the project managers. The Missile Command had found through experience that commodity managers needed some directive and control authority because of the complexity of missile system management, the telescoping of programs, and the multiple relationships both within and outside the command. The LCSIMO Manager was authorized to contact and work directly with the functional directorates and offices, appropriate system-oriented elements of those directorates/offices, and MICOM headquarters staff elements.[31]

(U) To conserve resources and increase efficiency, the Land Combat and Air Defense Special Items Management Offices were merged effective 16 September 1973 to form the Special Systems Management Office.[32] The Special Systems Manager had essentially the same authority and responsibility as the former special items managers. He provided weapon system policy, plans, priorities, and direction to the functional directorates, which were responsible for planning, programming, budgeting, reporting, and executing their respective portions of approved associated programs.[33]

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[30](1) MICOM GO 88, 30 Jun 71. (2) Ltr, SHILLELAGH PM, to Distr, 16 Apr 71, subj: Deprojectization of the PM's Ofc, SHILLELAGH Msl Sys. (3) MICOM GO's 77, 21 Sep 64; 80, 24 Aug 65; 39, 29 May 68; and 53, 8 Jul 68.

[31](1) MICOM GO 88, 30 Jun 71. (2) MICOM Anl Hist Sum FY 65, pp. 16-18. (3) MICOMR 11-10, 2 Jul 65, subj: Commodity Management. (4) MICOM Anl Hist Sum, FY 71, p. 15.

[32](1) MICOM GO 149, 12 Sep 73. (2) MICOM Anl Hist Sum, FY 73, p. 27.

[33]MICOMR 10-8, 8 May 75, and App. C thereto, Concept of Special Systems Management.

(U) When the Army Missile Command was split on 31 January 1977, the Special Systems Management Office was transferred to the US Army Missile Materiel Readiness Command (MIRCOM), which took over the missile readiness functions of the former MICOM.[34] On 6 May 1979, the Special Systems Management Office was realigned into the Weapon Systems Management Directorate. Within the new directorate, Readiness Project Officers were assigned full line authority and responsibility for management and staff coordination of their assigned materiel. Within MIRCOM, the Readiness Project Officers had authority equivalent to that of a project manager; however, because they had fewer resources, they received more support from the functional directorates. Mr. Stanley B. Prosser was the Readiness Project Officer for the SHILLELAGH. The Weapon Systems Management Directorate was transferred intact to the reactivated Army Missile Command on 1 July 1979.[35]

(U) On 5 July 1981, the Weapon Systems Management Directorate was abolished and its missions, functions, and resources (less certain engineering and product assurance functions) were transferred to the new Missile Logistics Center (MLC). The MLC also encompassed most of the missions and functions of the former Maintenance Engineering and Materiel Management Directorates and the Targets Management Office. Within the Missile Logistics Center, the SHILLELAGH functions were assigned to the Close Combat Systems Management Office, which exercised full line authority of the MICOM Commander and the MLC Director in managing its assigned systems and equipment.[36]

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[34] (1) MICOM GO 149, 12 Sep 73. (2) MIRCOM AHR, FY 77, p. 28. (3) DARCOM Perm Orders 4-1, 19 Jan 77.

[35] (1) DARCOM Perm Orders 59-4, 30 Jul 79. (2) MICOM AHR, FY 79, pp. 266-67.

[36] (1) MICOM Perm Orders 21-1 and 21-2, 10 Mar 81. (2) MICOMR 10-2, C7, 5 Jul 81. (3) Also see MICOM AHR, FY 81, pp. 6-8, 233-34.

CHAPTER IV

(U) RESEARCH AND DEVELOPMENT PROGRAM (U)

(U) Research and development of the standard range (2,000-meter) SHILLELAGH missile began in 1959 with the award of the development contract to Aeronutronic. The early years of development were fraught with technical problems which caused extensive redesign of major components. The resultant schedule slippages prompted both the contractor and the Government, including the Secretary of Defense, to propose several acceleration plans in 1961. Continuing technical difficulties, however, forced SHILLELAGH development to be reoriented into an applied research program late in 1961. During this effort, which continued through 1962, the contractor resolved the major design and engineering deficiencies and the system reentered full development. After a series of successful R&D flights which showed that the essential requirements for a 2,000-meter maximum range missile system were being met, the Chief of Research and Development, DA, approved limited production of the system in August 1964. This chapter summarizes the myriad engineering and management complexities involved in designing and testing the unique SHILLELAGH weapon system prior to its release for limited production.

Military Characteristics

(U) The basis of the SHILLELAGH missile development program was the military characteristics initially set forth in OTCM* 36753, dated 10 April 1958, and amplified in OTCM 37039, dated 2 April 1959, and OTCM 37245, dated 5 November 1959. Those requirements are described below.

(U) The missile would be effective at ranges from near 0 to 2,000 meters, with a rate of aimed fire of 6 to 8 missiles per minute. It was to be capable of destroying the heaviest armored vehicle likely to be encountered on the battlefield. A satisfactory initial level of performance was established as the defeat of 150mm of rolled homogeneous armor at 60° obliquity and associated equivalent targets at the maximum 2,000-meter range. The missile would be capable of engaging targets located 20° above and 10° below the horizon when the vehicle mounting the weapon system was level. The same basic missile with appropriate warheads was to be employable effectively and economically against unarmored targets including personnel, materiel, and field fortifications.

(U) Hit and kill probabilities for the missile were not specified; however, the ultimate engagement objective was to achieve, with a given load of ammunition, the largest number of successful target hits, each in the shortest possible time. The weapon-ammunition-fire control systems were required to produce significant improvements in antiarmor engagement capabilities by independently or collectively increasing the effect, decreasing the time to

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*Ordnance Technical Committee Meeting

hit, or improving the delivery accuracy of the projectile without prejudicing the overall practicality of the total system. The ability of the system to provide such capabilities would be determined by testing it comparatively against the best antiarmor weapons deployed at the time. The foregoing characteristics would apply to the maximum extent possible when engaging moving targets from a weapon system in motion, and while operating under conditions of darkness or limited visibility.

(U) The weapon system was to be usable on existing standard and future development armored combat vehicles; however, the primary requirements for system effectiveness were not to be compromised to obtain vehicle compatibility. The system was also to be as lightweight as practicable and simple to operate. The crew would consist of one gunner-controller and one loader, both of whom would be located inside the armored vehicle and able to operate the weapon without exposing themselves.

(U) The system would be capable of firing 1,000 missiles and withstanding 2,500 miles of vehicle operation with only organizational maintenance required; and 2,000 firings and 4,000 miles of vehicle operation without needing major overhaul or replacement of major components. The weapon and its combat vehicle mount would be transportable by rail, water, and air, and were to be free from interference from adjacent armament systems and from disclosure of firing positions to the greatest practical extent. The command guidance means would have the capability of substantially thwarting enemy countermeasures.

(U) The environmental and terrain requirements for the missile were the same as for the vehicle on which it was mounted. Those requirements were specified in OTCM 37180, approved on 17 September 1959, which initiated development and recorded the military characteristics for the AR/AAV. The MC's required the vehicle to be capable of operating in air temperatures ranging from -65°F to +125°F and of storage in temperatures of -65°F to +155°F. They also specified as essential an "emergency only" type of control for manual operation of the armament.

(U) In the development of the SHILLELAGH system, performance requirements would receive top priority, followed by durability, reliability, and ease of maintenance; configuration; associated equipment; chemical, biological, radiological, and atomic defense; transportability; and environmental and terrain requirements.[1]

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[1](1) OTCM 36753, 10 Apr 58 (Appendix A). (2) OTCM 37039, 2 Apr 59 (Appendix B). (3) OTCM 37245, 5 Nov 59 (Appendix C). (4) OTCM 37180, 17 Sep 59, subj: ARMORED RECONNAISSANCE/AIRBORNE ASSAULT VEHICLE, Initiation of Development and Recording of Military Characteristics (Department of the Army Project No. 545-02-003, Ordnance Project No. TW-429.) RSIC.

Background of Prime Contractor

(U) The Aeronutronic Division of the Ford Aerospace and Communications Corporation was founded in late 1955, when a group of California engineers formed a company called Systems Research Corporation. They changed the name of the company to Aeronutronic Systems, Incorporated, in May 1956. The next month, Ford Motor Company purchased the company and it became known as Aeronutronic Systems, Incorporated, a subsidiary of Ford Motor Company. In June 1959, shortly after award of the SHILLELAGH missile development contract, the name was changed to Aeronutronic Division of Ford Motor Company.

(U) After Ford purchased the Philco Corporation, Aeronutronic was placed under it, becoming Aeronutronic Division of Philco Corporation in July 1963. With a small change in July 1966, the name became Philco-Ford Corporation, Aeronutronic Division. In March 1975, it was renamed the Aeronutronic-Ford Corporation. Then in December 1976, the company was redesignated Aeronutronic Division, Ford Aerospace and Communications Corporation, a name which remained in effect into 1982.[2] For the sake of convenience, the contractor is generally referred to as Aeronutronic throughout this volume.

(U) The company grew rapidly in its early years. The number of company employees climbed from 125 in 1956 to 2,000 in mid-1960, while the volume of R&D sales increased from $167,000 in 1956 to $16 million in 1959. Before beginning work on the SHILLELAGH in 1959, Aeronutronic's contracts were mainly with the US Air Force, although a few Navy contracts had been awarded.[3]

Development Contracts

(U) In January 1958, Aeronutronic and three other firms received feasibility study contracts for a direct-fire antitank missile. In a follow-on contract for an advanced feasibility study, awarded on 26 June 1958 and amounting to $453,724 (DA-04-495-ORD-1329), Aeronutronic competed with the Sperry Gyroscope Company for the SHILLELAGH missile development contract. Aeronutronic won this competition and, on 11 June 1959, received a $3,303,704 contract (DA-04-495-ORD-1599) for development through 31 December 1959. This contract marked the beginning of the formal SHILLELAGH development program. The period covered by Contract ORD-1599 was shortened to end 16 November 1959, following the Government's approval for the contractor to use the Cornell

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[2]Ltr, Mgr, Ofc of Aeronutronic Div, Ford Aerospace and Communications Corp, to CG, MICOM, 2 Feb 82, subj: History of Name Changes for Ford Aerospace and Communications.

[3]Aeronutronic Publication, "This is Aeronutronic," 1960, Aeronutronic Div, Defense Products Group, Ford Motor Co.

Aeronautical Laboratory wind tunnel in lieu of Government facilities.[4] Chart 2 shows the major supporting contractors and agencies as of December 1959.

(U) On 17 November 1959, ARGMA awarded Aeronutronic a second development contract for SHILLELAGH (DA-04-495-ORD-1835), which, through many modifications, continued the development effort until 1 September 1963. A third contract (DA-04-495-AMC-309(Z)), awarded on 1 September 1963, carried the development program to its completion.[5]

Original Design Concept

(U) The original Aeronutronic design concept for the SHILLELAGH guided missile subsystem provided for a direct-fire, line of sight antitank missile, tracked and guided through an infrared command link. The purpose of the infrared command unit was to direct the missile automatically to an operator-determined line of sight (LOS). An automatic system would provide the advantage of utilizing the full maneuver capability of the missile to arrive at the LOS and achieve minimum range as early as possible, and to command the missile to impact on the target, without a requirement for excessive operator training.* The missile would be fired from a closed breech, low-pressure gun, which could also accommodate conventional ammunition. According to estimates in August 1959, the missile, 6 inches in diameter and 42 inches in length, would weigh 45 pounds at launch. The following illustration depicts the original missile configuration.

(U) The guidance and control equipment for the system included components onboard the combat vehicle (optics, computer, infrared tracker, and infrared transmitter) and on the missile (receiver, infrared tracking source, accelerometers, shaping networks, and gas jet reaction control devices). On the vehicle was an integrated sight, which would allow a gunner to fire either the missile or the 152mm companion round through the same optical sighting system without additional controls. These optics consisted of an integrated assembly to which a modified T-50 periscope unit was mounted.

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*Previous experience with wire-guided (manually directed) missiles, such as the French ENTAC, had shown that lengthy and repeated operator training was necessary to maintain proficiency in target engagement. In addition, it was found that even a skilled operator was only 50 percent effective in manipulating the missile to reach the LOS quickly, a critical factor which determined the minimum range at which the target could be engaged.

[4](1) 3d Ind, CG, MICOM, to CG, AMC, 11 Jun 65, subj: Request for Contract Adjustments - Public Law 85-804, ASPR Section XVII - Aeronutronic, a Div of Ford Motor Co. (now Philco Corp., Aeronutronic Div) ACAB No. 1055. (2) Notes for General Shinkle [BG J. G. Shinkle, ARGMA Cdr], 16 Sep 59, by A. E. Dean [CPT Archibald E. Dean, Chf, Antitank Wpns Sec, Land Combat Br, R&D Div, ARGMA]. (3) Summary of Major Events and Problems of the Ordnance Corps, Jul 59-Jun 60, prep by Hist Br, Exec Ofc, OCO, p. 71. (4) Also see above, pp. 13-16.

[5]Final Technical Report, SHILLELAGH Guided Missile System, Vol I of III, System Development History, Aeronutronic Publication No. S-3905, Aeronutronic Div of Philco-Ford, a subsidiary of Ford Motor Co, 24 Feb 67, p. 2.

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CHART 2

SHILLELAGH

GUIDED MISSILE SUBSYSTEM
PARTICIPATING DEVELOPMENT AGENCIES
CONTRACTORS

PRIME SUBSYSTEM CONTRACTOR	AERONUTRONIC, DIV. OF FORD MOTOR CO.
FIRE CONTROL SUBCONTRACTOR	RAYTHEON, SANTA BARBARA LAB.
T95 INSTALLATION DESIGN SUBCONTRACTOR	SPECIAL MILITARY VEHICLES OFFICE FORD

SUPPORTING AGENCIES

AREA OF SUPPORT	AGENCY
WARHEAD & FUSE DEVELOPMENT	PICATINNY ARSENAL
MOTOR PROPELLANT & IGNITER DEVELOPMENT	PICATINNY ARSENAL
GAS GENERATOR PROPELLANT & IGNITER DEVELOPMENT*	PICATINNY ARSENAL
MISSILE CONTAINER DEVELOPMENT*	WATERVLIET ARSENAL
THERMAL BATTERY DEVELOPMENT*	SIGNAL CORPS
DEVELOPMENT FLIGHT TEST SUPPORT	WHITE SANDS MISSILE RANGE
SUBSYSTEM ENGINEER TEST	WHITE SANDS MISSILE RANGE

*PROGRAMS IN PLANNING STAGE

As of December 1959

SOURCE: Min of 2nd OTAC SHILLELAGH Wpn Sys Com Mtg, 17-18 Dec 59, atchd to Ltr, Cdr, OTAC, to CG, ARGMA, 20 Jan 60, subj: Transmittal of Minutes. RHA Box 12-721.

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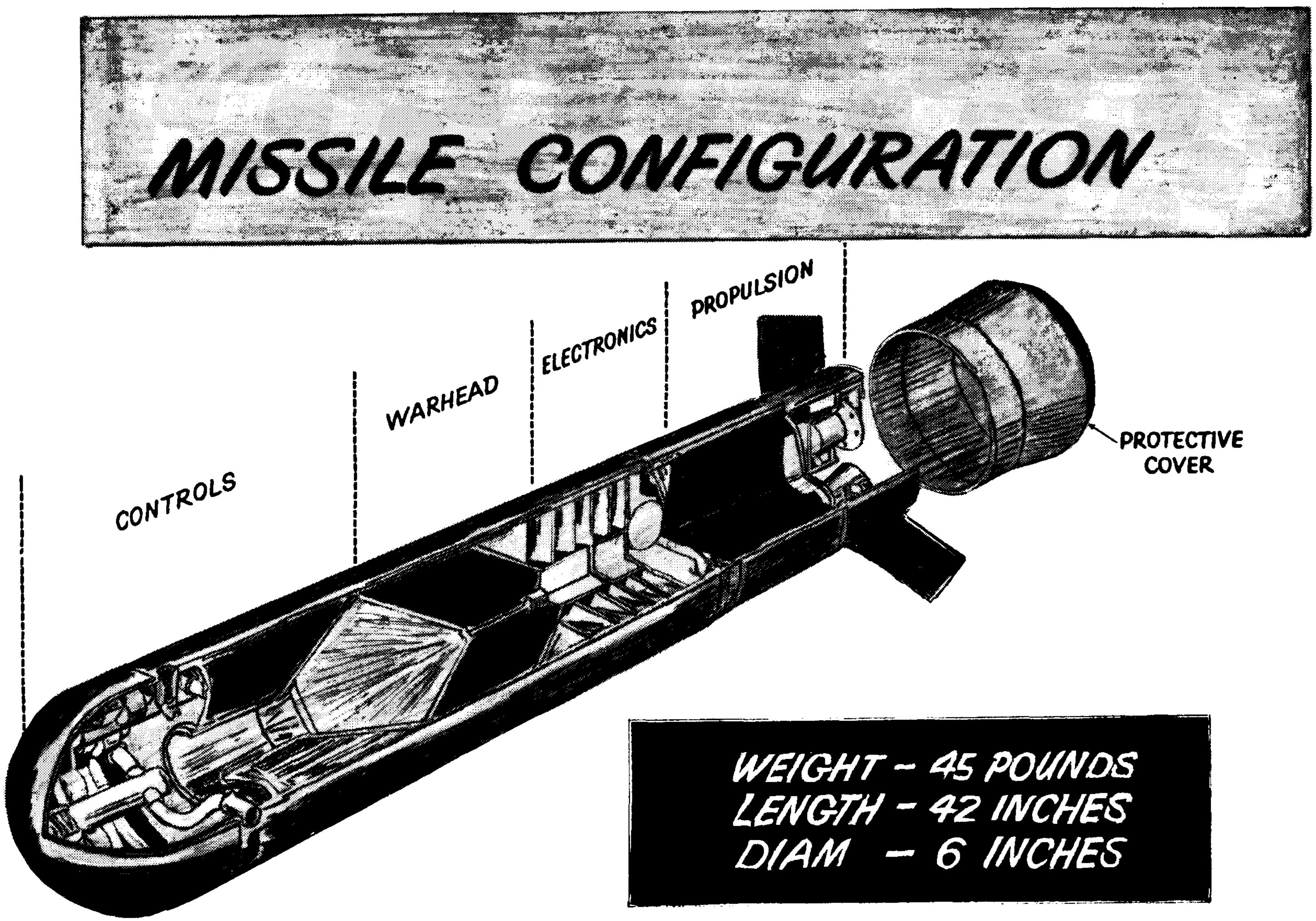

SOURCE: SHILLELAGH Guided Missile Subsystem Plan, ARGMA MSP-7, 31 Aug 59, ARGMA/AOMC, p. D-31

As of 31 August 1959

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(U) Under this concept (illustrated on p. 42) the gunner would establish the LOS by continuously tracking the target through the optics. The guidance equipment on the tank would track the infrared tracking source in the aft end of the missile, and automatically measure the missile's angular error from the LOS, compute lateral displacement of the missile from the LOS, establish a roll attitude reference, and transmit command information to the missile by means of a pulse-duration modulated infrared beam, discriminated by frequency in the audio band. The missile receiver would accept the composite signal and separate it to provide roll, yaw, and pitch signals to the missile control circuitry. The flight control system would regulate the control nozzles, which controlled the pitch, yaw, and roll of the missile through their thrust reactions. The solid propellant gas generator would provide a common continuous supply of hot gas, controlled by four solenoid valves. The pitch and yaw controls would each use a separate valve, whereas roll control would have two parallel valves. To achieve quasi-linear operations with a simple hot gas valve configuration, the control signals would be pulse-duration modulated at 20 cycles per second.

(U) The SHILLELAGH missile subsystem design was to be compatible with installation on existing standard and future development combat vehicles. Initially, Aeronutronic was directed to develop a completely tested engineering model system using the T95 tank as a test bed, because it was representative of all turrets to which the system would be adapted.[6]

Problems in the Early Years (1959-1961)

(U) The problems encountered in the first 2 years of SHILLELAGH missile development were many and varied and not easily solved because of a lack of supporting basic research for Aeronutronic engineers to draw upon. Consequently, unanticipated increases in cost and manhours, not commensurate with technical progress, had to be borne while attempting to "advance the state of the art."

(U) Development was particularly slow in the practical application of the infrared command link to the missile system. Engineers at Redstone Arsenal had begun research on the concept of infrared automatic command guidance for antitank missiles in connection with the Airborne Assault Weapon System (Project WHIP) studies in 1956 and 1957, and continued the investigation in in the abortive DART missile program. The concept had not been proven, however, at the time the SHILLELAGH program was approved in 1959. As viewed at that time, the infrared command link appeared to provide the least vulnerability to countermeasures and offered the opportunity to adequately address the major question: "Can infrared commands be used to guide a missile?" Aeronutronic, the prime contractor, expressed confidence that the concept was feasible,*

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*See above, pp. 14-15.

[6](1) SHILLELAGH Guided Missile Sub-System Plan, ARGMA MSP-7, 31 Aug 59, ARGMA/AOMC, pp. B-3, D-2, D-3, D-5, D-20, D-31, D-34. (2) SHILLELAGH Presentation to DDRE Representatives, 20 Jul 61, by MAJ John D. Hamilton, SHILLELAGH Br, R&D Ops, ARGMA/AOMC. (3) The Role of ARGMA In-House Laboratories in Army Programs (DOD Study Project No. 97), 9 Aug 61, ARGMA/AOMC, p. II-17.

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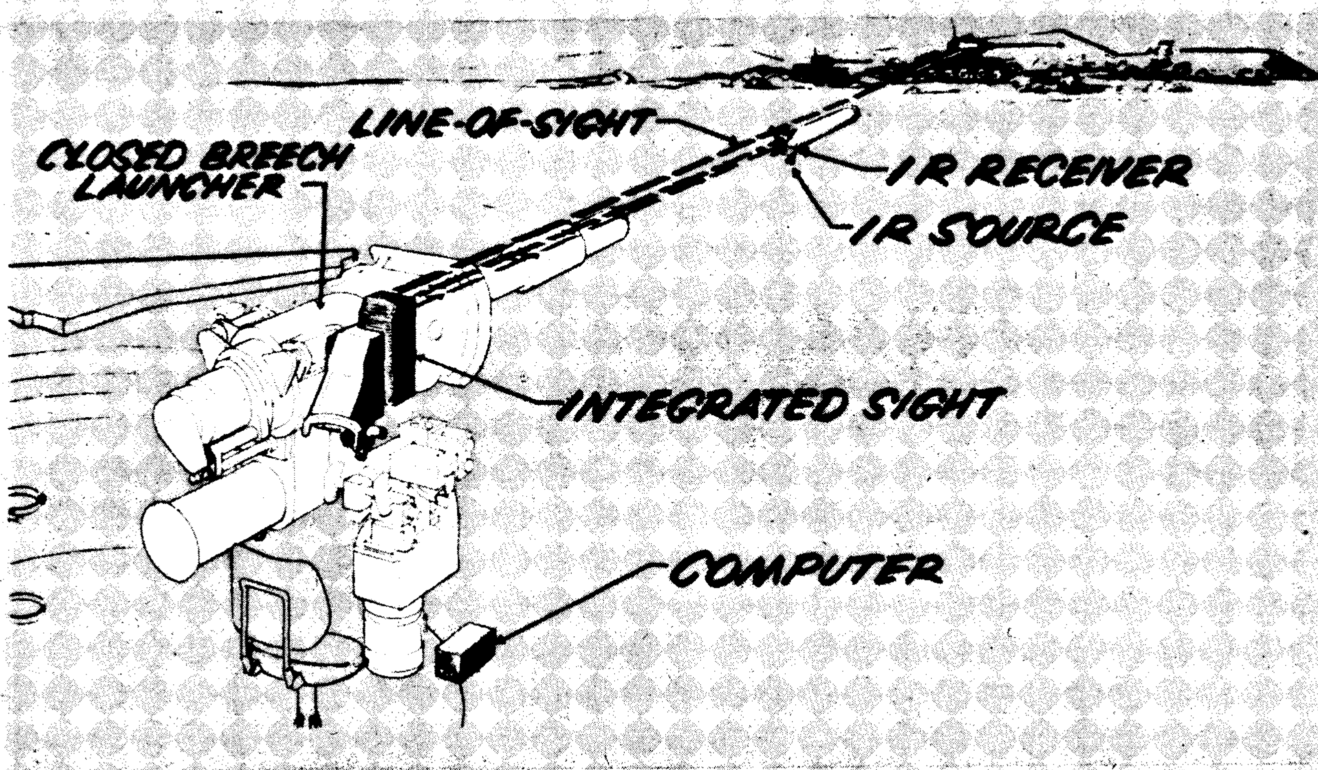
SHILLELAGH TACTICAL EMPLOYMENT

ARGMA



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and based its timetable and cost estimates on an optimistic forecast with few major problems. From the vantage point of hindsight, it became clearly evident by 1961 that more basic research in the infrared field should have preceded the accelerated development program for SHILLELAGH.

(U) The problems were not limited to the command link. Other concept degradations involved the change to the aft jet configuration (after discovering that nose jet control produced unexpected aerodynamic effects on fin stabilization), development of acceptable propellants and igniters, increase in missile weight and length, and the addition of more sophisticated components. Intertwined with these difficulties was the traditional problem of resource limitation. As in all development programs, the Army faced the tradeoff of time and funds pitted against attaining the required military characteristics for the system.[7]

Basic Problems in Guidance System

(U) On 30 April 1959, several months before Aeronutronic received the SHILLELAGH contract, the ARGMA R&D Division had requested the Missile Electronics Laboratory in the Ordnance Missile Laboratories (OML) Division to investigate the air turbulence modulation of solar radiation as a source of potential trouble in the missile's development. The detailed study of the entire guidance scheme necessitated by that request revealed some serious shortcomings in the missile tracking and command channels.

(U) As a result of those discoveries, the ARGMA Commander established an ad hoc committee on 21 July 1959 to thoroughly review the SHILLELAGH guidance concept. The committee, chaired by Mr. William B. McKnight of the Missile Electronics Laboratory, had members from Frankford Arsenal, Diamond Ordnance Fuze Laboratories, Engineer Research and Development Laboratories, and ARGMA's R&D and OML Divisions. They met on 5 and 6 August 1959 at Redstone Arsenal. On the second day, personnel from Aeronutronic and the Raytheon Company, the guidance system subcontractor, met with the committee to update information and answer questions.

(U) During the first committee session, representatives from the Infrared Branch (IB) of the Missile Electronics Laboratory presented calculations indicating predetection signal-to-noise ratios for both the tracker and data link at a range of 2,000 meters. The IB's computed ratios, approximately 5 to 1 in each component, differed substantially from Aeronutronic's figures, because the contractor failed to take key attenuation factors into account. The ARGMA engineers maintained that the most serious problem in the guidance system appeared to be the roll control technique employed. To achieve roll control within the required limits, a large increase in the signal-to-noise ratios then obtainable in the pitch and yaw channels would be necessary.

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[7] (1) Ibid., p. II-66. (2) Working Papers, SHILLELAGH Presentation to DDRE Representatives, 20 Jul 61, by MAJ John D. Hamilton, Chf, SHILLELAGH Br, R&D Ops, ARGMA/AOMC.

(U) The committee also discussed other factors which would tend to degrade the system's performance under field conditions, including accumulation of propellant discharges, as well as terrain debris, along the line of sight; and noise problems created by turbulent airflow between an infrared receiver and the sun or background. The latter problem had led the United Kingdom to terminate development of an infrared command link for their ORANGE WILLIAM surface-to-surface missile in favor of a high frequency microwave command link. ARGMA engineers determined that the difficulties experienced on ORANGE WILLIAM, however, were not necessarily applicable to the SHILLELAGH, except for the finding that the missile command receiver would be inoperable with the sun in the field of view. In the second day of the meetings, unanimous agreement was reached by all participating parties, including the contractor, that the signal-to-noise calculations presented by the committee were essentially correct, and that the calculations showed the SHILLELAGH guidance system to be a significant problem area.

(U) At the meeting's termination, the committee reached the following conclusions: (1) With components as then described, the signal-to-noise ratio was inadequate for operation at useful (1,000-2,000-meter) ranges even under near-ideal conditions; and (2) the roll control concept was not feasible within the framework of the planned guidance system. Based on these conclusions, the committee recommended immediate suspension of SHILLELAGH system development, except for work directed specifically at solving the guidance problems.[8]

Revised Guidance System - October 1959 Review

(U) On 27 August 1959, following the ad hoc committee meeting, Aeronutronic provided ARGMA with a list of possible improvements to upgrade the performance of the infrared link. To eliminate the roll control problem, the contractor proposed substituting a gyro reference system for the polarizers used in the original design. Because of this change in the original design, ARGMA requested Aeronutronic to submit a complete analysis of the guidance and control system, incorporating those changes necessary to meet basic performance requirements.

(U) To evaluate the contractor's revised guidance system, ARGMA established another ad hoc committee, consisting of the members of the 5-6 August committee, plus engineers with backgrounds in system analysis and inertial components. The committee, chaired by Dr. Lawrence H. O'Neill of Columbia University and the Rand Corporation, met at ARGMA on 8-9 October 1959, but found no fundamental deficiencies or obviously unworkable features in the revised plan. There was a general consensus, however, that the contractor did not provide adequate safety margins in certain respects, e.g., the predicted signal-to-

[8](1) The Role of ARGMA In-House Laboratories in Army Programs (DOD Study Project No. 97), 9 Aug 61, ARGMA/AOMC, p. II-16. (2) Ltr, William B. McKnight, Chairman, Committee for Investigation of SHILLELAGH Guidance Concept, to Chf, R&D Div, ARGMA, 21 Aug 59, subj: Recommendation on SHILLELAGH Development Program, w incl. (3) Paper, Notes for Gen Shinkle, by A. E. Dean, 16 Sep 59, re SHILLELAGH development program.

noise ratios planned for the guidance system did not allow for the uncertainties inherent in parametric estimates based on current knowledge. The committee stressed that adequacy of system components and circuits needed to be verified in experiments before a final design was approved. They also considered the projected development schedule (See Chart 3) to be overly optimistic, and forecasted appreciable time slippages. One major conclusion was that Aeronutronic was not furnishing sufficiently vigorous technical management to the SHILLELAGH program. The committee established February 1960 as the date for reviewing the detailed design criteria for the fire control plan and the progress in that area.[9]

Change to Aft Jet Configuration

(U) Meanwhile, wind tunnel tests conducted by Aeronutronic at the Cornell Aeronautical Laboratory between September and December 1959 demonstrated that the reaction jet controls performed more effectively when placed at the base of the missile (aft jet configuration) rather than just behind the missile nose (forward jet configuration) which was the original position. In fact, in analyzing the forward jet data, the contractor found that in certain jet patterns for roll command, the opposite roll effect resulted. The forward jet controls interfered with the aerodynamic body and fins, significantly reducing control effectiveness and missile stability. Those interferences were not discernable in the aft jet configuration data and stability was not appreciably affected. The contractor presented these results to ARGMA on 12 January 1960, and ARGMA approved the aft jet configuration.[10]

(U) The relocation of the gas generator and the valve system to the rear of the missile necessitated further extensive redesign of the missile. In the aft section, redesign involved integrating the hot gas control valve, ducting and nozzles, motor blast tubes and nozzles, and the infrared receiver and modulator into the shortest, most compact assembly. The fin actuation system was redesigned to be compatible with the rear location of the jet reaction control system. The specifications for the rocket motor, gas generator propellant, and igniters also required revision.

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[9](1) Ltr, Cdr, OTAC, to CG, ARGMA, 20 Jan 60, subj: Transmittal of Minutes, w incl: Minutes of 2d OTAC SHILLELAGH Weapon System Committee Meeting, 17-18 Dec 59. RHA Box 12-721. (2) Ltr, CG, ARGMA, to Mr. Gerald J. Lynch, Aeronutronic, a Div of Ford Motor Co., 16 Oct 59, re Ad Hoc Committee report on evaluation of revised fire control subsystem plan. (3) SHILLELAGH Monthly Progress Report, 30 Sep 59, ARGMA/AOMC, p. 12. (4) Ltr, Chief, SHILLELAGH Br, Tactical Sys Proj Ofc, R&D Ops, ARGMA, to Dr. Lawrence O'Neill, Rand Corp, 11 Aug 60, re SHILLELAGH Tech Rev No. 3.

[10](1) Ltr, Cdr, OTAC, to CG, ARGMA, 24 Jun 60, subj: Transmittal of Minutes, w incl: Minutes of 3rd OTAC SHILLELAGH Weapon System Committee Meeting, 12 and 13 April 1960, App II, ARGMA Status Report on Missile Sub-System. RHA Box 12-721. (2) ARGMA Working Paper, Review of SHILLELAGH Project, Bfg to AOMC, 8 Apr 60. (3) Final Tech Rept, SHILLELAGH Guided Missile System, Vol I of III, Sys Dev Hist, Aeronutronic Publication No. S-3905, 24 Feb 67, Aeronutronic Div of Philco-Ford Corp.

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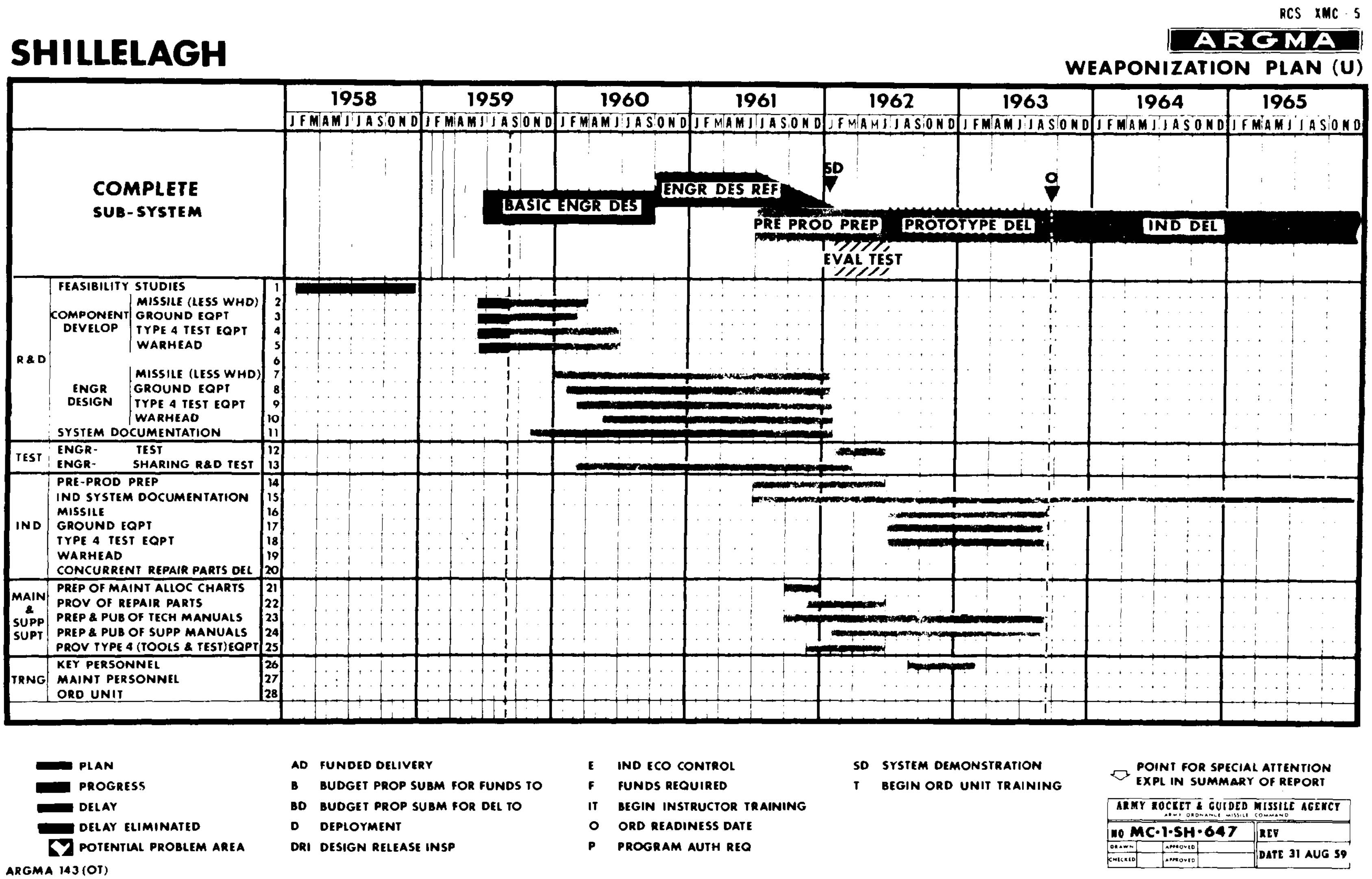
CHART 3



SOURCE: SHILLELAGH Guided Missile Sub-System Plan, ARGMA MSP-7, 31 Aug 59, ARGMA/AOMC.

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(U) The configuration change would allow revision of the gas generator mode of operation. With the control jets at the aft end of the missile, the gas generator could be operated within the barrel since the jets could exhaust into the breech of the gun tube. This would make the full control force available at the instant the missile emerged from the barrel. With the forward control jet configuration, operation within the barrel was not possible because adequate venting of the exhaust products was not available. The arrangement with the gas generator ahead of the rocket motor was adopted in March 1960.

(U) Closed breech launch studies of the effect of gas generator operation within the barrel indicated that the launch performance could be improved significantly by igniting the gas generator before the rocket motor was ignited, rather than firing the rocket motor first as in the original concept. In the new mode of operation, the gas generator (ignited first) produced breech pressures high enough to release the missile from the protective cap. The rocket motor was then ignited. Analytical studies indicated that this mode of operation allowed for a sizeable increase in the tolerance on rocket motor thrust buildup time, thereby easing the rocket motor development effort.[11]

(U) The movement of the gas generator to the rear of the missile caused a forward shift of the other integral components which, in turn, reduced the warhead standoff range from 2.5 calibers to .8 calibers. The Government then began studies of insertable and structural type warheads and various ogival shaped nose configurations and extensible probe designs. Picatinny Arsenal had responsibility for developing the warhead section to a design criteria furnished by Aeronutronic. In March 1960, a 5.8-inch diameter structural warhead was adopted in place of the previous 5.45-inch diameter insertable warhead. A study completed by the Ballistic Research Laboratories (BRL) in early April 1960 revealed that the shorter standoff warhead was slightly less effective than the long standoff model, but the difference was not enough to warrant continuing the nose probe and internal rearrangement studies aimed at obtaining longer standoff. A subsequent BRL evaluation confirmed that the 5.8-inch diameter structural warhead could defeat the prescribed tripartite target.[12]

(U) In May 1960, the contractor decided to use gyros in the autopilot to sense both yaw/roll and pitch. Previously, a pitch accelerometer had been used. Simulation studies conducted after the change to the rear control jets showed that a pitch gyro would perform better under the predicted extremes of system disturbances than would the pitch accelerometer.[13]

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[11](1) SHILLELAGH Guided Missile Subsystem, Interim Tech Rept No. 3, Jan-Mar 60, Aeronutronic, A Div of Ford Motor Co, 30 Apr 60, pp. 28-29, 67-68. (2) SHILLELAGH Monthly Progress Report, 28 Feb 60, ARGMA/AOMC, pp. 6-7. (3) SHILLELAGH Monthly Progress Report, 31 Mar 60, ARGMA/AOMC, p. 3.

[12](1) Ltr, Cdr, OTAC, to CG, ARGMA, 24 Jun 60, subj: Transmittal of Minutes, w incl: Minutes of 3rd OTAC SHILLELAGH Weapon System Committee Meeting 12 and 13 April 1960, App II - ARGMA Status Report on Missile Subsystem. RHA Box 12-721. (2) SHILLELAGH Monthly Progress Report, 28 Feb 60, ARGMA/AOMC, pp. 6-7.

[13]SHILLELAGH Tech Rev No. 3, Appendix Doc 22 to ARGMA Hist Sum, 1 Jul - 31 Dec 60.

(U) The additional design effort required because of the change to the aft jet configuration caused delays in the program schedule. The dynamic plume tests, critical in the evaluation of the signal-to-noise ratio and scheduled for April 1960, were set back to June and July 1960. The contractor, however, continued to project the date of June 1961 for the first fully guided flight. This program had been based on FY 1961 RDTE funding of $13.7 million, but OTAC had subsequently revised the FY 1961 RDTE funding guidance to $9.1 million, necessitating a 4- or 5-month slippage in the initiation of fully guided firings. The OTAC was not overly concerned about this slippage because schedules in March 1960 indicated that development of the missile was about a year ahead of the remaining systems.[14]

February 1960 Review

(U) In early February 1960, the ad hoc committee, chaired by Dr. Lawrence O'Neill, met again at the Aeronutronic plant to review the contractor's progress, particularly in the guidance and control area. The committee reported that the contractor had made satisfactory progress since October 1959 and the program was on schedule. Aeronutronic had also shown improvement in its technical management of the program by establishing necessary management controls to assure that problem areas would receive adequate and timely attention. However, the feasibility of system operations as described by the contractor remained to be demonstrated under dynamic conditions.

(U) One of the primary concerns in the system design was the effect of the rocket exhaust plume on infrared transmissions. Static plume tests and scanning tests already performed had indicated that critical external noise problems existed in the command link. The ad hoc committee commented that the degenerative effects of external, as well as internal, noises on the signal-to-noise ratio needed to be determined as soon as possible. Any problems interfering with the command link would require resolution to prevent the signal-to-noise ratio from dropping below 5 to 1. The committee stressed that in view of the test results and normal design factors, little, if any, degradation from external noise sources could be tolerated in the command link at maximum ranges. Therefore, the contractor was urged to continue work on an accelerated basis to determine system deterioration caused by the plume, wake, scanning noises, and sun on the signal-to-noise ratio available at the command receiver, and to determine as soon as possible the degenerative effects of internal noise on the command link.[15]

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[14] (1) ARGMA Working Paper, Rev of SHILLELAGH Proj, Bfg to AOMC, 8 Apr 60. (2) DF, Chf, Control Ofc, AOMC, to Distr, 15 Apr 60, subj: Minutes of the SHILLELAGH Project Review.

[15] (1) DF, Chf, Control Ofc, AOMC, to Distr, 15 Apr 60, subj: Minutes of the SHILLELAGH Project Review. (2) Ltr, Cdr, OTAC, to CG, ARGMA, 24 Jun 60, subj: Transmittal of Minutes, w incl: Minutes of 3rd OTAC SHILLELAGH Weapon System Committee Meeting 12 and 13 April 1960, App VII, ARGMA Discussion on February Review. RHA Box 12-721.

Problems with Propellants and Igniters

(U) In August 1959, after reviewing proposals obtained by Aeronutronic for motor propellant development, ARGMA selected Picatinny Arsenal as the motor propellant developer. The ARGMA based this selection on five factors: the physical properties of the propellant, environmental requirements, development and production costs, availability of production facilities, and experience in double base propellants. Although overall technical supervision of the program was exercised by ARGMA, Picatinny Arsenal and Aeronutronic maintained direct technical liaison.

(U) Picatinny Arsenal was responsible for providing a propellant grain and igniter which met the ballistic requirements for the missile within the existing dimensional limitations, and most importantly, was compatible with the missile guidance system. The guidance concept required that the exhaust plume of the rocket motor not interfere excessively with the transmission of infrared signals through this plume. This specification posed a severe limitation on the propellant composition. After a thorough analysis of the available types of solid propellant, Picatinny selected a double base type which was essentially smokeless at relatively low flame temperatures.[16]

(U) The change to the aft jet configuration in January 1960 caused revisions in the specifications for the rocket motor, gas generator propellant, and igniters.[17] Studies concluded in March 1960 resulted in placement of the gas generator ahead of the rocket motor. This arrangement provided the most efficient assembly of parts and a grain case favoring minimum heat transfer.[18]

(U) In June 1960, while preparing for the dynamic plume tests, Aeronutronic discovered problems with the gas generator grain and the ignition systems for both the rocket motor and the gas generator. The grain, supplied by Picatinny Arsenal, left deposits of an unknown substance on the gas generator valves, which tended to degrade their performance. In order to proceed with the dynamic plume tests, Aeronutronic used an available commercial propellant, while Picatinny continued development of a suitable gas generator propellant. The problems with the ignition systems involved an excessive delay in ignition and erratic burning of the propellant grains. The contractor used a proprietary conductive film ignition system in the dynamic plume tests, while Picatinny continued developing an acceptable ignition system.[19]

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[16] (1) Ltr, Cdr, OTAC, to CG, ARGMA, 20 Jan 60, subj: Transmittal of Minutes, w incl Minutes of 2nd OTAC SHILLELAGH Weapon System Committee Meeting, 17 & 18 Dec 59. RHA Box 12-721. (2) SHILLELAGH Phasing Meeting #2 Minutes, 17-18 Nov 59. Presentation of Rocket Motor Propellant Charge and Igniter for the SHILLELAGH Missile System. RHA Box 12-721. (3) Hist of ARGMA, 1 Jan - 31 Dec 59, pp. 155-156.

[17] SHILLELAGH Monthly Progress Report, 28 Feb 60, ARGMA/AOMC, pp. 6-7.

[18] SHILLELAGH Monthly Progress Report, 31 Mar 60, ARGMA/AOMC, p. 5.

[19] SHILLELAGH Monthly Progress Report, 30 Jun 60, ARGMA/AOMC, pp. 3-4.

August 1960 Review

(U) The ARGMA ad hoc committee, meeting again in late August 1960, found the overall performance of the contractor since October 1959 to be generally satisfactory. The committee observed that Aeronutronic had acquired a competent technical staff and had demonstrated significantly improved performance on the guidance subsystem. Analytical, laboratory, and static field tests were judged as satisfactory, as were the theoretical design and the command and missile-borne lamp development. The committee again urged the contractor to prove the actual feasibility of the system, subsystem, and component performance. The lack of definitive tests, which would provide data unobtainable from other sources, was aggravated by the problems with the motor and gas generator grain. Since the interaction between the guidance system and the propellant was so complete, positive determination of guidance feasibility would have to await the establishment of parameters for the propellant and ignition system. The committee saw the propulsion system problems as resulting, in part, from the division of responsibility between Aeronutronic and Picatinny Arsenal.

(U) The committee felt that one of the rationales for their review was to substantiate the belief of other responsible Government officials that Aeronutronic was not conducting the SHILLELAGH program in a way which provided assurance that it would succeed. This conviction, through its effects on the contractor and ARGMA, had impaired fruitful cooperation in mutual confidence. The committee perceived a fundamental difference of understanding of the contractual provisions defining the essential nature of the Aeronutronic effort. The ARGMA believed that the contractor was obligated to demonstrate subsystem feasibility through basic measurements before expending substantial effort and funds to evolve a near-final design. Aeronutronic had preferred, and was contractually authorized, to pursue early subsystem availability by coincident efforts to evolve a near-final, producible design while concurrently conducting basic research and tests. The committee found little basis for dissatisfaction with the contractor's efforts within the framework of the contract work statement, although their approach had delayed obtaining basic feasibility data. This telescoping of the program also involved higher technical, financial, and system availability risks than might have otherwise occurred. The committee made five recommendations as follows:

- The SHILLELAGH program should be continued and adequately supported.

- Any extension of the present contract should allow the Government to redirect the program, as necessary, following critical tests.

- Aeronutronic should be assigned contractually the complete responsibility for propulsion and gas generator units, including the authority to subcontract, and should acquire additional staff for that work.

- The Government should increase its support for development of critical elements of the program, and should provide a small amount of supplementary funds for backup efforts on such devices as propulsion and gas generator units, photo detectors, and elements of the autopilot.

•Aeronutronic should be urged to promptly obtain test results which would permit judgment of the SHILLELAGH's feasibility as then conceived.[20]

Changes in Propulsion Development Program

(U) Following the August 1960 technical review, the ARGMA Commander, COL John G. Zierdt, directed Aeronutronic and Picatinny Arsenal to take action to correct the propulsion system problems. He pointed out that the provision of propellant grains by the Government did not relieve Aeronutronic from ultimate system responsibility, and requested Picatinny Arsenal to appoint experienced personnel to investigate the motor and gas generator development problems, strengthen management participation in the SHILLELAGH program at Picatinny, and to support an Aeronutronic resident engineer at Picatinny.[21]

(U) At about the same time, ARGMA received a letter from Aeronutronic expressing concern about the ability of Picatinny Arsenal to develop suitable rocket motor and gas generator grains and igniters. The contractor recommended that the work at Picatinny be phased out of the missile subsystem development program, and that Aeronutronic be authorized to subcontract with propellant suppliers to furnish the most appropriate propellant and igniters for the system. The ARGMA reviewed the progress of the motor and gas generator development and found that Aeronutronic's references to unsatisfactory performance by Picatinny could not be attributed to a lack of capability. In fact, with the exception of occasional slippage because of fluctuating requirements, Picatinny had responded as effectively as conditions permitted. According to ARGMA, the problem centered around the technical organization of the SHILLELAGH development program. Consequently, Colonel Zierdt assigned technical supervision of development in this critical area to the ARGMA Propulsion Laboratory.[22]

(U) In response to Colonel Zierdt's request, the Commanding General of OSWAC assigned four additional experienced professional personnel to the program and accorded it increased priority.[23] Aeronutronic augmented their propulsion staff with four experienced engineers, assigned a resident engineer

[20] SHILLELAGH Tech Rev No. 3 Committee Rept. App Doc 22 to ARGMA Hist Sum, 1 Jul - 31 Dec 60.

[21] (1) Ltr, Cdr, ARGMA, to Mr. Gerald J. Lynch, VP & Gen Mgr, Aeronutronic, A Div of Ford Motor Co, 9 Sep 60. App Doc 24 to ARGMA Hist Sum, 1 Jul - 31 Dec 60. (2) Ltr, Cdr, ARGMA, to CG, OSWAC, 9 Sep 60. App Doc 25 to ARGMA Hist Sum, 1 Jul - 31 Dec 60.

[22] (1) Ltr, Roy P. Jackson, Gen Ops Mgr, Aeronutronic, A Div of Ford Motor Co, to Cdr, ARGMA, 7 Sep 60. App Doc 23 to ARGMA Hist Sum, 1 Jul - 31 Dec 60. (2) Ltr, Cdr, ARGMA, to Mr. Gerald J. Lynch, VP & Gen Mgr, Aeronutronic, A Div of Ford Motor Co, 16 Nov 60. App Doc 28 to ARGMA Hist Sum, 1 Jul - 31 Dec 60.

[23] Ltr, CG, OSWAC, to CO, ARGMA, 23 Sep 60. App Doc 26 to ARGMA Hist Sum, 1 Jul - 31 Dec 60.

at Picatinny, and made increasing use of recognized in-house and external consultants.[24]

(U) On 1 December 1960, engineers from ARGMA and Picatinny Arsenal met with contractor personnel at the Aeronutronic facility and agreed that major changes were required in the grain suspension design and ignition location for the engineering model design. In order to fulfill the Aeronutronic motor and gas generator requirements, they decided that a free-standing grain would be used in both the rocket motor and gas generator, instead of the current head-end suspension, and that head-end ignition would be used in lieu of aft-end ignition. They also selected MDB-7 propellant to replace the LFT-1 propellant as the gas generator grain.[25] In July 1961, the simultaneous launch mode was authorized for the SHILLELAGH, with the proviso that the capability to launch in the sequential mode be retained until igniters suitable for use in the simultaneous mode were developed.[26]

Tracker Problem

(U) Another serious problem which took longer than expected to resolve concerned a shimmer problem in the tracker. Shimmer, the effect of thermal waves on optical resolution, was recognized as a problem area after static tests of the fire control subsystem in mid-1960 revealed that shimmer noise in the amplitude modulated tracker exceeded the allowable level. Since basic work in shimmer resolution was inadequate, Aeronutronic and Raytheon worked toward a solution for over a year, slowly making improvements. However, the overall performance of the tracker remained marginal. Aeronutronic, using company funds, then began developing a back-up shimmer rejection system—the pulse duration modulation system, based on a time-measuring principle rather than the amplitude-measuring concept used in the original tracker. Preliminary experiments with breadboard equipment yielded excellent results. As a result, the contractor and ARGMA decided in July 1961 to adopt the pulse duration modulated tracker, which necessitated redesigning two-thirds of the cards in the electronic assembly. The contractor planned to use experimental models of the new tracker in the guided flight tests.[27]

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[24] Ltr, Gen Ops Mgr, Tactical Weapon Sys Ops, Aeronutronic, A Div of Ford Motor Co, to Cdr, ARGMA, 19 Oct 60.

[25] (1) SHILLELAGH Monthly Progress Report, 31 Dec 60, ARGMA/AOMC, p. 3. (2) Ltr, Dep Dir, Research & Engineering Drte, USAOTAC, to Cdr, ARGMA, 14 Apr 61, subj: Transmittal of Minutes, w incl: Minutes of 5th OTAC SHILLELAGH Weapon Sub-System Committee Meeting, 15-16 Feb 61.

[26] SHILLELAGH Monthly Progress Report, 31 Jul 61, ARGMA/AOMC, p. 5.

[27] (1) SHILLELAGH Monthly Progress Report, 31 Aug 60, ARGMA/AOMC, p. 1a. (2) Ltr, Dep Dir, Research & Engineering Drte, OTAC, to Cdr, ARGMA, 14 Apr 61, subj: Transmittal of Minutes, w incl: Minutes of 5th OTAC SHILLELAGH Weapon Sub-System Committee Meeting, 15-16 Feb 61. (3) SHILLELAGH Presentation to DDRE Representatives, 20 Jul 61, by MAJ John D. Hamilton, SHILLELAGH Br, R&D Ops, ARGMA/AOMC.

Transmitter Problem

(U) In testing, the tungsten lamps used in the transmitter were found to have only one-fourth of the power required. To obtain adequate power, the contractor replaced them with xenon arc lamps, which had nearly 10 times the power obtainable from tungsten. This change introduced another problem: the xenon arc transmitter in its existing state of technology was deemed unacceptable (too large) for use on a combat vehicle. The contractor then had to develop a transmitter small enough, yet powerful enough, to fulfill system requirements.[28]

(U) The change from the tungsten to the xenon arc source also necessitated redesign of the power supply and modulator. Additional voltages were needed in the power supply, and the modulator output power was increased because the modulation technique was electronic rather than mechanical as in the previous design. In addition to the circuit design, a complete repackaging was required to dissipate the additional heat generated in the power supply by the electronic modulator.[29]

Sight Program Changed

(U) On 9 May 1960, OTAC directed that the integrated sight be replaced by a sighting system with separated transmitters. This action led to the design of a periscopic sight which would incorporate a unity power surveillance function, 8-power scope, and infrared mechanical "zoom" tracker. This design was referred to as the SHILLELAGH periscopic sight to differentiate it from the SHILLELAGH articulated sight being developed by Frankford Arsenal. The periscopic sight would be a back-up for the articulated sight development, in case unforeseen difficulties were experienced with the latter design.[30]

Problems with Missile Weight and Size

(U) As the SHILLELAGH missile moved from a concept to a developmental design, changes in its weight and length ensued. In January 1959, Aeronutronic estimated that the missile would weigh 39 pounds at launch, and be 6 inches in diameter and 39 inches in length. By August 1959, those specifications had grown to a weight of 46.5 pounds at loading and 45 pounds at launch and a length of 42 inches; the diameter remained 6 inches. At a meeting in March 1960, the contractor presented, and OTAC accepted, a missile length of 42 inches and weight of 48.5 pounds. The next month, Aeronutronic released an interim

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[28](1) SHILLELAGH Monthly Progress Report, 31 Jan 60, ARGMA/AOMC, p. 3. (2) SHILLELAGH Presentation to DDRE Representatives, 20 Jul 61, by MAJ John D. Hamilton, SHILLELAGH Br, R&D Ops, ARGMA/AOMC. (3) Ltr, Dep Dir, Research & Engineering Drte, OTAC, to Cdr, ARGMA, 14 Apr 61, subj: Transmittal of Minutes, w incl: Minutes of 5th OTAC SHILLELAGH Weapon Sub-System Committee Meeting, 15-16 Feb 61.

[29]SHILLELAGH Monthly Progress Report, 31 Jan 61, ARGMA/AOMC, pp. 3-4.

[30]DF, Chf, Control Ofc, to Distr, 4 Oct 60, subj: Minutes of the SHILLELAGH Project Review.

technical report which indicated an increase in length to 45.5 inches and in weight to 54.8 pounds. Most of the increases occurred in the gas generator and rocket motor section as the contractor attempted to solve design problems. The ARGMA felt that retaining the length of 42 inches and weight of 48.5 pounds as accepted by OTAC in March 1960 could produce undesirable tradeoffs at this time. At this stage of development, optimization of the components was not possible, but was expected as the final engineering design was approached. In the meantime, ARGMA placed a design limitation of 42 inches in length and 50 pounds in weight on the contractor.

(U) In June 1960, the Assistant Chief of Ordnance, BG C. W. Clark, expressed concern about the increases in length and weight of the SHILLELAGH and the fact that these changes could adversely affect the fightability of the SHILLELAGH as part of the AR/AAV weapon system, since the fighting compartment of the vehicle was based on a missile approximately 42 inches long. General Clark also questioned the degree of technical supervision of the contractor applied to these critical characteristics. The ARGMA then requested the Human Engineering Laboratory (HEL) to study the effect of the new dimensions on the fightability of SHILLELAGH in the selected AR/AAV. The HEL study showed that the increased size and weight required a longer loading time, which was, however, still under the required limit of 10 seconds. They found that length was more critical than weight in loading time and established a limit of 46 inches as the maximum that could be handled in the AR/AAV turret. The ARGMA agreed to get concurrence from OTAC on any changes over 42 inches in length and 50 pounds in weight, as an interim limitation, pending the establishment by OTAC of major missile parameters for the recently-selected AR/AAV concept.[31]

(U) Length and weight continued to be a problem. In October 1960, ARGMA reported that the contractor had reduced the missile's design gross loading weight to 54.5 pounds and the length to 41.5 inches through development modifications. By reconfiguring the rocket motor and gas generator case geometry, repackaging the electronics section, and repackaging the aft section of the missile around a unitized jet control valve, the contractor reduced the length of the missile within the limitation of 42 inches.[32]

Problems in Dynamic Plume Tests and Short Range Tests

(U) In the dynamic plume tests, the contractor planned to demonstrate the accomplishment of a major objective in the SHILLELAGH missile test program: use of the infrared command link under simulated flight conditions. The tests were to determine the effects of rocket motor and gas generator exhaust (or

[31](1) SHILLELAGH Guided Missile Sub-System Plan, ARGMA MSP-7, 31 Aug 59, ARGMA/AOMC, pp. D-2, D-3. (2) SHILLELAGH Presentation to DDRE Representatives, 20 Jul 61, by MAJ John D. Hamilton, SHILLELAGH Br, R&D Ops, ARGMA/AOMC. (3) Ltr, Asst Chf of Ordnance, to CG, OTAC, 13 Jun 60, subj: SHILLELAGH Missile, XM13. (4) DF, Asst CofS, R&D, AOMC, to Distr, 13 Jul 60, subj: SHILLELAGH Presentation for CG (Minutes).

[32](1) DF, Chf, Control Ofc, AOMC, to Distr, 4 Oct 60, subj: Minutes of the SHILLELAGH Project Review. (2) Working papers, entitled Briefing to General Schomburg, 20 Oct 60, on Status of SHILLELAGH Development.

plume) on the infrared command link and tracking unit. The method of test was to place the missile on an aerodynamically clean monorail sled, boost the sled to maximum velocity, and bring the booster to rest before the missile passed a simulated tank station. The missile's infrared source was tracked from the tank station and commands were transmitted to the missile's infrared receiver from the tank station.

(U) The dynamic plume test sleds and the motor and gas generator ignition systems were to have been furnished by the Government. However, the contractor provided them to preclude further delays in the tests, which had already been postponed from April 1960 to June and July because of the change in the aft jet configuration. Still, the tests could not begin until July 1960, because of technical problems with the gas generator propellant grain and the ignition systems of both the rocket motor and gas generator.

(U) Between 14 July and 23 November 1960, 21 plume tests were conducted, (11 static and 10 dynamic firings), of which 12 were considered successful. The data obtained from these tests were adequate to identify the noise input of the rocket motor and to provide some coefficient data. However, because of track vibration, particulate matter from the track (in the form of a low flying cloud), and a structural failure of the sled, no test runs were performed at maximum missile speeds. The data obtained at medium speeds were poor and Aeronutronic was unable to interpret most of it. Because of these inadequacies, the tests failed to demonstrate that the command link would operate under simulated flight conditions. The rocket motor did not appear to be a limiting factor; however, the effects of the gas generator plume and full missile velocity were not determined. Assessments indicated that possible problem areas existed in high noise levels immediately after rocket burnout and in the IR receiver, attributed to the close proximity of the ducting. In December 1960, ARGMA directed that the dynamic plume test program be suspended pending further evaluation of test results and study of the optimum technique for meeting test objectives.[33]

(U) The nine-round short range firing test program began on 1 November 1960 and was completed on 19 May 1961. The primary objective of these tests was to obtain missile environmental data during travel down the gun tube and during the first 15 to 25 feet of flight. The results of the first seven firings, completed in March 1961, indicated that the practicability of using a complete infrared command guidance link and a jet reaction control system could not be determined until fully guided firings were conducted. Significant problem areas requiring resolution before the August 1961 fully guided firings involved

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[33](1) Working Papers, Bfg to General Zierdt, ARGMA Cdr, 31 Mar 61, & to General Schomburg, AOMC CG, 28 Apr 61, by Mr. E. S. Brooks, ARGMA Control Ofc, subj: Status of SHILLELAGH. (2) ARGMA Hist Sum, 1 Jul - 31 Dec 60, pp. 131-34. (3) SHILLELAGH Monthly Progress Report, 30 Jun 60, ARGMA/AOMC, pp. 3-4. (4) Ltr, Dep Dir, Research and Engineering Drte, OTAC, to Cdr, ARGMA, 14 Apr 61, subj: Transmittal of Minutes, w incl: Minutes of 5th OTAC SHILLELAGH Weapon Sub-System Committee Meeting, 15-16 February 1961.

the hot gas operation of the jet reaction control valves, ignition of the rocket motor and gas generator, redesign of the missile receiver optics to enable them to withstand the launch environment, and improvement of the missile tracker performance, which had been marginal.[34]

Summary

By mid-1961, it was thus abundantly evident that Aeronutronic had underestimated both the complexity and magnitude of the SHILLELAGH development effort and that additional supporting research should have preceded the entry of the system into the development phase. As a result, the Government expended considerable funds in attempting to advance the state of the art, while at the same time supporting a large and growing Aeronutronic organization. The total Aeronutronic R&D program cost, accepted at $19.1 million in May 1957, had grown to $28.8 million in September 1959, to $31.9 million in May 1960, and to $46 million in February 1961. The contractor had received a total of $23.9 million for the SHILLELAGH development program as of 15 May 1961, and most of that had been spent on redesign effort to correct deficiencies in the original concept. Officials at ARGMA reasoned that the increased costs resulted partially from Aeronutronic's underestimation of the magnitude of the SHILLELAGH development effort and partially from the repetition of work, new approaches to problems, and increasing subcontract cost.

(U) As originally envisioned, the development approach was to involve a progression from an experimental model to an engineering model, with reliability established before the first guided flight. Instead, because of technical difficulties and frequent design changes, Aeronutronic was approaching the first guided flight test with what amounted to an experimental model which had undergone only flight assurance testing. During the first 2 years of development, testing had progressed through laboratory breadboards to static firings, dynamic sled tests, soft suspension firings, and vertical spin stabilized firings, all with the net result of basing design changes on fragmented information. Initial calculations and concepts had been proven wrong several times over, resulting in the complete redesign of major components, retest, and use of alternate components to achieve the desired results.

(U) Conceptually, the SHILLELAGH was to be a "wooden missile" comparable to tank ammunition, with 99 percent reliability. Because of the lack of reliability testing and the introduction of more sophisticated design features, such as gyros, the Government questioned whether or not reliability even approaching the conceptual goal would ever be achieved. Moreover, proof that the concept could become a militarily useful weapon would not be available until the first guided flight tests in August 1961.

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[34] (1) SHILLELAGH Monthly Progress Report, 31 Mar 61, ARGMA/AOMC, p. 1a. (2) Working Papers, Bfg to General Zierdt, ARGMA Cdr, 31 Mar 61 & to General Schomburg, AOMC CG, 28 Apr 61, by Mr. E. S. Brooks, ARGMA Control Ofc, subj: Status of SHILLELAGH. (3) SHILLELAGH Monthly Progress Report, 31 May 61, ARGMA/AOMC, p. 2.

(U) As of mid-1961, the program was thus approaching the point where a decision would have to be made either to pursue solutions to problems regardless of time or funds, or determine that neither time nor funds could achieve a successful SHILLELAGH subsystem. To provide the basis for such a decision, ARGMA, in May 1961, requested the Ballistic Research Laboratories to conduct an impartial evaluation of Aeronutronic's accomplishments toward a system of desired performance. The results of this evaluation, which was to include data derived from the initial guided flights and be completed by mid-December 1961, would have a significant bearing upon the future of the SHILLELAGH development program.[35] But, instead of this deliberate approach to deciding the future of the SHILLELAGH, plans were afoot in the Department of Defense to accelerate the program before conclusive demonstration of the design feasibility in the fully guided test firings. After a series of tedious, time-consuming planning exercises, the SHILLELAGH development program was accelerated, only to be reoriented to an applied research effort because of continuing technical difficulties. It is the program acceleration planning exercises in 1961 to which this study now turns.

SHILLELAGH Acceleration Plans

Influence of Political Changes

(U) John F. Kennedy's assumption of the presidency in January 1961 had a profound influence on national defense strategy and on the SHILLELAGH program. While he did not renounce the use of the nuclear arsenal, Kennedy placed renewed emphasis on developing nonnuclear weapons and conventional forces. The US and its allies would seek to keep the peace and promote freedom against the spread of communism by maintaining an impressive strategic deterrent, flexible enough to avoid total nuclear war if possible, but potent enough to convince any aggressor that he had no choice but peace. The US would maintain nuclear-free forces to deter or quickly extinguish limited or small wars. This philosophy sparked increased high-level interest in developing and deploying nonnuclear weapons, such as the SHILLELAGH.

(U) Kennedy chose as his Secretary of Defense, Robert S. McNamara, a highly successful industrial manager for the Ford Motor Company, parent company of Aeronutronic. McNamara came to DOD determined to eliminate the delay in decisionmaking. Secretary McNamara made it clear from the start that he would not merely sit as a judge selecting the best of various proposals that would trickle up to him. He was determined to lead, not be led; to initiate ideas, not sort out well-masticated compromises. He viewed the committee system with its endless bargaining and compromises as the major cause of delay in the decisionmaking process and intended to replace it where possible by asserting

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[35] (1) SHILLELAGH Presentation to DDRE Representatives, 20 Jul 61, by MAJ John D. Hamilton, SHILLELAGH Br, R&D Ops, ARGMA. (2) DF, Chf, Control Ofc, AOMC, to Distr, 15 May 61, subj: Minutes of SHILLELAGH Guided Missile Sub-System Command Presentation, w incl: Bfg, Status of SHILLELAGH.

greater executive authority, responsibility, and control over the department and its operations.[36]

Aeronutronic Proposal

(U) One manifestation of McNamara's new policies occurred in the SHILLELAGH program during the April-May 1961 period. On 21 April 1961, Aeronutronic presented a briefing in Washington to OCO, CONARC, DA, and DOD officials on accelerating the SHILLELAGH program. Shortly thereafter, a DOD staff member requested information directly from Aeronutronic regarding the earliest possible availability of the SHILLELAGH, the major actions required of the Government to meet an accelerated schedule, and the effect of such revisions on estimated costs.

(U) In his reply to the Secretary of Defense on 22 May 1961, Mr. Gerald J. Lynch, Vice President and General Manager of Aeronutronic, indicated that the first tactical production missiles could be made available in June 1963 and that by March 1964 the full production rate could be obtained. To meet this schedule, he said the Government would have to authorize an immediate increase in the rate of R&D expenditures; augment the direct support currently provided the contractor by Government agencies; accelerate award of the missile pre-production engineering and tooling and facility contracts to June 1961 and August 1961, respectfully; and establish the M60 main battle tank as the first weapon carrier to assure availability for SHILLELAGH flight tests early in CY 1962. Mr. Lynch acknowledged that the Army had no input to this plan and had not concurred in it. On 31 May 1961, ARGMA representatives visiting the Aeronutronic plant learned of the request from the Secretary of the Defense and obtained an extract of Aeronutronic's letter to Secretary McNamara.[37]

OTAC/ARGMA Proposal

(U) Meanwhile, in early May 1961, the Weapon System Manager at OTAC began developing a plan to accelerate the availability of the SHILLELAGH subsystem. Like Mr. Lynch, he felt that the most obvious method for obtaining earlier deliveries was to use the M60 main battle tank as the basic vehicle platform rather than the approved AR/AAV, which was still in development. At OTAC's request, ARGMA, on 29 May 1961, submitted a plan for an M60 tank-mounted SHILLELAGH with an availability date of December 1964, 17 months earlier than the original plan incorporating the AR/AAV weapon mount.

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[36](1) James E. Hewes, Jr., *From Root to McNamara: Army Organization and Administration, 1900-1963*, Special Studies (Center of Military History, US Army: Washington, DC, 1975), pp. 304-05 (2) Lloyd Norman, "McNamara and His Band," *Army*, Vol. 12, No. 2 (Sep 61), pp. 37-43, 84.

[37](1) SS, ORDXR-1-305, Industrial Ops, ARGMA, 6 Jun 61, subj: SHILLELAGH Missile Sub-System Plan, w incl: DF, Cdr, ARGMA, to CG, AOMC, 6 Jun 61, same subj, w incl: Extract fr Ltr, Gerald J. Lynch, VP & Gen Mgr, Aeronutronic, Div of Ford Motor Co., to The Honorable Robert McNamara, SECDEF, 22 May 61, re Aeronutronic Plan for Earliest Possible Availability of the SHILLELAGH. (2) Msg, CofOrd, to CG, OTAC, 1 Jun 61, re Aeronutronic Proposal for Acceleration.

Army Position on the Aeronutronic Proposal

(U) Upon receipt of the Aeronutronic proposal, the DA Chief of Research and Development directed the Chief of Ordnance to prepare an Army position on it. Representatives from ARGMA, OTAC, and OCO evaluated the contractor's plan and compared it with both the existing plan for the SHILLELAGH on the AR/AAV and the OTAC/ARGMA scheme for accelerated development. Table 1 compares the major milestones of the three plans.

(U) The contractor's plan was based on the premise that the first fully guided test firings would prove highly successful, and therefore tended to commit the Army to an industrial program before conclusive demonstration of the design feasibility. The technical problems encountered in the SHILLELAGH program to date in no way indicated an early or trouble-free completion of development. Essentially, the proposal involved a high risk for the Army and would involve funding increases of a magnitude yet to be expressed, but sure to be substantial. In the absence of complete information on the contractor's proposal (for example, no provision was specifically included for the conduct of Ordnance engineering and service tests), Ordnance could not make a detailed analysis, but did recommend that Aeronutronic develop a cost estimate and detailed time phasing for their proposed program to serve as the basis for a detailed review. Ordnance also recommended that no significant additional RDTE or PEMA funds be furnished to Aeronutronic until they had conclusively demonstrated design feasibility in the first series of fully guided flights, scheduled to begin on 15 August 1961.[38]

Directed and Reasonable Risk Plans

(U) After reviewing the Aeronutronic and Ordnance acceleration plans in June 1961, the Department of Defense directed that the Army develop a plan to expedite availability of the SHILLELAGH subsystem and allow for initial tactical deliveries in the summer of 1964, some 2 years earlier than scheduled in the plan using the AR/AAV. As a result of this directive, ARGMA prepared and forwarded to OTAC, on 7 August 1961, two SHILLELAGH subsystem plans—a directed plan and a reasonable risk plan—both predicated on using the M60E2 vehicle.

(U) The directed plan provided for tactical missile deliveries 7 months earlier than indicated in the ARGMA plan of 20 May 1961. The reasonable risk plan, advocated by the Chief of Ordnance, considered such unusual measures as sole source procurement; early release for limited production; commitment of substantial PEMA funding late in 1961 or early 1962; and application of the

[38](1) SS, ORDXR-C-44, ARGMA Control Ofc, 7 Jun 61, subj: Comments on Aeronutronic Proposed Accelerated SHILLELAGH M60E2 Program. (2) DF, Dir, Indus Ops, ARGMA, to CofS, AOMC, 13 Jun 61, subj: SHILLELAGH Missile Sub-System Plan, w incl: Proposed DF, CofOrd to Chf of R&D, DA, subj: Compression of SHILLELAGH Program. (The proposed DF contained the Ordnance position as developed by ARGMA, OTAC, and OCO. On 12 June 1961, OCO notified ARGMA that the Deputy Chief of Ordnance had signed the communication and sent it to the Chief of R&D.)

TABLE 1

(U) CURRENT PLAN VERSUS ACCELERATED PLANS - JUNE 1961

Milestone	Current Program w AR/AAV	Aeronutronic Proposal w M60E2[a]	OTAC/ARGMA Proposal w M60E2
Preproduction Engrg Contract	Jun 62 (M) 1 Oct 62 (V)	15 Jun 61	1 Jan 62 (M) 1 Feb 63 (V)
Tooling & Facility Contract Award	Oct 63 (M) Apr 65 (V)	15 Aug 61	Nov 62 (M) Nov 63 (V)
R&D Documentation Complete (Prelim release to Indus)	Dec 61 (M)[b] Nov 64 (V)[b]	Dec 61	Dec 61 (M)[c] Oct 62 (V)
R&D Prototype Vehicle Available	Nov 62	Early 1962	Jul 62
Tested R&D Prototype (Compl contr test, T95)	-	Jul 62	-
Tested R&D Prototype (Tactical)(Compl contr test, tactical vehicle)	Mar 63	Dec 62	Feb 63
Engineer/Service Test	Jul 63-Jun 64	-	Mar 63-Feb 64
First Delivery-Tactical Missile	Mar 66[d]	Jun 63[e]	Sep 64[f]
First Delivery-Tactical Vehicle	Apr 66	-	Jun 65

Legend: M-Missile System
V-Tactical Vehicle

NOTES:

[a]Aeronutronic proposal did not specifically consider the tactical vehicle but assumed its availability in phase with missile system.

[b]No preliminary release planned. This would be a final release based on competitive procurement.

[c]Experimental model.

[d]First production missiles for nontactical use delivered July 1964.

[e]Although Aeronutronic's letter to the Secretary of Defense stated that this was the delivery date of the first tactical missile, later coordination by ARGMA with the contractor revealed that this should be interpreted as meaning the first missile delivered, which must be allocated to nontactical use.

[f]First production missiles for nontactical use delivered August 1963.

SOURCE: Proposed DF, Chief of Ordnance to CRD, DA, subj: Compression of SHILLELAGH Program, atchd to DF, Dir, Indus Ops, ARGMA, to CofS, AOMC, 13 Jun 61, subj: SHILLELAGH Missile Sub-System Plan.

principle of concurrency to include initiating engineering tests well before concluding development tests and user testing very early in the engineering test phase. The term "reasonable risk" was defined as being technical risk, exclusive of monetary risk, which had a reasonable chance of program success. Since both the President and the Secretary of Defense had expressed an interest in the SHILLELAGH program, the Chief of Ordnance felt it reasonable to assume that justifiable requests for additional funds would be approved. Key phasing dates for the two plans are shown below.

	Directed Plan	Reasonable Risk Plan
R&D engineering release	Feb 62	Feb 62
R&D engineering release-M60E2	15 Oct 62	15 Oct 62
R&D final release	1 Oct 63	1 Oct 63
Engineer and service test completed	1 Oct 63	1 Oct 63
Tooling and Facilities	1 May 62	1 Nov 62
Tactical delivery of missiles, G&C, & test equipment	1 Jan 64	1 Aug 64
Repair parts delivery	1 Nov 63	1 Jun 64

(U) The R&D release date, the same for both plans, was optimistic and assumed immediate authority to expend funds at a rate almost three times greater than that currently authorized. The directed plan would provide the user with hardware of a configuration which had undergone about one-third the required R&D testing and no engineering or service testing. Changes required as a result of the latter tests could be incorporated only after some 10,000 missiles had been delivered to the user. The reasonable risk plan would allow an additional 7 months to complete engineering and service tests and provide hardware which reflected production engineering. Thus, the tactical user would receive a SHILLELAGH missile system more closely resembling the final R&D design release.

(U) The contractor estimated that a sizable increase in funding would be needed to meet an accelerated program schedule. Taking into consideration the increased cost as a result of program slippage to date, plus the cost of acceleration, $56 million would be required for FY 1962 and $20.6 million for FY 1963. These cost figures were indicative of the hugh amount of development remaining to be done.

(U) The projected RDTE cost was the same for both the directed and reasonable risk plans—$105,278,000. Differences surfaced, however, between PEMA and OMA projections. The estimated PEMA cost of the directed plan was $525,834,000, in contrast to $491,254,000 for the reasonable risk plan. The estimated OMA cost of the directed plan was $7,859,000, slightly more than $1 million above the estimate for the reasonable risk plan of $6,778,000.

(U) Drawing upon past experience and lessons learned in other missile programs, ARGMA officials argued that more time for R&D and industrial testing should be allowed than that indicated in either plan. Purely from a technical standpoint, they recommended that field delivery of the system be delayed by at least 10 months from the date shown even for the reasonable risk plan. Such a program, they asserted, would be much more efficient, require fewer special authorities, assure the delivery of a more reliable and technically sound system to the user, and permit earlier initiation of more desirable and economical procurement practices such as breakout and competitive negotiations. Considering the marginal progress made in the SHILLELAGH development program to date and the extensive development yet to be done before a serviceable weapon could be deployed, they were convinced that premature initiation of production would merely transfer development problems from the R&D phase to the early industrial phase, making solutions far more difficult and expensive.[39]

Decision by the Secretary of Defense

(U) Upon receipt of the directed and reasonable risk plans, in August 1961, the Secretary of Defense established an ad hoc committee to review military requirements for the SHILLELAGH and the tactical ability of the system to perform in the military environment in which it was expected to operate. The committee was to provide a technical assessment of the missile and its related components, as well as a status report and appropriate guidance on future R&D program requirements. Members of the committee received a complete briefing on the SHILLELAGH system at OTAC Headquarters on 31 August 1961 and at Aeronutronic's Newport Beach facility on 1 September 1961. This was followed on 20 September 1961 by an OTAC/ARGMA presentation on the proposed plan for the directed program to the Chief of Ordnance, who then submitted the plan to the Secretary of Defense. The official review of the SHILLELAGH/M60 program ended with an Army/Aeronutronic briefing to the Secretary of Defense on 30 September 1961.

(U) On the basis of information generated in the review of the program, the Secretary of Defense decided that the SHILLELAGH would not be applied to the M60 vehicle, but would be mounted on the AR/AAV (SHERIDAN) as originally planned. He directed that Aeronutronic start an immediate 2-month acceleration of the SHILLELAGH research and development effort, during which time other R&D aspects of the program would be presented to facilitate a final decision.

Implementation of the DOD Decision

(U) To meet this advanced timetable, the Assistant Secretary of the Army (R&D), on 4 October 1961, authorized the issuance of a 60-day, $8 million letter contract to Aeronutronic for accelerated development work, specifying that expenditures could not exceed $4 million per month.[40] Accordingly, OCO,

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[39] (1) SHILLELAGH Sub-System Plans for M60E2 Vehicle (Directed and Reasonable Risk), 7 Aug 61, ARGMA/AOMC, pp. i, 3-5, 36, 54-55. (2) Msg, CG, OTAC, to CG, ARGMA, DTG 052125Z Jul 61, re SHILLELAGH Acceleration. (3) Msg, CofOrd to CG, OTAC, DTG 302124Z Jun 61, incl to Ltr, CG, AOMC, to Cdr, ARGMA, 6 Jul 61, subj: Revision of SHILLELAGH Weapon System Plan. (4) SHILLELAGH Monthly Progress Report, ARGMA/AOMC, 31 Jul 61, pp. 7-8.

[40] (1) SHILLELAGH Monthly Progress Reports, ARGMA/AOMC: 31 Aug 61, pp. 6-7; 30 Sep 61, pp. 6-7. (2) Memo, Asst Secy of the Army (R&D) to CofOrd, thru Chf of R&D, DA, 4 Oct 61, subj: Accelerated Shillelagh-Aeronutronic Program.

on 5 October 1961, directed the Los Angeles Ordnance District (LAOD) to negotiate the contract with Aeronutronic for the period 10 October to 9 December 1961, as a modification to the existing R&D contract (ORD-1835). Aeronutronic promptly began a substantial personnel buildup and subcontracted for several technical backup programs.[41]

(U) In response to an OTAC request, ARGMA submitted a plan on 4 October 1961 reflecting the accelerated SHILLELAGH-AR/AAV program as approved by the Secretary of Defense. This plan reflected the following milestones: (1) confirmation of missile feasibility and preliminary R&D release to industry in April 1962; (2) tooling and facility contract award in May 1962; (3) limited production release and production contract award in December 1962; (4) completion of engineering design in August 1963; (5) first production delivery in October 1963; (6) completion of engineering design and user tests and type classification as standard in January 1964; and (7) first delivery to troops in July 1964.

(U) The Deputy Commander of AOMC emphasized that this plan was predicated on complete success in all future development efforts, although past experience had shown that assumption to be highly improbable. Both ARGMA and AOMC recommended that the decision to accelerate the program beyond the 2-month period be contingent on performance of the missile subsystem in guided flights in the next 3 months. The time-phasing and conceptual approach to programming for the missile subsystem was essentially the same in the accelerated AR/AAV plan as in the directed and reasonable risk plans using the M60E2 tank. Therefore, the attendant risks and impacts contained in the M60E2 studies for the directed plan were directly applicable to the plan for the AR/AAV. It would be necessary, for example, to freeze the design for production before completion of essential development tests. Moreover, it was highly possible that, with a program acceleration of this nature, Ordnance would not be able to provide adequate support for initial deliveries of equipment for troop use.[42]

(U) By the time ARGMA delivered the AR/AAV-SHILLELAGH plan, it was already becoming obvious that the decision to accelerate the program, even for 2 months, was premature. The first guided flight test on 15 September 1961 (a month later than scheduled) and the first three closed loop guidance tests, conducted between 22 September and 6 October 1961, all ended with disappointing results. By the end of December 1961, Aeronutronic had attempted 11 closed loop missile firings, only 9 of which were fired and only 1 of those was completely successful.[43]

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[41](1) Msg, CofOrd to CO, LAOD, DTG 051123Z Oct 61, re Acceleration of SHILLELAGH Program. RHA Box 12-659. (2) SHILLELAGH Monthly Progress Report, ARGMA/AOMC, 31 Oct 61, p. 1. (3) Hist of ARGMA, 1 Jul-11 Dec 61, pp. 75-77. (4) Hist Rept, Industrial Div, ARGMA, in Final Diary of ARGMA, 1 Jul-11 Dec 61, p. 262.

[42]Ltr, Dep Cdr, AOMC, to CG, OTAC, 4 Oct 61, subj: SHILLELAGH Sub-System Plan for AR/AAV Weapon System.

[43]See below, pp. 65-66.

Alternate Plans for the Accelerated AR/AAV-SHILLELAGH Program

(U) It therefore came as no surprise when OTAC asked ARGMA for three alternate plans for the SHILLELAGH portion of the accelerated AR/AAV program. The first plan, submitted to OTAC on 13 October 1961, called for execution of the first production contract in August 1962, before the limited production type classification scheduled for 31 December 1962, and for initial production deliveries in October 1963. The second plan, submitted on 16 October 1961, reflected the same time phasing, but used an advanced vehicle production rate of 200 per month instead of the 75 vehicles per month called for in Plan 1. The cost estimates for Plans 1 and 2 are shown below:

	PLAN 1	PLAN 2
FUNDS		
Research & Development	$113.370	$113.487
Industrial	576.499	577.308
Field support	14.224	34.096
TOTAL	$704.093	$724.891

MAJOR ITEMS	Quantity	Est Cost*	Quantity	Est Cost*
Missile	172,068	$407.642	172,966	$410.499
Depot Test Equipment	3	6.134	3	6.442
Go-no-go test equip	26	5.478	30	6.044
On-Vehicle G&C	2,471	129.815	2,132	143.173
Type IV tools & test equip	98	31.947	96	35.082
Depot test equip	3	9.707	3	10.164

*Including Industrial and Field Service Cost

Under the third subsystem plan, the SHILLELAGH missile and on-vehicle guidance and control equipment would be phased in about 8 to 12 months after availability of the AR/AAV. For this study, availability of the vehicles was considered to be the same as for Study 1. Taking into consideration the use of possible expedients, ARGMA determined that tactical deliveries of equipment could begin in July 1964, making deployment of the AR/AAV, with the SHILLELAGH missile and on-vehicle guidance and control equipment, possible in May 1965. The phasing for this study indicated a 10-month delay in deployment of the weapon system complete with conventional ammunition and missiles; however, deployment of the AR/AAV with conventional ammunition was still scheduled in July 1964. The extension of the missile program by 10 months would reduce both the technical and monetary risks.[44]

[44] (1) SHILLELAGH Sub System Plan for the Accelerated AR/AAV Vehicle (Study 1), 13 Oct 61, ARGMA/AOMC. (2) SHILLELAGH Sub System Plan for the Accelerated AR/AAV Vehicle (Study 2), 16 Oct 61, ARGMA/AOMC. (3) Supplement #2 AR/AAV-SHILLELAGH Accelerated Program, 17 Oct 61, ARGMA/OTAC SHILLELAGH Task Force, pp. 1-4. (4) SHILLELAGH Monthly Progress Report, ARGMA/AOMC, 31 Oct 61, pp. 6-7. (5) Msg, CofOrd to CG, OTAC, DTG 131417Z Oct 61, re Alternate Plan for Accelerated SHILLELAGH-AR/AAV Program.

Fire Control and Guidance System Flight Tests

(U) While the acceleration plans were being reviewed and modified, Aeronutronic commenced the flight test program to prove out the infrared command guidance concept. The results of these tests would determine whether or not the accelerated program would continue beyond December 1961. A total of 20 missile firings were conducted (or attempted) during 1961, 9 to confirm fire control system effectiveness and 11 to test the closed loop guidance system. (For complete test results, see Appendix E, Firings 1 through 20.)

Fire Control Tests

(U) Before flight testing the closed loop guidance system, the contractor conducted nine fire control flight tests at White Sands Missile Range (WSMR) in the April-September 1961 period. In Phase I, four missiles were fired to measure free flight attenuation of the infrared coded signal and noise in the missile detection system during rocket motor and gas generator operation. Phase II consisted of five firings to evaluate separately the performance of the inner loop control system and the outer loop guidance system, and to determine performance of the tracker-transmitter link. Although several problems occurred with late motor ignition and parachute malfunctions, the test data indicated generally satisfactory results.

(U) The fire control flight test on 15 September 1961 marked the first guided flight of a SHILLELAGH missile. The missile, launched at an angle of 85° above the horizon, was successfully guided through the capture phase and motor burnout transient. It received guidance commands for about 2.8 seconds, after which it moved to the right beyond the field of view of the transmitter and continued in stabilized flight until the recovery parachute was deployed. Analysis of flight data indicated that excessive drift in the yaw/roll gyro produced an inner loop yaw signal larger than the outer loop guidance command could correct.

Closed Loop Guidance Test

(U) The closed loop guidance test program offered the first opportunity for the Army to judge if the SHILLELAGH missile concept could become a militarily useful weapon. In the September-December 1961 period, the contractor attempted 11 missile firings in this series, 9 of which were fired. Of the nine, only one round, CL-7, fired on 22 November 1961, was completely successful. All closed loop firings were conducted at WSMR.[45]

(U) The closed loop flight tests revealed several deficiencies in the guidance and control components and the rocket and gas generator. They demonstrated conclusively that the smoke trail produced by the T16 rocket

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[45] (1) ARGMA Hist Sum, 1 Jan-30 Jun 61, pp. 71-72. (2) History of ARGMA, 1 Jul-11 Dec 61, pp.79-84.

motor propellant was more severe than could be tolerated by the tracking and command links. During rocket motor burnout, as the motor chamber pressure decayed, the motor nozzles emitted a cloud of smoke which completely obscured the tracking and transmission signals for periods as long as four-tenths of a second. When coupled with other normally expected flight path disturbances, these signal dropouts were sufficient to cause the loss of several missiles which would otherwise have been successfully returned to the line of sight, and in almost all flights resulted in trajectory deviations far in excess of normal transients after motor burnout. Both Picatinny Arsenal and Aeronutronic were investigating various rocket propellants in an effort to reduce the exhaust plume. Ammonium nitrate propellants appeared to be the best type to use where a minimum smoke trail was the most important criterion.[46]

Applied Research Program

Reorientation of Program

(U) As a result of the problems encountered in the closed loop flight tests, the DOD and Army staff directed a general reorientation of the SHILLELAGH development effort to a program of applied research on the key technical problems. Accordingly, OCO, on 8 December 1961, authorized the Los Angeles Ordnance District to extend the current letter contract for a 60-day period, beginning 10 December 1961, with the following conditions:

- The scope of the expedited applied research program would be furnished by ARGMA.
- Negotiations with Aeronutronic would be at the lowest possible funding level commensurate with the scope of work furnished, but, in no event, would exceed $900,000 per month.
- The definitive contract to be finalized within 60 days would not exceed $13.2 million and would provide for contract completion by 30 April 1962.

The Chief of Ordnance recognized that current funds would only permit continuation of the program through April 1962, and that additional funding of $4 million would be required to complete the applied research program. Therefore, negotiations with the contractor would provide for two increments of work. The first would be fully funded in the amount of $13.2 million; and the second

[46](1) Semiannual Hist Rept, Tactical Systems Proj Ofc, R&D Ops, ARGMA/AOMC, in Final Diary of ARGMA, 1 Jul-11 Dec 61. (2) Presentation of Missile Flight Test Program by Mr. L. F. Heilig, Chf Engr, Tactical Wpn Sys Ops, Aeronutronic, in Conference Minutes, SHILLELAGH R&D Review Meeting held at Detroit Arsenal, OTAC, 2 Mar 62. RHA Box 12-721.

would be in the form of an option to the Government, which would be exercised by 30 April 1962.[47]

(U) The modification to contract DA-04-495-ORD-1835 to decelerate the development program, implemented on 8 December 1961, provided an extension until 6 February 1962. Through a number of additional modifications in CY 1962, the applied research program was extended to December 1962.[48]

(U) No ordnance support readiness date was established for the SHILLELAGH missile under the reoriented program. If, and when, the program again became a full development effort, release and readiness dates would be determined, based on authorized funding.[49] In the applied research program, the contractor would essentially be providing answers to two basic questions. Could the infrared command link be made to operate through the obscuration created by motor and gas generator plumes? And, could the missile be made reliable enough for use in its intended role in the field? The Army Ordnance Missile Command placed major emphasis on flight and reliability testing to assure the accumulation of enough data for the Army to make a decision on the future of SHILLELAGH in September 1962. Any slippage in this decision point could result in program termination in favor of another approach to the problem.[50]

Flight Tests

(U) To determine the feasibility and reliability of the missile, the contractor conducted several series of tests during 1962 to evaluate propellant compatibility, and the effects of sun angle and environmental conditioning, vehicle transportation, moving line of sight, and limited visibility. Except for three experimental firings in the Arctic in late 1962, all guided firing tests were conducted at the White Sands Missile Range. (For complete test results, see Appendix E, Firings 21 through 46.)

(U) The propellant evaluation tests showed that the combination of double base N-5 rocket motor propellant and LFT-3 ammonium nitrate propellant for the gas generator was satisfactory. With these propellants, the missile system

[47](1) History of ARGMA, 1 Jul-11 Dec 61, pp. 84-85. (2) Msg, CofOrd to LAOD, DTG 081632Z Dec 61, re Decelerated Program with Aeronutronic.

[48](1) Semiannual Hist Rept, Industrial Div, ARGMA/AOMC, in Final Diary of ARGMA, 1 Jul-11 Dec 61, pp. 264-65. (2) Hist of HQ, AOMC, 1 Jan-30 Jun 62, p. 78. (3) MICOM Anl Hist Sum, 1 Jul 62-30 Jun 63, pp. 142-43. (4) Hist Rept, SHILLELAGH PM, FY 65.

[49]SHILLELAGH Monthly Progress Report, 31 Dec 61, ARGMA/AOMC, pp. 5-6.

[50]Missile Development Status, Bfg by MAJ John Hamilton, Chf, SHILLELAGH Br, R&D Ops, AOMC, in Conference Minutes, SHILLELAGH R&D Review Meeting, held at Detroit Arsenal, OTAC, 2 Mar 62. RHA Box 12-721.

demonstrated its ability to maintain the fixed line of sight trajectory and impact the target within accuracy requirements, even under conditions of maximum exhaust plume concentration.

(U) The firings in May and June 1962 demonstrated the capability of the missile to hit targets moving across the field of view. These firings marked the first use of infrared guidance in this mode—a significant milestone in the development of SHILLELAGH. Another firing proved the missile's capacity to hit a target at maximum range when the target was barely visible through blowing dust. The results of this firing satisfied the limited visibility test objectives; therefore, the second scheduled firing was cancelled.

(U) Other firings tested the missile's capability to withstand an operational road transportation environment, then maintain a fixed line of sight trajectory during flight. In July and August 1962, several missiles were flown to determine guidance system performance when the sun was either near the edge of the missile receiver field of view or near the tracker line of sight.

(U) During the winter of 1962-63, nine flights were conducted under arctic conditions at Fort Greeley, Alaska, to determine the low temperature limit at which condensation of the missile's exhaust plume weakened the command link enough to cause missile failure. Three of these tests fell within the timeframe of the applied research program. In the nine-round series, completed on 16 March 1963, there were five successful flights and four failures. The major cause of failure was the inability of the infrared command data to penetrate the ice fog. The test data indicated that the SHILLELAGH's lowest effective operating temperature was around -20°F, well above the requirement of -65°F specified in the military characteristics.

Findings and Conclusions

(U) The applied research program was considered successful, not only from a demonstration standpoint, but also from the aspect of fulfilling its basic objectives and furnishing answers to a number of critical questions about the system and its capabilities. The contractor had amply assured operational feasibility and the ability to achieve high reliability. The infrared command and tracking link successfully guided the missile with significantly improved capability for first round hit probability at extended ranges over existing tank armament.

(U) While expressing satisfaction with the test results and confidence in the ultimate success of the program, the Army Missile Command pointed to several significant system limitations. The results of arctic firings and other laboratory tests indicated that the missile probably would not fulfill the requirement for operation at -65°F, but above -20°F—the most probable temperature range in which the system would be used—the SHILLELAGH could be expected to perform well. Another significant limitation was the low probability of operation when the sun was within a 40° cone (20° half angle) behind the launching vehicle transmitter. Firings with the sun directly behind the transmitter would probably never be completely successful; however, studies were being conducted on the use of different missile receiver detector cells to increase the probability of operation under these conditions. The applied research program data also revealed that the missile weight would probably not be reduced below 55 pounds. And it was doubtful that a rate of fire of six to eight missiles per minute would be achieved at maximum range, because of the increased missile flight time. This rate of fire could more probably be met at ranges of 1,000 meters.[51]

Final Development Program

(U) Confidence in the ultimate success of the SHILLELAGH program having been restored, the Assistant Secretary of the Army for Research and Development, in January 1963, approved an AMC request to increase the scope of work and period of performance of the current Aeronutronic contract. The Army Missile Command received approval to reinstate the development program early in February 1963, and modified the R&D contract (DA-04-495-ORD-1835) on 6 May 1963 to cover development from 3 December 1962 through 31 August 1963, at a cost of $12,288,888. A new contract (DA-04-495-AMC-309(W)), awarded to Aeronutronic on 1 September 1963, extended the research, development, test, and evaluation effort until December 1965.[52]

Final Flight Tests

(U) Aeronutronic conducted the final development flight test series from September 1963 through October 1964. In this series of 63 firings, the missile met test objectives on 58 flights (see Appendix E). These flights satisfied a number of objectives, including design prove-out, warhead compatibility, SHERIDAN compatibility, system capability after environmental conditioning and road travel, and system capacity against moving and transient targets. Ten flights were successfully conducted 21-25 September 1964 as a military

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[51](1) SHILLELAGH Applied Research Program Technical Report and Status, Aeronutronic Publication No. (S)1814, 7 Sep 62, pp. 3-1 - 3-3, 3-20 - 3-35, 5-8-6. RSIC. (2) Technical Information Report CD-5, Supplement II, AMC, Nov 62, subj: Development of Antitank Weapons. RSIC. (3) History of HQ, AOMC, 1 Jan-30 Jun 62, pp. 77-80. (4) MICOM Anl Hist Sum, 1 Jul 62-30 Jun 63, pp. 145-46. (5) Ltr, SHERIDAN/SHILLELAGH PM, to CG, MICOM, 27 Feb 63, subj: Gen. Sheridan "In-Process" Review Meeting 29-30 Jan 63, w incl: Speech "Missile Status" by Mr. Lloyd Lively. RHA Box 13-103. (6) SHILLELAGH Development Test Firing Data, Sec 1, Jan 62-25 Sep 64. RHA Box 12-721. (7) Report to SHERIDAN/SHILLELAGH PM, Interim Technical Analysis of Arctic Program (Report T-63-1), 15 Feb 63, prep by George Sipes, SHILLELAGH Br, Dev Div, R&D Drte, MICOM. (8) Also see SHILLELAGH Dev Test Firing Data, Appendix E.

[52](1) MICOM Anl Hist Sum, 1 Jul 62-30 Jun 63, p. 146. (2) Hist Rept, SHILLELAGH PM, FY 65, pp. 4-5. (3) Msg, USAMC to LAPD, DTG 292230Z Jan 63, re Amendment to Aeronutronic Contract. RHA Box 12-659.

inspection of the system. The flight on 23 September 1964 marked the first firing by a military gunner.[53]

Component Development

(U) During the final phase of the development program, the contractor made a number of component changes to fulfill system requirements. Several modifications were made in the rocket motor grain system, and a dual igniter system for the rocket motor was added. Because of vibration problems, the gyro developed by the Whittaker Gyro Company was replaced by a Clary Dynamics Company prototype. The original tungsten lamps for the missile source were off-the-shelf items manufactured by the General Electric Company. These were replaced by lamps specifically developed by the Sylvania Products Company to meet missile specifications. To satisfy reliability requirements, Aeronutronic changed from a commercially available missile motor to one designed by American Electronics, Incorporated, and later to another motor developed by Wright Machinery Corporation.

(U) A number of refinements were also necessary in the guidance and control equipment. Initial development resulted in an experimental model design which proved the system concepts in firings from a fixed launcher and the T95 test bed. As system requirements were finalized, the contractor began developing the engineering model guidance and control (G&C) system, for installation in the SHERIDAN vehicle. The requirements for high reliability and self-test capability dictated the overall design, representing an exhaustive tradeoff of numerous design variables which had to be optimally controlled to realize the ultimate system objectives.

(U) The starting point for development of the signal data converter (SDC) was an experimental model designed by the Raytheon Company with Aeronutronic tracker signal processing circuitry. This model, which had no self-test capability, was used in R&D firings before September 1962. The design requirements of reliability, environment, maintainability, producibility, and cost implied an all-electronic design, free from factory and field adjustments. Since the SDC contained about 60 percent of the electronic components used in the vehicle-mounted gear, it was expected to have the largest frequency of maintenance of any of the all-electronic components. Hence, any significant degradation of its mean-time-between-failure (MTBF) rate resulting from the use of complex electromechanical elements was undesirable. To improve the MTBF, a simple and flexible all-electronic range programmer was developed which required only two modules with no special components. This programmer proved to be one of the most important design contributions to the high G&C reliability. At the end of the development program, two complete engineering model SDC's underwent 2,500 hours of continuous standard battlefield day operation without any electronic component failures.

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[53]SHILLELAGH Development Test Firing Data (Standard Range), Apr 61 - Oct 64. RHA Box 12-721.

(U) The design of the engineering model modulator began in October 1962, following the decision to use two 150-watt lamps, instead of a single 300-watt lamp. The change to two lamps would avoid the frequency mixing effects found with one lamp. Design and reliability tests, and the engineering test/service test (ET/ST) program uncovered no major design problems in the modulator.

(U) The transmitter, which provided the infrared link for the missile, originally had a single xenon arc lamp to transmit both pitch and yaw signals. However, during testing, "backscatter" from the command beam created noise in the tracker. This problem was solved by using two lamps in the transmitter, one each for pitch and yaw commands. The final design of the xenon arc transmitter centered around two major requirements: reliable rapid starting to meet system requirements for capture, and arc stability. A three-electrode xenon arc lamp was designed to solve the starting problem. The three electrode xenon arc lamps developed by the Hanovia Lamp Division of Englehard Industries was adopted over the one developed by the PEK Laboratories, because of its superior arc stability.[54]

Release for Limited Production

(U) In May 1964, following 22 consecutive successful firings in the R&D series, members of the AMC Subcommittee for SHERIDAN/SHILLELAGH recommended that the missile be type classified as limited production. In their view, the significant increase in hit and kill probabilities to be gained by the field commander using the weapon justified its earliest possible release. The R&D testing to date had indicated that the missile system would be highly reliable and extremely accurate for its intended use, and that the essential requirements for a 2,000-meter maximum range missile system were being met. The engineering test/service test, scheduled to begin later in 1964, would confirm those findings and the degree to which the system met both essential and desired military characteristics.

(U) The Chief of Research and Development, DA, approved the LP type classification on 12 August 1964. The major missile system items were identified as follows:

Guided Missile, Anti-Tank XMGM-51A (Shillelagh)
Guided Missile, Anti-Tank XMTM-51A (Training)
Guidance and Control Group: (Shillelagh) XM25
Missile Test Set, Drawing No. EX10122245
Transmitter Alignment Test Set, Drawing No. EX10122012

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[54]Final Technical Report, SHILLELAGH Guided Missile System, Vol I of III, System Development History, 24 Feb 67, Aeronutronic Pub No. S-3905, pp. 53-57, B-1, B-2, 62-64, 67, 69-78.

The vehicle-mounted guidance and control group consisted of the tracker, signal data converter, modulator, rate sensor, power supply transmitter, cable set, and test and checkout panel. The missile test set was formerly called the forward area contact support set.[55]

(U) In mid-October 1964, some 2 months after the missile was approved for limited production, an in-process review was conducted on the SHERIDAN* weapon system to update the DA staff and Combat Developments Command (CDC) on the status of both the vehicle and the missile. Development testing had revealed certain system limitations which could require revision and/or clarification in the military characteristics. Most of these changes concerned the vehicle, e.g., gun launcher elevation and depression limits, water speed, 2,500-mile parts life, RADIAC** requirement, gun launcher tube replacement time, maximum speed, turret armor protection, smoke device, swimming capability, commander's night observation device, laser computer system, spotting charge in the XM411 target practice (TP) round, arming distance for the XM410 white phosphorous (WP) round, functioning reliability of conventional rounds, accuracy of XM411 TP and XM410 WP rounds, and fragmentation requirements for the XM409 high-explosive antitank-multipurpose (HEAT-MP) round.

(U) Several limitations on missile performance were also recorded. The required rate of fire of six projectiles per minute had not been met. The CDC and DA staff representatives requested that the problem of projectile loading and breech operations while a missile was in flight be investigated further to keep the firing cycle of multiple projectiles as short as possible. Therefore, no change was made in this requirement.

(U) Arctic development tests had indicated a low temperature limit between -15°F and -25°F for firing the missile. At and below these ambient temperature limits, the motor and gas generator exhausts formed ice crystals which interfered with the line of sight. Without adequate optical line of sight, the missile command system would not function.

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*The AR/AAV was not type classified as limited production until 18 November 1965. (AMCTC Item 3845, Meeting No. 11-65, 18 Nov 65, subj: Sheridan Weapon System - Recording of DA Staff Approval of Limited Production [LP] Type Classification of Armored Reconnaissance/Airborne Assault Vehicle: Full Tracked, 152MM, XM551 [General Sheridan], D/A Project 1X579191D392 [AMCMS 5583.12.203].) RSIC.

**radio activity detection, identification, and computation

[55]AMCTC Item 2923, Meeting No. 1-65, 21 Jun 65, subj: Guided Missile, Anti-Tank XMGM-51A (Shillelagh); Guided Missile, Anti-Tank XMTM-51A (Training); Guidance and Control Group: (Shillelagh) XM25; Missile Test Set, Drawing No. EX10122245; Transmitter Alignment Test Set, Drawing No. EX10122012 - Recording of DA Staff Approval of Nomenclature and as Limited Production. RSIC.

(U) Another recognized limitation involved sun interference. When the sun was either behind the target or behind the weapon system, the guidance system would not operate properly. Further testing would determine exact limitations in this area. Tests had also shown that the SHILLELAGH transmitter had a signature characteristic which could reveal to the target vehicle when the missile was launched. A narrower beam pattern in the transmitter would restrict this visibility to areas near or in line with the target.[56]

Study of SHILLELAGH in Heavy Antitank Assault Weapon Role

(U) In mid-1962, while Aeronutronic was confirming the feasibility of the SHILLELAGH missile in the applied research program, the Army was contemplating the use of this missile in the heavy antitank assault weapon (HAW) role. On 13 July 1962, AOMC called upon Aeronutronic to begin an intensive effort along those lines. Concurrently, feasibility studies were being performed on the TOW* missile in the combat vehicle weapon system (CVWS) role. The results of these studies would be used in determining future funding for both systems. At that time, AOMC anticipated that only one system, to perform both roles, would be funded.

(U) On 18 July 1962, AOMC began negotiating with Aeronutronic on the SHILLELAGH HAW system development and demonstration. The contractor agreed to start immediately on the HAW effort in order to complete a missile demonstration in the HAW role by 1 October 1962. The ongoing SHILLELAGH applied research effort, financed with FY 1962 funds, was reoriented to direct about 60 percent of the remaining work towards the HAW task. A contract modification, signed on 8 August 1962, included the HAW effort from 18 July through 1 September 1962. On 31 August 1962, a 3-month supplement was signed to fund the SHILLELAGH program through 30 November 1962, although the HAW effort was covered only until 1 October 1962.[57]

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*The TOW (tube-launched, optically-tracked, wire-guided) missile concept was selected by the Ballistic Research Laboratories to meet the HAW requirements. Feasibility studies on the concept were conducted between January and July 1962, and, on 2 August 1962, Hughes Aircraft Company was selected as the prime development contractor. (MICOM Anl Hist Sum, 1 Jul 62-30 Jun 63, pp. 146-47. Also see Mary T. Cagle, *History of the TOW Missile System*, [MIRCOM, 20 Oct 77], pp. 22-25, 95-98.)

[56] AMCTC Item 3238, Meeting No. 4-65, 15 Feb 65, subj: Armored Reconnaissance/Airborne Assault Vehicle: Full Tracked, 152MM, XM551. (Gen. Sheridan) 5W45-02-003: OMS Code 5510 12.203 - Recording of In-Process Review (Release for Production) Meeting and Proposed Military Characteristic Changes. RSIC.

[57] (1) SS, ORDXM-R-452, R&D Drte, n.d., subj: Interim Analysis of SHILLELAGH Development Program and AOMC Recommendations, w incl: Ltr, Dep to DCG/Guided Missiles, AOMC, to CG, OTAC, 12 Jul 62, same subj. RHA Box 13-104. (2) MICOM Anl Hist Sum, 1 Jul 62-30 Jun 63, pp. 142-43.

(U) To evaluate the capability of the SHILLELAGH missile in the HAW role, Aeronutronic conducted five open breech launches between 7 August and 26 September 1962. Three short range unguided firings were conducted at the Aeronutronic remote test site near Newport Beach, California, to qualify the open breech launcher for guided firings, as well as to gain environmental data on launch effects on personnel nearby. Following these flights, Aeronutronic conducted two guided firings at White Sands Missile Range, proving that the missile could be fired from the open breech launcher and accurately guided to ranges in excess of 2,000 meters.[58]

(U) Meanwhile, on 24 August 1962, the Deputy Chief of Staff for Logistics, DA, directed the Army Materiel Command to prepare plans for fulfilling the combat vehicle weapon system and heavy antitank assault weapon system roles using the following contingencies: SHILLELAGH missile serving in both the HAW and CVWS roles; TOW missile fulfilling both the HAW and CVWS roles; TOW missile serving in only the HAW role; and SHILLELAGH missile fulfilling only the CVWS role. The AMC assigned primary responsibility for the studies to the Army Tank-Automotive Center, which obtained appropriate input from MICOM*. The resulting TOW versus SHILLELAGH Comparative Cost Study, dated 24 September 1962, revealed that the most expensive of the proposed plans was the one using both of the missile systems, i.e., SHILLELAGH in the CVWS role and TOW in the HAW role, the total cost being estimated at $7.54 billion. The cost of fielding the SHILLELAGH to fulfill both roles was $7.39 billion; while the cost of deploying the TOW to serve in both roles was $7.29 billion.[59]

(U) On 30 August 1962, MICOM reported to AMC that conclusive evidence of the feasibility of using the TOW missile for the CVWS role (based on closed breech firings) could not be conducted before 1 December 1962. However, higher headquarters had scheduled mid-October 1962 as the decision point on the missile or missiles to fulfill the CVWS and HAW roles. In view of this, and the cost of investigating the TOW for the CVWS role, MICOM recommended that the comparative studies be terminated.

(U) In early September 1962, the Ballistic Research Laboratories agreed with MICOM's position, and recommended that both systems be developed for their respective role. If either TOW or SHILLELAGH were selected to fulfill both the CVWS and HAW roles, the Army would have to accept less than the optimum system for one role or the other. The advantages derived from having the TOW in the HAW role and the SHILLELAGH in the CVWS role were, from the technical

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*The Army Ordnance Missile Command (AOMC) became the Army Missile Command (MICOM) on 1 August 1962.

[58]Final Technical Report, SHILLELAGH Guided Missile System, Vol I of III, System Development History, Aeronutronic Publication No. S-3905, 24 Feb 67, Aeronutronic Div of Philco-Ford Corp., p. 43.

[59]Fact Sheet, Kelly F. Prady, P&P Drte, MICOM, 19 Mar 69, subj: TOW vs SHILLELAGH Comparative Cost Study, 24 Sep 62, atchd to Ltr, Cdr, OTAC, to CG, MICOM, 1 Oct 62, subj: Transmittal of Report. RHA Box 14-131.

point of view, substantive and indicated that development of both systems was warranted.[60]

(U) After considering the issue, the Defense Department, in November 1962, decided to continue the development of both missiles: the SHILLELAGH for the CVWS role and the TOW for the HAW role. A modification to the Aeronutronic contract, executed on 6 November 1962, deleted all work on the HAW program and required the contractor to apply all remaining effort to the applied research program.[61]

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[60] (1) SS, AMSMI-R-530, R&D Drte, 29 Aug 62, subj: Permission to Delete Investigations of TOW for CVWS, w incl: Msg, CG, MICOM, to CG, AMC, DTG 301510Z Aug 62. (2) Ltr, CO, BRL, to CG, AMC, n.d. (circa early Sep 62), subj: TOW/SHILLELAGH - Decision Concerning Initiation of Development, RHA Box 13-168.

[61] (1) SHILLELAGH Missile System Master Plan, SSMO, MICOM, Feb 76, p. 9. (2) MICOM Anl Hist Sum, 1 Jul 62-30 Jun 63, p.143.

CHAPTER V

(U) INDUSTRIAL PROGRAM (U)

(U) The SHILLELAGH missile production began with award of the initial hardware and tooling contract early in November 1964 and continued through May 1971. During this timeframe, the SHILLELAGH underwent significant modifications to extend its range, reduce the missile keyway depth, and adapt it to the M60 tank platform. Product improvements incorporated in the missile after the SHERIDAN/SHILLELAGH weapon system reached the field in June 1967 are covered in the chapter dealing with system deployment. The effort to adapt the SHILLELAGH to the joint US/German Main Battle Tank (MBT-70), which began in October 1965, was discontinued with termination of the MBT-70 program in mid-1972.

Initial Sole Source Procurement

(U) For the first two production buys, covering FY 1965 and FY 1966 hardware requirement, the prime development contractor, Aeronutronic, received sole source contracts. In August 1963, Aeronutronic had been awarded an advance production engineering contract (DA-04-495-AMC-254), for the period 13 September 1963 to 26 October 1964. Following approval of the limited production release in August 1964, MICOM awarded Aeronutronic the first engineering services contract (DA-04-495-AMC-556 [W]), on 26 October 1964.

(U) The initial hardware and tooling contract (DA-04-495-AMC-555 [W]), awarded to Aeronutronic on 9 November 1964, called for the delivery of 1,375 missiles and 98 sets of guidance and control (G&C) equipment, but was later modified to increase the hardware buy to 1,393 missiles and 109 G&C sets. Under this contract, valued at over $30 million, Aeronutronic produced missiles from January 1966 through January 1967 and G&C sets from March 1966 through February 1967.[1]

(U) On 30 December 1965, Aeronutronic received a cost-plus-incentive-fee contract (DA-01-021-AMC-13705 [Z]), for the FY 1966 production of SHILLELAGH missiles. With subsequent additions, the contract, amounting to $76.9 million, provided for 16,552 missiles and 683 sets of G&C equipment. This production contract, as well as all succeeding ones, specified the manufacture of extended range (3,000-meter) missiles. Although Aeronutronic was supposed to complete

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[1](1) MICOM Anl Hist Sum, FY 67, p. 60. (2) Cmt 2, SHILLELAGH PM to Project Director, Research & Engineering Drte, MICOM, 3 Apr 69, subj: Request for Information for Case Study, w incls. (3) SHILLELAGH Fact Book. File: SAIMS Group, Land Combat Cost & SAIMS Analysis Br, Cost Analysis Div, Comptroller.

deliveries in September 1967, shortages of both contractor- and Government-furnished items caused final deliveries to be delayed to March 1968.[2]

(U) The contractor produced the SHILLELAGH components (missile subassemblies, guidance and control group elements, and test equipment) at the Government-owned Lawndale Army Missile Plant in California. Effective 23 November 1964, AMC placed the contractor-operated Lawndale plant under MICOM jurisdiction. Final assembly of the missiles took place at the Iowa Army Ammunition Plant at Burlington, where Mason and Hanger Silas Mason Company, Incorporated, performed as the fuze line operator under a subcontract with Aeronutronic. In August 1966, the Commander of MICOM designated this facility as the SHILLELAGH Missile Assembly Facility, Iowa.[3]

Competitive Procurement

(U) In 1965, both AMC and DA had approved MICOM's plan for competitive procurement of the SHILLELAGH missile, less explosive components. The plan called for the selected second source producer to receive a firm-fixed-price educational buy in FY 1966, which would contain options for part of the FY 1967 missile requirements.[4] Following a highly competitive selection process for the second source producer, MICOM, on 28 March 1966, awarded a $1.5 million fixed-price-incentive-fee contract (DA-01-021-AMC-14299) to the Martin-Marietta Corporation at Orlando, Florida. This contract, termed an educational buy, initially specified the production of 160 missiles and 20 missile subassemblies, but included options for additional hardware. Exercise of the options brought the total number of missiles produced under this contract to 4,960.[5]

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[2](1) MICOM Anl Hist Sum, FY 66, pp. 64-65. (2) MICOM Anl Hist Sum, FY 68, pp. 45-46. (3) AMCTC Item 5236, 20 Apr 67, subj: Recording of SHILLELAGH Product Improvement Change and Applicable Nomenclature: Guided Missile, Surface Attack: MGM-51B (XMGM-51B); Guided Missile, Practice: MTM-51B (XMTM-51B). Recording of Change in Nomenclature: Dummy Guided Missile: M-29 (XM-29); Shipping and Storage Container, Guided Missile: M-555 (XM-555). RSIC. This document later cited with subject shortened to Recording of SHILLELAGH Product Improvement Change and Applicable Nomenclature.

[3](1) Ltr, DCG Land Combat Sys, MICOM, to CG, AMC, 28 Sep 64, subj: Request for Project Approval for Establishment of a SHILLELAGH Staging Area. (2) AMC GO 10, 23 Feb 65. (3) SS, AMSMI-I-243-64, D/P&P, 10 Dec 64, subj: Memorandum of Agreement between US Army Missile Command and US Army Ammunition Procurement & Supply Agency, SHILLELAGH Assembly Plant. (4) DF, Cdr, MICOM, to Distr, 1 Aug 66, subj: Shillelagh Missile Assembly Facility, Iowa. (5) SS, AMSMI-OE-46-66, Installations & Services Office, 22 Jul 66, same subj. (6) MICOM Anl Hist Sum, FY 66, pp. 66-67.

[4]DF, Dep Dir, P&P, to CG, MICOM, 5 Oct 65, subj: Fact Sheet - Commanding General's Visit to USAECOM.

[5](1) MICOM Anl Hist Sum, FY 66, p. 65. (2) SHILLELAGH Fact Book. File: SAIMS Group, Land Combat Cost & SAIMS Analysis Br, Cost Analysis Div, Comptroller.

(U) In FY 1968, both Aeronutronic and Martin/Orlando were awarded production contracts. Martin/Orlando received a letter contract (DAAH01-68-C-1020) in December 1967 for 4,500 missiles; however, on 1 March 1968 that production figure was raised to 7,540. Aeronutronic received a similar contract (DAAH01-68-C-1402) on 1 March 1968, for 4,500 missiles. The production and funds under the latter contract were later incorporated into an existing Aeronutronic contract for guidance and control sets (DAAH01-67-C-0002)*, which eventually included production of 21,846 missiles and 1,132 G&C sets.[6]

(U) According to the competitive procurement plan, when Martin/Orlando reached full competitive status, the entire SHILLELAGH missile program would be procured and funded on a competitive basis. Therefore, early in FY 1969, Aeronutronic and Martin competed for the multiyear production contract, which included a "fly before buy" provision described below. Aeronutronic won that contract, which was awarded on 29 July 1968. The contract (DAAH01-69-C-0059) included procurement of 18,700 missiles in FY 1969, 17,000 in FY 1970, and 17,000 in FY 1971, plus options for additional missiles in FY's 1970-74. In August 1968, Aeronutronic also received a contract (DAAH01-69-C-0489) for 231 G&C sets.

(U) Martin/Orlando delivered the last of the 12,500 missiles under their second source production contracts in September 1969. Meanwhile, in August 1969, the Army recommended to DOD that the decision to buy SHILLELAGH missiles beyond FY 1970 be deferred until major problems with the M60A1E2 tank's turret and gun control systems were resolved. In September 1969, a DOD program change decision cancelled the FY 1971 procurement and deleted $41.6 million from the FY 1971 SHILLELAGH program. One month later, planned procurement of the SHERIDAN vehicles was sharply reduced. A review of the total requirement for missiles to support the SHERIDAN, M60A1E2, and MBT-70 led to the decision in January 1970 that no additional SHILLELAGH's would be procured beyond FY 1970, pending a decision on fielding the MBT-70.

(U) During FY 1970, an additional 203 missiles were procured, bringing the total procurement under the multiyear contract to 35,903 missiles. In August 1970, AMC directed MICOM to terminate the production contract at the completion of the currently funded production and to phase down the production facilities. Aeronutronic delivered the final production missiles in May 1971.[7]

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*Awarded on 10 November 1966, definitized on 28 February 1967.

[6](1) Ibid. (2) MICOM Anl Hist Sum, FY 68, pp. 45-47. (3) MICOM Anl Hist Sum, FY 67, p. 61. (4) MICOM Closed Out Contract Listings, Jul 67 - Jun 69.

[7](1) MICOM Anl Hist Sum, FY 69, p. 37. (2) MICOM Anl Hist Sum, FY 71, pp. 119-20. (3) SHILLELAGH Fact Book. File: SAIMS Group, Land Combat Cost & SAIMS Analysis Br, Cost Analysis Div, Comptroller. (4) SHILLELAGH Missile System Review, "AMC Briefing to GEN Chesarek - 22 Sep 69," SHILLELAGH Project Manager.

Production Summary

(U) Plans called for restarting production when needed to meet additional M60, MBT-70, or other vehicle requirements;[8] however, no additional requirements materialized. The May 1971 deliveries thus completed production of the SHILLELAGH missile. In all, 88,194 missiles were produced—75,694 by Aeronutronic and 12,500 by Martin/Orlando. Table 2 shows the missiles and major items produced by contractor, together with the average and unit costs. Missile deliveries by fiscal year were as follows:[9]

Fiscal Year	Quantity
1966	7,837
1967	7,880
1968	16,188
1969	27,784
1970	20,955
1971	7,550
	88,194

(U) The "fly before buy" provision in the SHILLELAGH multiyear procurement contract, MICOM's first use of this concept, assured the Government that the hardware would perform to specifications before it was accepted. In effect, the arrangement required the contractor to share with the Army the risks of poor production practices—quality and process control—and the possible introduction of substandard vendor parts into the missile during production.

(U) From each production lot of about 1,650 missiles, a representative sample of 18 missiles was randomly selected and divided into four groups (3 groups of 5 missiles each to be tested and 1 group of 3 missiles held as a contingency in case of a "no-test" for any missile in the 3 test groups). The test groups underwent various preflight conditioning by the contractor, such as transportation vibration, temperature shock, drop shock, altitude, and humidity. Missiles that successfully passed the conditioning phase were delivered to White Sands Missile Range for firing from a fixed launcher at a maximum range target. The flight performance of these sample missiles determined Government acceptance of the entire 1,650-missile lot, which represented a production cost of about $3 million.

(U) The criteria permitted lot acceptance with less than three failures in a lot sample. If three, but less than five, failures occurred, a second sample was selected, conditioned, and retested. If the combined failures of both the first and second samples were less than seven, the lot was accepted. With seven or more failures, the contractor had to perform failure analysis and submit rework plans to the Army for approval.

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[8] SHILLELAGH Weapon System Project Transition Plan, 13 Nov 70, atchd to Ltr, Secretary of the Army to CG, AMC, 8 Feb 71, subj: Termination of Project Management for SHILLELAGH Weapon System.

[9] FONECON, M. T. Cagle w Ms Julia Wilson, D/Mat Mgt, Missile Logistics Center, 24 Nov 82.

TABLE 2

SHILLELAGH MISSILE AND MAJOR ITEM PRODUCTION

Item/Contractor	Contract No.	Quantity	Average Cost	Unit Cost
MISSILES				
Aeronutronic	DA-04-495-AMC-555	1,393	$12,318	a/
Aeronutronic	DA-01-021-AMC-13705	16,552	4,036	$4,052
Aeronutronic	DAAH01-67-C-0002	21,846	2,563	2,720
Aeronutronic	DAAH01-69-C-0059	35,903	1,814	1,938
Martin-Marietta	DA-01-021-AMC-14299	4,960	2,649	2,359
Martin-Marietta	DAAH01-68-C-1020	7,540	2,287	2,865
		88,194		
GUIDANCE & CONTROL UNITS				
Aeronutronic	DA-04-495-AMC-555	109	$121,027	a/
Aeronutronic	DA-01-021-AMC-13705	683	36,536	$42,753
Aeronutronic	DAAH01-67-C-0002	1,132	25,789	31,890
Aeronutronic	DAAH01-69-C-0489 b/	231	16,065	20,600
		2,155		
SENSORS b/				
Minneapolis-Honeywell	DAAH01-68-C-2092	489	not reported	$2,269
POWER SUPPLY UNITS b/				
Varo, Inc.	DAAH01-68-C-2100	489	$1,800	$1,793
TRANSMITTER ALIGNMENT TEST SETS				
Aeronutronic	DA-04-495-AMC-555	31	$1,985	NSP*
Aeronutronic	DA-01-021-AMC-13705	84	1,055	NSP
		115		
MISSILE TEST SETS				
Aeronutronic	DA-04-495-AMC-555	14	$80,492	NSP
Aeronutronic	DA-01-021-AMC-13705	20	70,310	NSP
Aeronutronic	DAAH01-67-C-0002	4	85,637	NSP
		38		

*Not separately priced

TABLE 2 (Continued)

SHILLELAGH MISSILE AND MAJOR ITEM PRODUCTION

NOTES:

[a]Unit price not applicable because Contract -555 was cost-plus-incentive-fee.

[b]Aeronutronic Contract -0489 did not include sensors and power units. These items were broken out to Minneapolis-Honeywell and Varo, Incorporated. They were included in previous Aeronutronic contracts for G&C units.

Contracts with Reflectone, Inc., for production of Conduct-of-Fire Trainers, were negotiated by the US Naval Training Service Center at Orlando, Florida, and are not included.

SOURCE: SHILLELAGH Fact Book. File: SAIMS Group, Land Combat Cost and SAIMS Analysis Branch, Cost Analysis Division, Comptroller.

(U) In practice, however, the provisions for rework and retest were not used in the SHILLELAGH production contract, because Aeronutronic met the acceptance criteria in all 22 lots tested. Only 9 of a total of 297 missiles fired failed to hit the target. Before the "fly before buy" provision, the missile rejection rate had ranged from roughly 4 percent to 8.5 percent. The implementation of "fly before buy" gave the contractor added incentive to strengthen his quality control program, resulting in a rapid drop in the missile rejection rate. The Missile Command later used the same concept on other missile systems, such as the TOW, with equally good results.[10]

Engineering/Service Test Program

(U) The integrated engineering test/service test (ET/ST) of the 2,000-meter SHERIDAN/SHILLELAGH system began on 3 March 1965 and continued through 17 February 1967 at the following locations:

Aberdeen Proving Ground, Maryland -------------	Mar 65-Jun 66
White Sands Missile Range, New Mexico ---------	Mar 65-Oct 65
Fort Knox, Kentucky --------------------------	Apr 65-Dec 65
Yuma Proving Ground, Arizona ------------------	Jul 66-Aug 66
Arctic Test Center, Alaska -------------------	Nov 66-Feb 67

The test program, conducted by the US Army Test and Evaluation Command (TECOM), consisted of missile firings under conditions of rain, snow, and fog (limited visibility); electromagnetic radiation and static electrical safety tests; concentrations of carbon-monoxide; keyless missile firings; moving target short range firings (high traverse rate); rapid fire; and firings in desert and arctic environments. Of a total of 265 ET/ST firings, 183 missiles successfully achieved the test objectives, and 17 firings were rated as "no test." The 65 failures were classified as follows: missile and G&C failures - 34; vehicle failures - 1; system limitations - 23; gunner errors - 2; and accuracy failures - 5.[11]

(U) In March 1966, following completion of the bulk of the ET/ST program, TECOM concluded in a comprehensive report that the XM551 SHERIDAN weapon system represented a major advance in design and performance, had demonstrated a wide range of capabilities, and had achieved a high percentage of design goals in firepower, mobility, and versatility. It was also noted that the SHILLELAGH missile provided an increased hit and kill probability over existing tank weapon systems. In general, the system accuracy and armor-defeating capabilities were deemed to meet or exceed the requirements of the established military characteristics. Other conclusions, however, maintained that the total SHERIDAN system was not suitable for Army use because of specified

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[10](1) James G. Hughes, MICOM SHILLELAGH Engineer, "'Fly Before Buy,'" *Army Logistician* (Mar-Apr 73), pp. 34-36. (2) MICOM Anl Hist Sum, FY 70, p. 33. (3) MICOM Anl Hist Sum, FY 71, p. 120.

[11]SHILLELAGH Missile System Agenda and Supporting Data for Special In-Process Review, 29-30 Nov 67, SHILLELAGH PMO, pp. 34-37.

safety, durability, reliability, performance, training, and maintenance limitations. In addition, the lack of a satisfactory conventional capability represented a significant tactical restriction on the system.[12]

(U) In a follow-on ET/ST report issued in May 1967, TECOM asserted that the reliability of the SHILLELAGH missile and guidance system was found to be unsatisfactory and, as a result, the full potential of the system was not being realized. Indications pointed to a need for design changes, better quality control, and further testing. Tests had demonstrated that the missile system could not be fired at night with the passive sights provided in the SHERIDAN vehicle. Furthermore, the system's performance in rain was marginal since the missile could not be controlled to the maximum visible range of the gunner. Tests had also revealed that carbon-monoxide accumulation in the SHERIDAN turret, as a result of SHILLELAGH firings with the hatches closed, constituted a safety hazard.[13] Other improvements required to make the system suitable for Army use included a means to alert the gunner to obstacles along the missile flight path (because of a line-of-sight deviation at ranges less than 500 meters); an increase in the life of the gun tube and gun/launcher seal; improved ballistic protection in the missile transmitter unit; a reduction in the necessity to frequently bleed the recoil system; and a reduction in the amount of electrical power drawn when the turret systems were in standby operation.

(U) The Combat Developments Command agreed with TECOM that the noted deficiencies should be corrected before release of the system for troop use. Since the system had already entered production, TECOM recommended that early production models undergo confirmatory tests to verify the corrective action. In addition, TECOM recommended that waivers to the military characteristics be requested to accept limitations in the rate of aimed fire, slope climbing and swimming ability, integral capability of replacing optical components, tube changing time, firing on the move, and training time.[14]

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[12] Ltr, Cdr, TECOM, to CG, WECOM, 15 Mar 66, subj: Report of Engineering and Service Test of Sheridan Weapon System, XM551, USATECOM Project No. 1-4-2521-(U).

[13] Ltr, Cdr, TECOM, to CG, AMC, 15 May 67, subj: Ninth Partial Report on Integrated Engineering and Service Test of Armored Reconnaissance/Airborne Assault Vehicle, XM551 (Sheridan/Shillelagh)(Missile and Turret Phase), Report No. DPS-2156, USATECOM Project Nos. 1-4-2521-06/-08, RDT&E Project No. 1X57919-1D392, w incl: Report, same subj, James W. Fasig & Wesley G. Swank, Feb 67, pp. vii, 11-13, II-1.

[14] Ltr, Cdr, CDC, to CRD, DA, 25 Apr 66, subj: Proposed Type Classification Standard A of the Sheridan Weapon System, XM551, w Appendix A, incl to AMCTC Item 4661, Meeting No. 6-66, 23 Jun 66, subj: SHERIDAN WEAPON SYSTEM, Reclassification from Limited Production to Standard-A Type. RSIC.

Standard A Type Classification

(U) The process of classifying the system as Standard A began in March 1966, when the ET/ST (except for desert and arctic testing) was essentially completed. This testing revealed certain deficiencies and shortcomings, which were being corrected, and the need for certain waivers, which the Army Materiel Command characterized as relatively minor in nature and representing necessary tradeoffs to assure meeting the exacting requirements of other more essential characteristics. The AMC asserted that the XM551 SHERIDAN with the SHILLELAGH missile would provide the Army with a major advancement in tank-like weapon systems and that the system was suitable for Standard A type classification.

(U) While acknowledging that the Army had a firm Southeast Asia requirement for the SHERIDAN with its conventional 152mm ammunition, both the Combat Developments Command and the Continental Army Command expressed concern about deficiencies in those munitions and maintained that the problems should be overcome before designation of the system as Standard A. The SHERIDAN Project Manager argued that failure to classify the system as standard could jeopardize production funds, dissipate the momentum built up in the program, and lead to program stretchout and increased costs. The Test and Evaluation Command stated that the corrections being implemented appeared to overcome the deficiencies found in the ET/ST.[15]

(U) On 21 May 1966, DA approved Standard A type classification for the General SHERIDAN weapon system, which included the SHILLELAGH missile system components. Excluded from the type classification approval were the 152mm conventional ammunition, trainers, grenade projector, and the gunner's passive periscope. As part of the type classification action, DA approved the requested waivers pertaining to maximum vehicle width, amphibious operation, quietness of operation, time to replace gun-launcher tube, rate of fire, replacement of optical components from within the turret, and tube life. The items classified as Standard A were identified as follows:[16]

Armored Reconnaissance/Airborne Assault Vehicle: Full Tracked, 152mm, M551 (General Sheridan)
Guided Missile, Surface Attack: MGM-51A
Guided Missile, Practice: MTM-51A
Test Set, Guided Missile: AN/TJM-1
Alignment Set, Infrared Transmitter, Guided Missile Remote Control System: M45.

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[15] (1) Ltr, SHERIDAN PM, to OCRD, DA, 29 Mar 66, subj: In-Process Review of the XM551 Armored Reconnaissance Airborne Assault Vehicle (General Sheridan) - Prior to Planned Type Classification as Standard A, incl to AMCTC Item 4661, Meeting No. 6-66, 23 Jun 66, subj: SHERIDAN WEAPON SYSTEM, Reclassification from Limited Production to Standard-A Type. RSIC. (2) Excerpts from SHERIDAN In-Process Review and Type Classification.

[16] AMCTC Item 4661, Meeting No. 6-66, 23 Jun 66, subj: SHERIDAN WEAPON SYSTEM, Reclassification from Limited Production to Standard-A Type; w incl: 1st Ind, CRD, DA, to CG, AMC, 21 May 66 on Ltr, SHERIDAN PM to OCRD, DA, 29 Mar 66, subj: In-Process Review of the XM551 Armored Reconnaissance Airborne Assault Vehicle (General SHERIDAN) - Prior to Planned Type Classification as Standard A. RSIC.

Desert and Arctic Testing

(U) The Test and Evaluation Command conducted the desert phase of the ET/ST at Yuma Proving Ground, Arizona, from 1 June through 7 September 1966. The overall hit performance of the SHILLELAGH missiles against both stationary and moving targets at a 2,000-meter range was considered satisfactory. Accuracy of the conventional 152mm rounds, however, did not meet established criteria. Problems peculiar to desert operation of the M551 SHERIDAN vehicle included excessive transmission and coolant temperatures, unacceptable air cleaner performance, and an unsatisfactory ratio of total maintenance man-hours to vehicle operating hours. The test results indicated that the system was only marginally acceptable for operation in a desert environment, and identified several essential military characteristics that were not met. The TECOM recommended that changes be incorporated in the SHERIDAN vehicle to correct the deficiencies and as many of the shortcomings as possible, and that a production vehicle be provided for a check test under desert summer conditions.[17]

(U) The arctic portion of the ET/ST, conducted at Fort Greely, Alaska, during the winter of 1966-67, confirmed previous assessments that the SHILLELAGH missile system could not be effectively used below -20°F to -25°F. In the arctic test, 14 MGM-51A missiles and 6 XMGM-51B extended range missiles were fired under temperature conditions ranging from a high of -3°F to a low of -37°F, at both fixed and moving targets at ranges of 1,000 to 3,000 meters. Only 7 of the 20 missiles were successful. Primary causes of the 13 failures included ice fog formation below -25°F, gunner visibility problems, and missile component failures. Another problem seemingly peculiar to arctic firing was flash-back, a phenomenon in which flash or flame emitted from the breech when it opened after the missile fired.

(U) The ice fog resulted from the freezing of water vapor which was the product of combustion from both the rocket motor and the gas generator grain. The infrared command data was unable to penetrate this ice fog and the gunner lost control of the missile. Following the arctic development tests in 1962-63, CONARC had been formally notified of this limitation and replied that no future effort should be expended to extend the lower temperature limit. The DA staff also received information on the limitation during the in-process review leading to the standard A classification in May 1966.

(U) In April 1967, TECOM reported that the SHERIDAN/SHILLELAGH was unsuitable for arctic use. In addition to problems with the missile, they reported deficiencies on the vehicle engine, track, winterization kit, gun/launcher, human factors, and overall system reliability. The system would have to undergo

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[17]Ltr, Cdr, TECOM, to CG, AMC, 7 Apr 67, subj: Final Report of Integrated Engineering/Service Test (Desert Summer) of the Armored Reconnaissance/ Airborne Assault Vehicle, M551 (Sheridan/Shillelagh), USATECOM Project No. 1-4-2521-70, RDT&E Project No. 1X579141D392, w incl: Final Report, Philip J. Moravec & David F. Faulkner, 1LT, Armor, Oct 66, pp. iii, 7, 9-10, 40-41, 92-93.

a check test under arctic conditions after improvements to correct the deficiencies.[18]

Confirmatory I Test Program

(U) The primary objectives of the 173-round Confirmatory I test program, conducted by TECOM during CY 1967, were to assure the adequacy of corrective actions taken after the ET/ST's and to demonstrate the M551 SHERIDAN/SHILLELAGH system's compatibility with extended range (3,000-meter) missiles. Of the 173 firings, 138 were conducted at Fort Knox, Kentucky, 24 at Aberdeen Proving Ground, Maryland, and 11 at the US Army Tropic Test Center in the Panama Canal Zone. In addition to the primary test program objectives, the firings at Fort Knox evaluated the conduct-of-fire trainer and the shallow key missile configuration.

(U) Hardware reliability—defined as the probability that the missile and G&C system would function properly—was recorded as 90 percent. However, the probability that the system as a whole, to include the gunner, track vehicle, and missile system, would hit a 7-1/2 foot by 7-1/2 foot target—called system reliability—was only 57 percent.[19]

The Extended Range SHILLELAGH Missile

(U) The 1958 document initiating the Combat Vehicle Weapon System Project described requirements for both a midrange and a long-range missile. The midrange project resulted in development of the basic 2,000-meter MGM-51A SHILLELAGH missile. In 1961, after DA reiterated the requirement for the long-range system, the Army and Aeronutronic considered a number of approaches to fulfilling the requirement for a follow-on system which would increase the

[18](1) Final Report, SHERIDAN-SHILLELAGH Arctic ET/ST Program, Aeronutronic Div, Philco-Ford Corp. Publication No. C-4208, 12 Oct 67, pp. 1, 3, 43. (2) Memorandum for DCG, AMC, fr SHILLELAGH PM, circa Feb 67, subj: Arctic SHILLELAGH Missile Test Firings, w incl: Summary of SHERIDAN/SHILLELAGH ET/ST Arctic Phase. (3) Ltr, Cdr, TECOM, to PM, SHERIDAN, 17 Sep 69, subj: Final Report, Product Improvement Test of Sheridan Weapon System, M551, Under Arctic Winter Conditions, USATECOM Project No. 1-VC-080-551-005 (Formerly 1-4-2528-60).

[19](1) SHILLELAGH Missile System, Agenda and Supporting Data for Special In-Process Review 29-30 November 1967, SHILLELAGH PMO, pp. 36-37. (2) SHILLELAGH Missile System Review, "AMC Briefing to GEN Chesarek - 22 Sep 69," SHILLELAGH PM. (3) Project Manager's Annual Review, atchd to DF, Chf, Sys Engrg Div, SHILLELAGH Project Office, to Program Management Ofc, SHILLELAGH Project Office, 9 May 67, subj: Project Manager's Annual Review.

SHILLELAGH's effective range by 50 percent without a significant degradation in hit probability.[20]

(U) The Army Ordnance Missile Command interpreted the long-range system as one superior to the midrange missile, which would replace that missile in the 1970's. In the 1961-62 timeframe, the Army Ordnance Missile Command considered several programs as having applicability to the long-range requirements. The optical contrast seeker then being developed at the Army Ordnance Missile Command had the most promise of fulfilling the technical guidance requirements with a substantial improvement in firepower and a capability for indirect fire. Plans at that time were to extend this effort to include an optical correlation seeker. In April 1963, MICOM tasked Aeronutronic to investigate increasing the range capability of the basic 2,000-meter SHILLELAGH to 3,000-3,500 meters. For the next 12 months, the prime contractor and MICOM considered various approaches to the engineering problems involved in achieving that objective.[21]

(U) On 3 April 1964, personnel of the SHERIDAN/SHILLELAGH Project Office and Aeronutronic briefed the Assistant Secretary of the Army (Research and Development) on a program that would yield the extended range. The range increase could be obtained by minimum changes to the missile; however, the modifications presented some disadvantage to the user, in that the missile would be slightly longer and heavier. During the briefing, two other more elaborate and more expensive programs were presented, which would yield higher performance and/or lesser weight and length. The Department of the Army selected the minimum change approach, which would cost about $7.42 million, and released $1.3 million to initiate the program in June 1964. The following month, the SHERIDAN/SHILLELAGH Project Office's Missile Engineering Division at MICOM authorized Aeronutronic to begin work on the extended range missile under the current R&D contract (DA-04-495-AMC-309). In FY 1965, $3,328,000 was expended on the improvement program.[22]

(U) The extended range product improvements involved minimum changes to the missile and missile guidance set group. A longer-burning gas generator was added to the missile to allow increased missile flight time. This change

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[20](1) OTCM 36753, 13 Feb 58, subj: Initiation of Combat Vehicle Weapon System Project. RSIC. (2) OTCM 37998, 17 Nov 61, subj: Combat Vehicle Weapon System (Long Range). RSIC. (3) SHILLELAGH Extended Range Study, 7 Aug 64, SHILLELAGH Lead Lab, Electromagnetics Lab, R&D Drte, MICOM. RHA Box 13-103.

[21](1) Ltr, CG, AOMC, to CofOrd, 10 May 62, subj: Research Activities Pertinent to the Armored Combat Vehicle Weapons System, Long Range. (2) Final Technical Report, Extended Range SHILLELAGH RDT&E Program, 1 Feb 66, Aeronutronic Publication No. C-3437, pp. v, 2. RHA Box 13-103. (3) SHILLELAGH Extended Range Study, 7 Aug 64, SHILLELAGH Lead Lab, Electromagnetics Lab, R&D Drte, MICOM. RHA Box 13-103.

[22](1) MFR, Dep PM, SHILLELAGH, 10 Nov 64, subj: Extended Range Program Recommendation. RHA Box 13-103. (2) AMCTC Item 5236, 20 Apr 67, subj: Recording of SHILLELAGH Product Improvement Change and Applicable Nomenclature.

caused an increase of 1.7 inches in length and 2.17 pounds in weight, bringing the length to 45.4 inches and weight to 61.28 pounds. A lengthened wiring harness with improved insulation and thermal insulators was added in the aft section. Wiring changes were made in two modules of the signal data converter (vehicle-mounted G&C equipment), which extended recycle time to permit missile control to the 3,000-meter range. A new module was also added to improve accuracy beyond 2,000 meters, and the missile test set was modified to accommodate either the 2,000-meter or 3,000-meter missile. None of these changes affected the accuracy or kill probability of the missile below 2,000 meters.[23]

(U) In May 1965, MICOM awarded Aeronutronic a $943,041 cost-plus-fixed-fee contract (DA-01-021-AMC-12293) for flight tests of the extended range missile. From May 1965 through January 1966, Aeronutronic conducted 26 development flight tests at WSMR. In this test series, 10 missiles were fired from the SHERIDAN vehicle and 16 from the M60A1E1 vehicle against both moving and transient targets. Before firing, the missiles underwent various environmental conditioning, such as high and low temperatures, temperature shock, transportation and handling shocks, sand, dust, humidity, fungus, salt spray, and immersion. The 26 flights resulted in 23 successes and 3 partial successes, thus substantiating the 3,000-meter capability of the missile.[24] The performance and physical characteristics of the R&D missile are shown in Table 3.

(U) At the extended range SHILLELAGH in-process review on 24 August 1965, the Project Manager reported that the minor changes in the missile and guidance and control equipment to provide the 50 percent increase in range would be incorporated as product improvements in the second year (FY 1966) production contract. The Project Manager and the Commander of MICOM agreed that introducing the improvements in the second year buy was the most economical approach, since it would eliminate the need for a costly retrofit program. The modifications would also be incorporated into the M60 ET/ST missiles and G&C equipment. As a result of production engineering refinements in gas generator manufacturing, the production cost of the improved missile would be no greater than that of the shorter range missile.

(U) In October 1966, DA approved an AMC request to replace the 2,000-meter missile (MGM-51A and MTM-51A) with the product-improved 3,000-meter missile. This action, recorded by the AMC Technical Committee on 20 April 1967, classified the extended range missile as Standard A and assigned the designations MGM-51B for the tactical missile and MTM-51B for the training missile. The

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[23](1) Ibid. (2) Final Technical Report, Extended Range SHILLELAGH RDT&E Program, Aeronutronic Publication No. C-3437, 1 Feb 66, pp. vii, viii. RHA Box 13-103.

[24](1) MICOM Anl Hist Sum, FY 66, p. 65. (2) SHILLELAGH Fact Book. File: SAIMS Group, Land Combat Cost and SAIMS Analysis Br, Cost Analysis Div, Comptroller, MICOM. (3) AMCTC Item 5236, Meeting No. 4-67, 20 Apr 67, subj: Recording of SHILLELAGH Missile Product Improvement Change and Applicable Nomenclature.

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TABLE 3
(U) EXTENDED RANGE MISSILE PERFORMANCE AND PHYSICAL CHARACTERISTICS
(as of February 1966)

	RDTE REQMT	ACTUAL	REMARKS
Range Capability (meters)			
-25°F	2900	2950	
+25°F	3150	3240	+25°F was peak of curve in RDTE
+145°F	2930	3170	
Stationary Target Hit Probability	86% (Goal)	86%	at +70°F - 3000-meter range
Moving Target Hit Probability	83%* (Goal)	83%**	at +70°F - 3000-meter range
Loading Weight (pounds)	62.5	61.28	2.17 lbs. above the 2000-meter missile
Loading Length (inches)	45.4	45.4	1.7 inches longer than the 2000-meter missile

*Hit Probability not stated in RDTE; derived from overall mission reliability of 82% in RDTE.

**At 13 MPH crossing velocity.

SOURCE: Final Technical Report, Extended Range SHILLELAGH RDTE Program, Aeronutronic Publication No. C-3437, 1 Feb 66, p. viii. RHA Box 13-103.

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3,000-meter SHILLELAGH would be the primary weapon for the M551 SHERIDAN, the M60A1E1 tank, and the MBT-70.[25]

The Shallow Key Missile Program

(U) Another significant change applied to the SHILLELAGH missile during the production phase was a reduction in the size of the missile key. The original missile had a longitudinal key, .241 inch wide, .130 inch deep, and 10 inches long, located just behind the warhead. The key, which fit into an interfacing slot or keyway in the gun tube, prevented the missile from rolling as it traveled down the gun tube. It was also used during loading to index the missile in the gun tube so that the missile gyros could be properly oriented.

(U) Early results of the SHERIDAN/SHILLELAGH ET/ST revealed that the gun tube life was limited by structural cracks, which originated in the missile keyway at the muzzle end of the gun tube. After conducting gun life tests, TECOM concluded that the safe tube life was limited to firing 100 rounds of conventional ammunition. Following modifications and additional testing, TECOM raised the safe life of the tube to 200 rounds. The May 1966 type classification action for the SHERIDAN had established 200 rounds as the minimum acceptable life for the tube, while a 500-round life was desired.

(U) Since the gun tube life was limited by cracks in the tube, as opposed to the usual erosion, the SHERIDAN and SHILLELAGH Project Offices, along with Watervliet Arsenal, initiated a joint program to correct the cracking problem. They investigated four alternatives: (1) Introduce the SHERIDAN into the field with a reduced gun service life, (2) add material to the gun, (3) make changes to the missile/launcher interface to reduce the concentration of stress in the keyway, and (4) add a lightweight collar to the muzzle of the gun tube. They decided that a combination of the latter two alternatives was the most practical, economical, and desirable from an overall weapon system standpoint.

(U) To reduce the stresses in the gun tube missile keyway, the depth of this keyway was reduced so that it was no deeper than the existing rifling grooves and thus did not extend into the parent metal of the gun tube. An added incentive for reducing the missile groove in the gun came from development of the MBT-70, which would use a kinetic energy round that would induce much higher stresses in the gun tube than either the SHERIDAN or the M60A1E1 gun. Watervliet Arsenal, in conjunction with the MBT-70 Project Office, had determined that the missile guide keyway in the MBT gun, the XM150, should not extend below the rifling grooves.

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[25] (1) Ibid. (2) MICOM Anl Hist Sum, FY 66, p. 67. (3) SS, AMCPM-SM-9-66, SHILLELAGH PM, 3 Sep 65, subj: Extended Range SHILLELAGH. (4) Ltr, CG, MICOM, to CG, WECOM, 10 Sep 65, subj: Extended Range SHILLELAGH.

(U) In July 1965, MICOM requested Aeronutronic to investigage the feasibility of reducing the height of the missile key and the depth of the gun tube keyway, and to determine the optimum configuration of the interface between the key and the keyway. The contractor selected the optimum configuration based on pull tests of various key configurations through a gun tube with multiple keyway configurations. The design was confirmed by a four-missile, short-range flight test program. The optimum key configuration reduced the height of the key from .130 inch to .075 inch, and incorporated a 3° taper extending back about 1/2 inch on each side of the forward end of the key. The optimum keyway had straight or vertical sidewalls and was cut no deeper than the rifling grooves.[26]

(U) In July and August 1966, six shallow key missiles were successfully flown at Aberdeen Proving Ground from a shallow keyway gun tube that had been worn with 150 companion round firings. All firings in this test series were successful, with the impact points falling within the standard 7-1/2 square-foot target. Data from these firings and the pull tests indicated that the shallow key missile had a high probability of success, but additional verification testing would be necessary. As an interim measure, the SHILLELAGH Project Manager, in mid-August 1966, recommended that the SHERIDAN and M60 gun tubes be machined with a straight sidewall, deep slot, which would be compatible with either the standard key or shallow key missile. The SHERIDAN Project Manager declined to implement a reduced keyway into production, however, until the conventional ammunition could be tested with the reduced keyway gun. In addition, TECOM requested that tests be conducted to confirm the safety of the reduced missile key/reduced keyway gun.

(U) During January and February 1967, Aeronutronic successfully fired six shallow key missiles from a standard deep keyway gun tube at the White Sands Missile Range. On the basis of these and previous firings, the SHILLELAGH Project Manager concluded that missile performance during shallow key/deep keyway tube firings was no different from that of the shallow key/shallow keyway tube firings. Consequently, he advised the M60, SHERIDAN, and MBT-70 Project Offices of his intention to cut the shallow key into missile production upon completion of the safety tests and receipt of a safety release from TECOM. All three projects concurred in the action; however, the SHERIDAN Project Manager planned to withhold the shallow keyway from production until a number of other gun improvements under development could be incorporated concurrently. The M60 Project Office agreed to implement the shallow keyway into their production after TECOM issued the safety release.

(U) The desired safety tests, as outlined by TECOM, consisted of mechanically jamming shallow key missiles into a gun tube to determine what would happen if the missile should jump out of the tube keyway and jam inside the gun tube during firing. In the first safety test, conducted at Redstone Arsenal on 10 January 1967, the jammed missile was successfully fired and impacted a

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[26](1) SHILLELAGH Missile System Agenda and Supporting Data for Special In-Process Review 29 & 30 November 1967, SHILLELAGH PM, pp. 90, 92, 94. (2) Final Technical Report, Reduced Key Flight Test Program, SHILLELAGH Guided Missile System, Aeronutronic Publication No. C-3968, 28 Feb 67, pp. 1, 3, 15.

steel plate located 250 feet from the gun muzzle. Following two successful firings at Aberdeen in April 1967, TECOM issued a safety release for firing shallow key missiles from either a shallow or deep-keyway gun tube. The SHILLELAGH Project Manager, on 25 May 1967, thus initiated standard change procedures to incorporate the shallow key design into missile production. At the same time, the SHILLELAGH, SHERIDAN, and M60 Project Managers approved a TECOM plan to retrofit existing SHERIDAN Type I confirmatory missiles and M60A1E1 ET/ST missiles to the shallow key configuration for further confidence testing.

(U) At the special in-process review, held 29-30 November 1967, the SHILLELAGH Project Manager reported that the shallow key improvement would in no way degrade the performance of the SHILLELAGH missile fired from either a deep keyway or a shallow keyway gun tube. Moreover, the combination of the shallow key missile and shallow keyway gun tube was expected to prolong the life of the gun tube and result in overall cost savings. The review attendees, including representatives of CDC, AMC, ATAC, TECOM, Picatinny Arsenal, and the Army Armor and Engineering Board, agreed with the SHILLELAGH Project Manager's recommendation that the shallow key missile be considered a product improvement and that it be type classified as Standard A.[27]

(U) The Department of the Army approved the shallow key missile as Standard A in January 1968. In the same action, the designation MGM-51C was assigned to the tactical missile and MTM-51C to the training missile.[28] Conversion of the existing stock of MGM-51B deep key missiles to the MGM-51C shallow key configuration began at the Anniston Army Depot in August 1968 and was completed in February 1969.[29]

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[27](1) Ibid., pp. 1, 3, 15. (2) SHILLELAGH Missile System Agenda and Supporting Data for Special In-Process Review 29-30 November 1967, SHILLELAGH PMO, pp. 94, 96, 98. (3) Summary Report, Shallow Key, Deep Keyway Compatibility Series, SHILLELAGH Production Engineering Evaluation Flight Test Program, Aeronutronic Publication No. C-3997, 3 Mar 67, pp. 1, 3-5, 15-17, 27. (4) Ltr, SHILLELAGH PM to CG, WECOM, 17 Aug 66, subj: SHILLELAGH Shallow Key Program. (5) Msg, CG, MICOM, to CG, WECOM, DTG 201630Z Jan 67, subj: Implementation of the Shallow Key on SHILLELAGH Missiles. (6) MFR, SHILLELAGH PM, 24 May 67, subj: Implementation of Shallow Key. (7) Ltr, Cdr, TECOM, to CG, AMC, 3 Aug 67, subj: Final Report on Engineering Test of Shallow Key Shillelagh Missile (Safety Test), RDT&E Project No. 1X579191D392, USATECOM Project No. 1-4-2521-16, w incl. (8) Ltr, SHILLELAGH PM, to Distr, 20 Dec 67, subj: SHILLELAGH Missile System In-Process Review (IPR), w incl: Official Minutes.

[28]AMCTC Item 5895, 22 Mar 68, subj: Recording of DA Approval of Special In-Process Review, SHILLELAGH Missile System, DA Project 1X579191D334 (AMCMS 5584.12.251). RSIC.

[29](1) DF, SHILLELAGH PM to Proj Dir, Research and Engineering Drte, MICOM, 3 Apr 69, subj: Request for Information for Case Study, w incl: History of the SHILLELAGH Missile System. (2) SHILLELAGH Missile System Master Plan, SSMO, MICOM, Feb 76, p. 16.

(U) Parallel with the shallow key studies and tests, the contractor had investigated a missile configuration with the longitudinal key removed. In June and July 1965, two keyless missiles were flown at WSMR. The in-barrel roll of these missiles was about the same as that of the keyed missiles. These results prompted the testing of 37 additional keyless missiles from early October 1965 to mid-March 1966 during the SHERIDAN/SHILLELAGH ET/ST program. On several flights, the missile roll approached the point where it would interfere with the missile gyros. If the roll excursion angle exceeded 29°, both missile gyros would tumble and the missile would lose attitude reference in pitch, yaw, and roll.

(U) To evaluate the extremes of roll which could be expected, Aeronutronic conducted eight "worst case" keyless missile firings in October and November 1966. These missiles were designed and fabricated to bring the probable major contributors to in-barrel missile roll to their extreme tolerance limits. Four missiles were fired from an XM162 gun and four from a longer, simulated XM150 gun (for use on the MBT-70). All the missiles functioned normally and peak roll excursions were below the gyro tumble angle, although several approached that point. As expected, the missile roll deviations were, on the average, greater on the flights from the longer MBT-70 XM150 gun. Further testing of the keyless missile was suspended, pending final design of the MBT-70 automatic loader and flight testing from that gun.[30] The MBT-70 program was later terminated.[31]

Adaptation of SHILLELAGH to the M60 Tank

(U) In the 1960's, the main battle tanks deployed by the Army were the M60 and the improved M60A1. The M60, first produced in 1959, was the first US tank to mount a 105mm gun and to be equipped with a diesel engine. The M60A1 model, released for production in 1962, incorporated improvements in ballistic protection, which enhanced its survivability on the battlefield but increased its weight to nearly 53 tons, some 2 tons heavier than the M60. It will be recalled that, in 1961, serious consideration was given to mounting the SHILLELAGH on the M60 tank instead of the XM551 SHERIDAN vehicle to expedite availability of the weapon system.* The idea of an M60/SHILLELAGH system again surfaced 2 years later, this time as a means of providing an improved interim tank pending availability of the MBT-70.

(U) At the request of DA, the Combat Developments Command, in 1963, conducted a study to determine the combat effectiveness of the 105mm gun/SHILLELAGH combination on the main battle tank. This study resulted in a recommendation to use the SHILLELAGH as the primary armament on the M60 series

*See above, pp. 58-62.

[30] (1) Final Technical and Test Report, Keyless SHILLELAGH Program, Aeronutronic Publication No. U-4066, 12 May 67, pp. 1, 4-6, 8. (2) SHILLELAGH Missile System, Agenda and Supporting Data for Special In-Process Review 29 & 30 November 1967, MICOM, p. 35.

[31] See below, pp. 96-97.

tank. In 1964, the Army Weapons Command presented to DA four turret concepts for mounting the SHILLELAGH weapon system. Subsequently selected for use was the compact turret design which reduced the frontal exposed area by 40 percent and incorporated a completely new main armament and fire control system. The turret mounted the existing 152mm gun/launcher, used on the SHERIDAN vehicle, and was also designed to accommodate the 152mm kinetic energy round and the laser range finder when they became available. The new M60A1E1 system would have almost twice the armor penetration of the M60A1 tank and would weigh about 56 tons when combat loaded.

(U) The Department of Defense approved a program change proposal for the M60/SHILLELAGH program in December 1964. With AMC approval of the engineering development program in March 1965, Aeronutronic was awarded a contract (DA-01-021-AMC-12009) to adapt the SHILLELAGH to the M60 tank. In the engineering development tests of the M60A1E1, conducted from October 1965 through January 1966, 7 standard range and 16 extended range missiles* were fired from the M60A1E1 tank. All but 3 of these 23 firings were successful, confirming the compatibility of the SHILLELAGH missile with the compact turret. None of the failures were attributed to use of the newly designed turret or the M60A1E1 launch vehicle.

(U) Because of the urgent requirement for an improved interim tank for use until the MBT-70 became available, the M60/SHILLELAGH program was accelerated to meet a planned deployment date of November 1967. The Army Weapons Command (WECOM) thus initiated production engineering on the M60A1E1 tank only 6 months after the R&D phase began. In December 1965, DA authorized procurement of long leadtime turret components. The Army Weapons Command awarded the Chrysler Corporation a contract for the long leadtime items in January 1966, and DA approved limited production for the M60A1E1 4 months later. (Initial tactical deployment of the M60/SHILLELAGH system, however, ultimately slipped to early 1975 because of major technical problems.)

(U) Engineering and service tests of the M60A1E1 began in January 1966 and continued until the fall of 1966, when they were suspended because of problems with the tank and the conventional ammunition. To correct the deficiencies, WECOM developed a closed breech scavenger system to remove the hazards of the combustible ammunition case, developed and tested a laser range finder, and modified and retested the components that failed to meet requirements. It was not until September 1968 that TECOM issued a rapid fire safety release for the system. Further testing following this release revealed a major problem with turret/gun control system reliability, raising questions about the adequacy of the fundamental design. In January 1969, the Army

*These firings were also part of the engineering development program for the extended range missile. During the same period, 10 extended range missiles were fired successfully from the SHERIDAN vehicle.

Materiel Command directed that engineering/service testing and vehicle assembly be halted until the problems could be resolved.[32]

(U) After further improvements were incorporated into the system, a special in-process review (IPR) was conducted in mid-October 1970. Representatives from CDC, AMC, CONARC, and the Logistics, Doctrine, and Systems Readiness Agency agreed that the modified M60A1E2 tank was ready to proceed into ET/ST. In those test firings, conducted from December 1970 through September 1971, the M60A1E2 generally met or exceeded the conventional round hit performance criteria. The SHILLELAGH missile, in 338 firings from the M60A1E2, met or exceeded accuracy criteria, as shown below. Criteria established for the missile were 80 percent hit probability at 0 to 2,000 meters range and 70 percent hit probability at 2,000 to 3,000 meters range.[33]

M60A1E2/SHILLELAGH Missile Firing Results

Target	Range (meters)	Rounds Fired	Hits	Percent Hits	Hit Probability
Stationary	1410-3000	68	62	91	85
Moving	1000-2225	101	90	89	84
Moving/ Stationary	1000-3000	169	152	90	86

(U) On 29 September 1971, TECOM issued a statement of suitability for the M60A1E2 tank. A development acceptance IPR, held on 12 October 1971, recommended that the program continue through retrofit production, which would include 540 tanks and 32 turret trainers. Following ASARC/DSARC* approval of the recommendation, the Deputy Secretary of Defense, on 4 November 1971, approved the program subject to certain constraints, including an intensified confirmatory

*Army Systems Acquisition Review Council/Defense Systems Acquisition Review Council.

[32](1) Formal Review of M60A1E2 Tank, Presentation by LTC Paul W. Simpson, M60 Tanks PM, to CG, AMC, 1 Oct 69, pp. 1-6. (2) Ltr, M60 Tanks PM, to CG, MICOM, 21 Jul 71, subj: Master Schedule for the M60A1E2 Tank, w incl. (3) Summary Briefing, LTC Spencer R. Baen, SHILLELAGH PM, Feb 66. (4) SHILLELAGH Missile System Agenda and Supporting Data for Special In-Process Review 29-30 November 1967, at MICOM, pp. 21-22. (5) MICOM Anl Hist Sum, FY 66, p. 66. (6) Ltr, Cdr, TECOM, to M60 Tanks PM, 8 May 69, subj: USATECOM Project No. 1-4-2040-36, Service Test of Tank, Combat, Full-Tracked, 152mm Gun, M60A1E2 with Closed Breech Scavenger System and Laser Range Finder, RDT&E Project No. 1M542706D351. (7) Anl Hist Sum, WECOM, FY 69, p. 218.

[33](1) Ltr, MG John R. Guthrie, Chairman, M60A1E2 Special In-Process Review, to CRD, DA, 1 Apr 71, subj: Minutes of M60A1E2 Special In-Process Review. (2) Extract from Tab B, Engineering Test/Service Test Results, Drte for Plans and Analysis' Summary of CDC Armor Agency's Evaluation of the M60A1E2 Tank, 24 Sep 71, incl to DF, Chf, Concept, Doctrine & Plans Div, Drte for Plans & Analysis, MICOM, to Land Combat Special Items Manager, 17 Feb 72, subj: USACDC Armor Agency's Evaluation of the M60A1E2 Tank - 24 Sep 71.

troop test. On 8 November 1971, DA approved type classification as Standard A for the M60A1E2 tank, which was redesignated as the M60A2. The Chrysler Corporation received the retrofit production contract in late November 1971. Delivery of the first retrofitted M60A2 tank slipped from October 1972 to February 1973, because of a labor strike at one of the subcontractor plants.[34] Tactical deployment of the M60A2/SHILLELAGH system to Europe was then delayed until early 1975, primarily because of problems with the main gun recoil system.[35] Meanwhile, on 29 June 1972, the Army Materiel Command transferred the overall responsibility for management and procurement of tanks and associated combat vehicles from WECOM to the US Army Tank-Automotive Command (TACOM).[36]

The MBT-70/SHILLELAGH Program

(U) In August 1963, the United States and West Germany initiated a joint development program for the Main Battle Tank-70 (MBT-70). The new 51-ton computer-age vehicle, called the "thinking man's tank," was designed to operate underwater or during nuclear attack and to fire either high energy conventional ammunition or the SHILLELAGH guided missile. The body of the tank could be raised or lowered, and tilted from front to back or from side to side for tactical or mobility reasons. The armament system featured a stabilized fire control system, a laser rangefinder, and a panoramic telescope for greater accuracy. The development contractors for the MBT-70 were the Allison Division of General Motors Corporation for the US and the German Development Corporation for West Germany. In October 1965, MICOM awarded a contract (DA-04-495-AMC-0959) to Aeronutronic to adapt the SHILLELAGH missile system to the MBT-70.

(U) In the MBT-70 development program, both US and German test agencies fired SHILLELAGH missiles from engineering design models of the tank. During the April-June 1969 period, US personnel fired 21 missiles from the MBT-70 at the White Sands Missile Range, 16 of which impacted the 7 1/2 square-foot target. In a subsequent test and evaluation program at the Aberdeen Proving Ground during July-August 1970, US personnel fired 13 missiles from the tank, 10 of which hit the target. From July 1970 through November 1971, the German test agency fired 51 SHILLELAGH missiles from the MBT-70, 47 of which impacted the target.

(U) Despite success in some areas, the joint MBT-70 development program experienced serious problems which led to its discontinuance. As the concepts began to appear in hardware form in the late 1960's, the disadvantages of the joint program began to outweigh the advantages. Differing objectives, philosophies, and techniques, combined with increased costs and lengthened schedules, eventually brought the program to a halt. In January 1970, the

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[34](1) WECOM Anl Hist Sum, FY 71, p. 228. (2) WECOM Anl Hist Sum, FY 72, pp. 173-75. (3) TACOM ARMA, FY 73, pp. 193-94. (4) TACOM ARMA, FY 74, p. 100.

[35]See below, pp. 103-05.

[36]AMC GO 149, 14 Jun 72, as amended by AMC GO 172, 7 Jul 72.

US and Germany revised the program to a cooperative effort under which each nation could make unilateral technical decisions to meet its own national requirements. This agreement also terminated joint funding of the program. To reduce costs, the US turned to an austere model of the tank, designated as the MBT-XM802.[37]

(U) Plans for the XM803 included a reconfigured SHILLELAGH missile which would be a 105mm supersonic missile with a 4,000-meter range. However, the MBT-XM803 program proved to be short-lived. In December 1971, the US Congress passed a compromise version of the Defense Appropriations Bill, which directed the Army to terminate the XM803 program by 30 June 1972. This bill also approved funds for a new tank development program. This new tank, designated as XM815 (which later became the XM1 and, finally, the M1 Abrams main battle tank), did not include a missile-firing capability. Therefore, the program for the supersonic SHILLELAGH was terminated.[38]

Revival of the SHILLELAGH/TOW Controversy

(U) In 1969 and 1970, the Army was again called upon to defend the requirement for both the SHILLELAGH and TOW antitank missiles. Controversy concerning the development of both missiles had first arisen in 1962, when the SHILLELAGH was completing its applied research phase and the TOW was entering the development stage.* Differences in views resurfaced in 1969 during congressional debate on TOW procurement funds. In response to a congressional request, the Army evaluated the feasibility of adapting the SHILLELAGH missile to the ground heavy assault weapon (HAW) role and the airborne antitank role in place of TOW.

(U) Although limited cost studies conducted in 1969 tended to indicate that the adaptation of SHILLELAGH to the HAW role could generate savings, more detailed fiscal analyses in 1970 refuted this. The SHILLELAGH contractor, Aeronutronic, claimed monetary reductions and an earlier field capability by using SHILLELAGH in the HAW role. The MICOM study, however, showed that a time delay of some 4 years and marked cost increases would be incurred by cancelling the TOW and substituting the SHILLELAGH for infantry antitank missions. The Army and the Director of Defense Research and Engineering agreed that TOW should continue to be employed in the HAW role.

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*See above, pp. 73-75.

[37](1) Ltr, Mgr, Tactical Surface Combat Systems, Aeronutronic Div, Philco-Ford Corp., to CG, MICOM, 29 Mar 72, subj: Submittal of Final Technical Report, Contract DA-04-495-AMC-959(Z), w incl: Final Technical Report, SHILLELAGH Missile Adaptation to US/FRG Main Battle Tank (MBT-70). (2) MICOM Anl Hist Sum, FY 66, p. 64. (3) USAMC Hist Sum, FY 71, pp. 90-91, 95, 108. (4) USAMC ARMA, FY 72, pp. 127-131, 139, 141-148. (5) "The MBT-70: Everything But Wings," *Army*, Nov 67, pp. 16-17.

[38](1) MICOM Anl Hist Sum, FY 72, p. 89. (2) MICOM Anl Hist Sum, FY 73, p. 94. (3) USAMC ARMA, FY 72, pp. 137-38. (4) USAMC ARMA, FY 73, p. 270.

(U) During this evaluation, the inherent differences in the two systems were again emphasized. Although both systems had enemy armor as a common target, they operated in different environments and played separate roles. The SHILLELAGH was designed specifically for firing from the closed breech gun tube of an armored vehicle. On the other hand, the TOW was intended to be fired by infantry units from an open breech, lightweight tube emplaced on an open vehicle or on the ground. The Army's conclusions prevailed and the Congress approved FY 1971 funds to continue with the TOW in the HAW role.

(U) A later investigation of SHILLELAGH versus TOW for airborne use (installed on COBRA and CHEYENNE helicopters) disclosed that total program costs were less for TOW in each case. The evaluation also concluded that development time for adaptation to the airborne role would be shorter for the TOW missile, and that the SHILLELAGH had certain limitations, such as range when fired from a hover position and sun interference, which made it less desirable for the helicopter role than the TOW.[39]

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[39] (1) Statement by General Bruce Palmer, Jr., VCofS, US Army, before the Committee on Armed Services, House of Representatives, Second Session, 91st Congress, on TOW/SHILLELAGH Reevaluation, circa Apr 70. (2) Ltr, Director of Defense Research and Engineering, to Chairman, Committee on Armed Services, US Senate, 6 Apr 70, re TOW/SHILLELAGH. (3) Mary T. Cagle, *History of the TOW Missile System* (MIRCOM, 20 Oct 77), pp. 95-98.

CHAPTER VI

WEAPON SYSTEM DEPLOYMENT AND FIELD SUPPORT

(U) Timely deployment to using units in the field remains the fundamental objective underlying the development of any weapon system. Following the initial issue of M551 SHERIDAN/SHILLELAGH systems to CONUS units in mid-1967, deployments were extended worldwide in early 1969. Early in 1975, SHILLELAGH missile systems mounted on M60A2 tanks were fielded to armor units in Europe and the Continental United States (CONUS). A comprehensive support concept integrated field and depot maintenance services with onsite technical assistance provided by the Army Missile Command. Inventory phasedown of both SHERIDAN vehicles and M60A2 tanks during the late 1970's was accompanied by parallel reductions in deployed SHILLELAGH missile assets. By FY 1981, only 140 SHILLELAGH-equipped SHERIDAN vehicles, designated as a residual fleet, remained in the Army inventory, while conventional guns replaced the SHILLELAGH's mounted on M60A2 tanks. During the entire period of SHILLELAGH deployment, MICOM developed and implemented extensive product improvement programs to correct deficiencies in the weapon system and to enhance its capabilities and operational performance.

Deployment of the SHERIDAN/SHILLELAGH System

First Tactical Units Equipped

(U) In June 1967, the 1st Battalion, 63d Armor, at Fort Riley, Kansas, became the first tactical unit to be equipped with the SHERIDAN/SHILLELAGH weapon system. During missile gunnery training in February 1968, tank crews of the 1st/63d Armor fired a total of 112 missiles, scoring 88 target hits. Of the 59 missiles fired at stationary 12-square-foot targets, at a 1,500-meter range, all but five impacted the target, the strike distance from the center aiming point averaging slightly less than 9 inches. The five misses were attributed to erratic missiles. In all cases it was the first missile that the gunners had ever fired. The success rate for firing at 6 x 10-foot moving targets was considerably lower, only 34 of the 53 missiles fired being registered as hits. According to the evaluation report submitted by the Commander, 1st/63d Armor, one of the misses was caused by a faulty missile, four were attributed to system discrepancies, and the remainder resulted from gunner errors.[1]

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[1](1) MICOM Anl Hist Sum, FY 67, p. 65. (2) Hist Rept, SHILLELAGH PM, FY 68, p. 1. (3) Ltr, Cdr, 1st Bn, 63d Armor, Ft Riley, KS, to ACSFOR, DA, 5 Mar 68, subj: Operational Report - Lessons Learned RCS CSFOR-65, w incl: Annex B - Missile Gunnery, atchd to Ltr, SHILLELAGH PM to Mr. John B. Lawson, VP & Gen Mgr, Aeronutronic Div, Philco-Ford Corp., 17 Apr 68, re SHILLELAGH Operational Tests By 1st Bn, 63d Armored Regiment. (4) Selected Acquisition Report, SHILLELAGH Missile System, as of 31 Mar 70, pp. 6, 7. File: MICOM, Msl Log Cen, Close Combat Weapon Systems Mgt Ofc.

(U) The SHERIDAN/SHILLELAGH system was issued in October 1967 to the 1st Squadron, 17th Cavalry, an 82d Airborne Division unit, at Fort Bragg, North Carolina. In April 1968, 10 SHERIDAN/SHILLELAGH systems were deployed to the 29th Infantry Brigade in Hawaii, marking the first fielding of the weapon system outside CONUS (OCONUS). The systems in Hawaii would be supported by direct exchanges of equipment, with repairs performed at the Anniston Army Depot in Alabama.[2]

Worldwide Deployment

(U) In October 1968, the Army Vice Chief of Staff approved overseas deployment of the M551 SHERIDAN vehicle. Shortly thereafter, AMC issued a suitability release and DA authorized fielding to Vietman, US Army, Europe (USAREUR), and Korea, with first priority given to Southeast Asia deployment.[3] In November 1968, the SHILLELAGH Project Manager requested that the SHILLELAGH missile system and support equipment also be released for issue with the SHERIDAN to tactical units overseas. To justify this request, he reported that support repair parts were available at the required levels through normal supply channels and special introductory training teams were scheduled to meet the requirements for overseas deployments. On 26 November 1968, the Army Materiel Command (AMC) approved a conditional worldwide release for the SHILLELAGH missile system and support equipment for issue to troops overseas. This release included the MGM- and MTM-51A, B, and C missiles (tactical and training missiles of the original range, extended range, and reduced key configuration), the guidance and control system, missile test set (AN/TJM-1), missile dummy round (M29C), transmitter alignment test set (M45), conduct of fire trainer (XM35), and guided missile system test set (AM/MSM-93). The release was limited to missiles accepted from the initial producer, Aeronutronic.[4]

(U) Although deployments to Korea and Germany were not included in the original master milestone schedule, DA authorized the fielding of SHERIDAN/SHILLELAGH systems to the Eighth Army (Korea) in November 1968 and to USAREUR in January 1969. In preparation for overseas deployments, new materiel introductory presentations on the SHERIDAN/SHILLELAGH equipment were given to specified tactical users and maintenance personnel in Korea, Japan, Vietnam, and Hawaii during December 1968.[5]

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[2](1) Ibid., p. 7. (2) MICOM Anl Hist Rept, FY 68, p. 47. (3) Ltr, SHILLELAGH PM to CG, AMC, 20 Nov 68, subj: Conditional Release of SHILLELAGH for Issue to Troops Overseas.

[3]WECOM Anl Hist Sum, FY 69, p. 124.

[4]Ltr, SHILLELAGH PM to CG, AMC, 20 Nov 68, subj: Conditional Release of SHILLELAGH for Issue to Troops Overseas, & 1st Ind, CG, AMC, to CG, MICOM, 26 Nov 68.

[5](1) Selected Acquisition Report, SHILLELAGH Missile System, as of 31 Mar 70, p. 7. File: MICOM, Msl Log Cen, Close Combat Weapon Systems Mgt Ofc. (2) History of the SHILLELAGH Missile System, incl 1 to DF, SHILLELAGH PM to Proj Dir, Research & Engineering Drte, MICOM, 3 Apr 69, subj: Request for Information for Case Study.

(U) The initial shipment of 60 M551 SHERIDAN vehicles was dispatched to Vietnam in January 1969. Although they did not carry the SHILLELAGH missile, the vehicles contained two of the seven SHILLELAGH guidance and control set components (power supply and rate sensor), which were also used for firing conventional ammunition. Eventually 240 SHERIDAN's with the "two-box" G&C system saw service in Vietnam. The 86th Ordnance Detachment (Land Combat Support System) arrived at Sagami Depot, US Army, Japan, in May 1969 to support the SHILLELAGH in Korea and the "two-box" system in Vietnam. By the end of FY 1969, initial quantities of SHILLELAGH missiles were deployed with the M551 SHERIDAN vehicle to all authorized theaters - CONUS, Europe, and the Pacific.[6]

(U) In the field, the SHILLELAGH missile was recognized as an accurate, long-range tank killer, but it was not well accepted on the M551 SHERIDAN vehicle. Tactical users felt that the lightweight M551 vehicle combined with the heavy recoil of the main gun could render the missile system inoperative. This was not a valid assumption; however, it could appear so to those who were unfamiliar with the SHILLELAGH system, because the recoil from conventional ammunition firings and the shock and vibration received from traveling over rough terrain would cause the checksight source lamp in the M149 telescope mount to move. If the operator then performed a missile system self-test without performing an alignment test, he could receive a signal data converter or tracker "no-go" signal. Consequently, excessive maintenance support ensued, which generated complaints from field commanders who needed a low downtime system for combat use. The checksight problem was one of the areas addressed in the guidance and control product improvement program which is discussed later. The SHILLELAGH equipment launch and flight reliability was consistently high, but overall system performance fell below MICOM assessment goals, primarily because of gunner errors. Those discrepancies, MICOM reported, could be reduced with better training equipment (particularly an improved conduct-of-fire trainer) and more troop firing exercises.[7]

(U) By the end of FY 1971, the SHILLELAGH missile was deployed with 40 SHERIDAN vehicles in Korea, 309 in Europe, and 252 in CONUS. The normal missile load (basis of issue) was 10 missiles per vehicle. In FY 1972, units of the Ohio and West Virginia National Guard received 64 SHERIDAN vehicles equipped with SHILLELAGH missile systems. In a realignment of the National Guard during FY 1974, these systems were reassigned to units in Idaho, Montana, Nevada, and Oregon.

(U) Additional deployments to Europe began in FY 1972 as a result of a DA study which recommended doubling the density of M551 vehicles in that area. With completion of this deployment in 1974, 32 troop units in Germany were

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[6](1) Hist Rept, SHILLELAGH PM, FY 69, p. 2. (2) MICOM Anl Hist Sum, FY 69, p. 40. (3) Fact Sheet, Chf, ADCCS/LCSS/SHILL Div, SSMO, to CG, MICOM, 8 Feb 74, subj: Data Relating to SHILLELAGH Missile System.

[7]Ltr, Cdr, MICOM, to DCG/Materiel Readiness, DARCOM, 28 May 76, re Status, Problem Areas, and Corrective Actions Taken on the SHILLELAGH Missile System, w incls.

equipped with 18 SHERIDAN's per unit, for a total density of 576 SHERIDAN's tactically deployed there. These vehicles, operating along the East/West German border, filled a vital role in USAREUR's tactical planning for the defense of West Germany. In concert with this role, improvements in the operational readiness of the SHERIDAN fleet in Germany became a major concern within DA.[8]

(U) The Tank-Automotive Command (TACOM), which had assumed program management responsibility for the SHERIDAN vehicle from WECOM on 29 June 1972, placed special emphasis on improving the operational readiness (OR) of the M551 fleet. During FY 1975, a substantial gain was achieved in the worldwide OR rate, which climbed from 66 percent in June 1974 to 80 percent in June 1975, exceeding the DA goal by 2 percent. The OR rate on USAREUR's M551 vehicles reached 90 percent in FY 1977, surpassing for the first time the 88 percent standard set in that theater.[9]

(U) During the 1975-77 period, application of laser rangefinders (LRF) was completed on USAREUR's active force M551's and those at Fort Knox and other selected CONUS locations. Following installation of the LRF's, the weapon systems were redesignated as M551A1 SHERIDAN's. By the end of FY 1978, all M551's in war reserve and other prepositioned stocks had been similarly upgraded, and the new LRF-equipped models comprised about 63 percent of the worldwide SHERIDAN fleet.[10] A more extensive product improvement program to enhance the performance and reliability, availability, and maintainability characteristics of the SHERIDAN vehicle and the SHILLELAGH guidance and control system was also under way in the mid-1970's.

Phasedown of the M551 SHERIDAN

(U) In February 1978, DA had approved a July 1977 ASARC Special Tank Task Force recommendation for replacing the M551 vehicles in armored cavalry units with improved M60-series main battle tanks. The new M60A1 tank, using conventional ammunition, appeared to offer increased firepower and survivability in sustained reconnaissance operations. Furthermore, there had been considerable dissatisfaction among tactical users with the M551 vehicle's reliability.

(U) At the beginning of the phasedown operation, there were 1,570 M551 SHERIDAN vehicles in the Army inventory, which included 867 deployed in USAREUR, 535 in CONUS, and 41 in the Pacific (Korea and Hawaii). An additional 55 were held in war reserve or float status, and 72 were assigned as residual

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[8](1) MICOM Anl Hist Sum, FY 72, p. 88. (2) MICOM ARMA, FY 73, p. 94. (3) MICOM ARMA FY 74, pp. 141-42. (4) SHILLELAGH Missile System Master Plan, Feb 76, SSMO, MICOM, p. 18.

[9](1) TACOM ARMA, FY 73, pp. 113-14. (2) TACOM ARMA, FY 74, p. 160. (3) TACOM ARMA, FY 75, p. 179. (4) AMC GO 149, 14 Jun 72, as amended by AMC GO 172, 7 Jul 72. (5) TARCOM AHR, FY 77, pp. 122-23.

[10](1) Ibid., p. 123. (2) TACOM ARMA, FY 75, pp. 179-80. (3) TARCOM AHR, FY 78, p. 109.

assets at Fort Bragg, Fort Knox, and the Arkansas National Guard. The conversion from M551 vehicles to M60A1 tanks in USAREUR's armored cavalry units began in June 1978 and was completed by April 1979. The CONUS and Pacific changeovers were concluded in FY 1980.[11]

(U) At the completion of the M551 phasedown, the SHERIDAN inventory had been reduced to a residual fleet of 140 vehicles, which DA planned to retain through the late 1980's. A total of 57 SHERIDAN's were assigned to an armor battalion in an airborne division, and 12 vehicles were still in use by the National Guard. The remaining 71 SHERIDAN's were held as CONUS POMCUS* stock. In FY 1981, the Anniston Army Depot applied improvements to the guidance and control components (test checkout panel, tracker, and signal data converter) of all 140 residual fleet vehicles. The M551's in POMCUS status also would be modified with the guidance and control improvements.

(U) Over 12,700 excess SHILLELAGH missiles turned in during the phasedown were placed in storage at the Anniston Army Depot. Since MICOM was in a long-stock position on the missiles, detailed screening and condition classification to verify their serviceability would be accomplished only if, and when, the supply posture dictated. During FY 1979-80, the depot demilitarized and disposed of some 4,800 code F (unserviceable-reparable) missiles.

(U) In FY 1980, the Army had decided to furnish 330 M551 SHERIDAN's to the National Training Center at Fort Irwin, California, for use as opposing force vehicles. These M551's went into operation during FY 1981. Only blank ammunition would be fired from the main gun of the SHERIDAN's. However, since a stabilized turret was required, three of the SHILLELAGH guidance and control component boxes (rate sensor, power supply, and signal data converter) would remain in the turret. Therefore, there would be a continuing requirement to provide depot maintenance (box turnaround) for these components.[12]

Deployment of M60A2/SHILLELAGH

(U) Troop confirmatory tests of the M60A2/SHILLELAGH system were conducted at Fort Knox and Fort Hood in the spring of 1974.[13] However, DA's approval for tactical deployment of the tank to Europe was delayed to December 1974, chiefly because of problems with the main gun recoil system. The MICOM Commander, in late November 1974, had authorized the full release of the SHILLELAGH missile

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*Prepositioned Organizational Materiel Configured to Unit Sets

[11] (1) Ibid., p. 109. (2) TARCOM AHR, FY 77, p. 123. (3) TARCOM AHR, FY 79, pp. 111, 137-38. (4) MICOM AHR, FY 78, p. 144. (5) MICOM AHR, FY 80, p. 211. (6) Routing & Transmittal Slip, Gene Finch, ADCCS/LCSS/SHILLELAGH Div, SSMO, to Mr. Cleveland, 23 May 79, w atchd distr for M551 SHERIDAN and M60A2.

[12] (1) TARCOM AHR, FY 79, p. 111. (2) MICOM AHR, FY 79, p. 278. (3) MICOM AHR, FY 80, p. 211. (4) MICOM AHR, FY 81, pp. 238-40.

[13] FONECON, M. T. Cagle w F. J. Mihalak, TACOM Hist Ofc, 8 Dec 82.

for use with the M60A2 tank. In February 1975, the first eight M60A2's equipped with SHILLELAGH missiles arrived in Germany. Company-size combat units began receiving the tanks in June 1975, and by March 1977 the planned deployment of 363 M60A2's to 6 USAREUR tank battalions was completed. In CONUS, 39 tanks with SHILLELAGH missiles were in service at Fort Knox and 59 at Fort Hood. The normal SHILLELAGH missile load for the M60A2 was 13 rounds per tank.[14]

(U) Initial plans envisaged an additional M60A2 tank battalion to be formed at Fort Hood in mid-FY 1977; however, DA had postponed that deployment until FY 1979. In April 1979, DA directed a significant reduction in the M60A2 force. Shortly thereafter, the plans to activate the additional battalion at Fort Hood were cancelled, and the M60A2-equipped USAREUR battalions were reduced from six to three.[15]

(U) The revised plans drafted in FY 1979 called for the 540 M60A2 tanks produced thus far to remain in the Army inventory through FY 1987. Most of them were assigned to three tank battalions in USAREUR (1st and 3d Armored Divisions and the 3d Infantry Division) and to one battalion in CONUS (2d Armored Division at Fort Hood). In addition, M60A2's sufficient to equip one additional USAREUR battalion were held in POMCUS stocks in Germany. The remainder of the 540 were being used for training at Fort Knox or were stored as war reserves and floats.[16]

(U) Significant problems with both the SHILLELAGH missile and M60A2 tank in the FY 1978-79 timeframe, however, influenced future deployment plans for the weapon system. In FY 1978, four missile malfunctions occurred in CONUS (two at Fort Knox and one each at Fort Hood and Fort Bliss) in which the missile's gas generator ignited, but the rocket motor failed to ignite. In each incident, the missile left the gun barrel, traveled about 30 meters and hit the ground, where it lay until the hot gases from the gas generator ignited the rocket motor, causing the missile to ascend in uncontrolled flight.[17] Investigation of the malfunctions led to a product improvement proposal to redesign the missile's gas generator/rocket thruster ignition sequence, adding an acceleration-sensitive switch which would prevent the gas generator from burning without rocket motor ignition. The modification was successfully demonstrated in February 1980 and plans were made to use the switch in the scheduled production verification tests of guidance and control improvements.

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[14] (1) TACOM ARMA, FY 74, p. 100. (2) TACOM ARMA, FY 75, pp. 124-25. (3) TACOM ARMA, FY 76, pp. 113-14. (4) Ltr, Cdr, MICOM, to Cdr, TACOM, 25 Nov 74, subj: Release of the SHILLELAGH Missile System for Use with the M60A2 Tank, Combat. (5) Fact Sheet, Chf, ADCCS/LCSS/SHILL Div, SSMO, to CG, MICOM, 8 Feb 74, subj: Data Relating to SHILLELAGH Missile System. (6) SHILLELAGH Missile System Master Plan, SSMO, MICOM, Feb 76, pp. 18-19.

[15] (1) TARCOM AHR, FY 77, p. 163. (2) TARCOM AHR, FY 78, p. 147. (3) TARCOM AHR, FY 79, p. 138.

[16] MICOM AHR, FY 79, p. 279.

[17] MIRCOM AHR, FY 78, p. 147.

However, the vendor could not deliver the switches in time to support these firings. Because of the early phaseout of the M60A2/SHILLELAGH (discussed below), this improvement effort was terminated.

(U) Additional problems experienced with the M60A2 tank during FY 1979 had markedly decreased user confidence in the system. A "catastrophic" equipment failure occurred in July 1979 while the 33d Tank Battalion was firing conventional ammunition in Germany. A valve block assembly of the tank was blown against the rear breech housing, causing the housing to fall inside the turret, breaking the tank commander's leg. The battalion also reported numerous other equipment failures involving both the tank and the missile during this gunnery program. The 3d Division Commander reported that frustration over the frequent failure of the missile system to hold a "ready" or "go" condition from checkout to firing, sometimes for several minutes duration, was the greatest deterrent to crew confidence in and proficiency with the SHILLELAGH.

(U) In view of the prevailing hardware deficiencies and other difficulties, such as a continuing shortage of skilled M60A2 turret mechanics, USAREUR and DA investigated ways to resolve the problem of unsatisfactory performance of the M60A2 tank. The alternative selected was early replacement of the tank. In May 1980, DA decided to accelerate the phaseout of the 540 M60A2 tanks in the active Army inventory. At that time, the Army had two M60A2-equipped battalions in USAREUR (1st Armored Division and 3d Infantry Division) and one in CONUS. In the phaseout, completed in FY 1981, the turrets on the M60A2 tanks were replaced with M48A5 turrets, which had conventional tank cannons. The SHILLELAGH missiles were returned to the Anniston Army Depot for storage.[18]

Maintenance Support

(U) Upkeep for the fielded SHILLELAGH missile systems, in both AR/AAV and tank-mounted modes, consisted of organizational, direct support (DS), general support (GS), and depot maintenance. At the organizational level, unit personnel cleaned and preserved the missile, inspected the munitions and container for nonstandard conditions, and forwarded damaged or unserviceable missiles to the Anniston Army Depot. The operator/crew used the onboard system self-test equipment to determine if the system was in a ready status. If a no-go condition was indicated, the organizational turret mechanic attempted to fault isolate the malfunction to a specific assembly. Using unit personnel had the capability to replace defective components of the guidance and control set group. In addition, the unit was equipped with an M45 optical alignment test set for use by the crew in checking the mechanical alignment of the transmitter relative to the tracker line-of-sight.

[18](1) MICOM AHR, FY 79, pp. 279-82. (2) MICOM AHR, FY 80, pp. 211-13. (3) MICOM AHR, FY 81, p. 238.

(U) Since the onboard self-test devices did not have the capacity for identifying all failures, an additional checkout capability was provided by the AN/MSM-93 guided missile system test set. This portable equipment, organic to the DS and GS units, was used onsite by a SHILLELAGH contact team capable of supporting 27 weapon systems. Using units turned in faulty components to the direct support activity, which either performed necessary repairs or forwarded the items to the general support unit for overhaul. The Land Combat Support System (LCSS) provided fault isolation and repair to the piece-part level at both DS and GS activities. The general support mission also included repairing and calibrating optics.

(U) At the Anniston Army Depot, the LCSS was augmented with acceptance inspection equipment for major overhaul of guidance and control assemblies and repair of selected subassemblies. Defective missiles requiring extensive overhaul were placed in storage for future rebuild if they were later needed for issue.[19]

(U) When the SHILLELAGH was first deployed in 1967, the LCSS, which was to provide field support, was not available. Therefore, the only maintenance assistance available was depot-level support provided by the contractor (Aeronutronic). Because of space limitations and the volume of production at the contractor's plant, MICOM, Aeronutronic, and Anniston Army Depot representatives signed an agreement on 14 June 1967 to establish the maintenance and repair function at Anniston as a Government-owned, contractor-operated facility. A modification to Aeronutronic's contract for long-leadtime components of test equipment (DA-01-021-AMC-14643) covered the movement of personnel and other requirements to establish the facility.

(U) By the end of FY 1970, the LCSS was supporting the SHILLELAGH missile system in CONUS, USAREUR, and USARPAC, and the two-box system in Alaska. Also in that year, the transition began from contractor to Government operation of the Anniston SHILLELAGH facility, with on-the-job training in guidance and control maintenance for depot personnel. Upon completion of the conversion on 30 June 1971, the depot assumed full organic support of the SHILLELAGH missile hardware.[20]

Product Improvements

Initial Improvement Program

(U) The MICOM completed a comprehensive plan in November 1971 to initiate a long-range product improvement program (PIP) for the SHILLELAGH missile system. Several months earlier, the ASA (R&D) had approved development of the plan and authorized sole source procurement for the effort. The need for additional

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[19](1) Hist Rept, SHILLELAGH PM, FY 69, pp. 2-3. (2) SHILLELAGH Maintenance Concept Presentation, Land Combat Support System Predeployment Conference, 6 Feb 68, pp. 93-96.

[20](1) MICOM Anl Hist Sum, FY 67, p. 64. (2) MICOM Anl Hist Sum, FY 70, pp. 36, 105. (3) MICOM Anl Hist Sum, FY 71, p. 121.

improvements to perfect the system had been determined largely through observation and analysis of a considerable number of SHILLELAGH tests conducted during the preceding several years. The most significant element of the PIP was aimed at increasing the missile's hardness against enemy countermeasures. Other planned upgrading actions included modifications to the tracker and signal data converter to improve the missile trajectory, guidance system signal-to-noise ratio, and overall system reliability and maintainability.[21]

(U) In January 1972, Aeronutronic received an $11.8 million contract for development of the PIP and appropriate technical data packages. However, in view of the subsequent congressional disapproval of the proposed XM803 main battle tank, which was designed to carry the SHILLELAGH missile, DA concurred with an AMC recommendation that no funds be authorized for the PIP. Consequently, in mid-November 1972, the Army Chief of Research and Development discontinued the product improvement program and instructed MICOM to terminate the engineering development contract with Aeronutronic.[22]

Guidance and Control Equipment Improvements

(U) In February 1975, MICOM submitted another product improvement proposal for the SHILLELAGH guidance and control equipment, as part of a larger TACOM-directed M551 SHERIDAN improvement program. The principal rationale for the PIP centered on the relative obsolescence of the early 1960's-vintage G&C system designs. The Missile Command maintained that recent technological advances, if substituted in the high-failure-rate items of the SHILLELAGH G&C equipment, would significantly improve the reliability, availability, and maintainability (RAM) of those components or modules and substantially reduce support costs.

(U) The total cost of PIP 1-76-03-006 was estimated at $14.24 million. The primary purpose of the PIP was to develop replacement hardware for the failure-prone items in the tracker, optical transmitter, and test checkout panel. Data collected by MICOM during the July 1971-April 1974 period showed that 31 percent of SHILLELAGH system failures were attributed to tracker assembly deficiencies and 26 percent to transmitter malfunctions. The system self-test circuitry in the signal data converter also needed detailed re-examination. About 30 percent of the G&C "black boxes" that indicated a "no go" status during the operator's self-test procedures had been found to be in a "go" condition when they were checked on LCSS test equipment.[23]

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[21] SHILLELAGH Missile System (Product Improvement Program) System Development Plan, dtd 1 Nov 71, revised 1 Sep 72, Land Combat Support Items Mgt Ofc, MICOM, pp. 16-17, 45, 54.

[22] (1) MICOM AHR, FY 71, p. 88. (2) MICOM AHR, FY 72, p. 94.

[23] (1) Product Improvement Proposal No. 1-76-03-006, 3 Feb 75, SSMO, MICOM, pp. 7-8, 30. (2) Incl 1 & 2 to CMT 2, Chf, Engrg Svc Div, Sys Engrg Drte, MRDEL, to Chf, ADCCS/LCSS/SHILL Div, SSMO, MICOM, 18 Oct 74, subj: Information on SHILLELAGH G&C Problems.

(U) The US Army Missile Command (MICOM) awarded Aeronutronic the guidance and control PIP contract (DAAH01-76C-1227) on 28 September 1976. The $2,348,650 contract called for the development of RAM modifications to the tracker, transmitter, and signal data converter. In mid-1977 the contract was increased by $1,916,000 to encompass self-test improvements. Prototype hardware was to be delivered for Government product improvement tests in the spring of 1978.[24]

(U) Aeronutronic delivered eight models of the improved G&C unit to MIRCOM in mid-1978. Of the 15 missile flights conducted during the follow-on development tests, 13 were hits and 2 were recorded as "no test" because of missile failures not associated with G&C system performance. Subsequently, MIRCOM awarded Aeronutronic a $6,460,000 letter contract (DAAH01-78C-1006) on 31 July 1978 for the production of 972 tracker and signal data converter modification kits, followed by a $371,085 engineering services contract (DAAH01-78C-1332) on 29 September 1978. Earlier that month the Teledyne Brown Engineering Company had received a $315,900 letter contract (DAAH01-78C-1233) for production of 972 test checkout panel modification kits.

(U) Deliveries of the tracker, signal data converter, and test checkout panel modification kits were completed by the spring of 1980. As part of the production verification tests conducted at Redstone Arsenal, six missiles were flight tested, all of which successfully impacted a stationary target. Shortly thereafter, an Anniston Army Depot team installed the improved SHILLELAGH G&C systems, on a conditional release basis, in the 57 M551 SHERIDAN residual fleet vehicles in use at Fort Bragg and in 12 M551's held by the Arkansas National Guard. The Commander of MICOM approved a full materiel release for issue of the SHILLELAGH improvements on 4 February 1981. Because of the ongoing phaseout of M551 vehicles and M60A2 tanks from the Army inventory, only 136 additional G&C units were scheduled for future modification, with over half to be installed in M551's programmed for POMCUS stocks and the remainder retained as spare components. The Anniston Army Depot completed the POMCUS installations during FY 1981.[25]

(U) The principal contributor to the optical transmitter's high failure rate had been the xenon arc lamp component. (Two lamps installed in the transmitter provided the infrared source for missile guidance signals.) Data furnished by USAREUR users during the July 1971-April 1974 period indicated that 45 percent of all SHILLELAGH transmitter failures in that theater were attributed to lamp malfunctions. The quartz envelope lamp was fabricated by employing complex glass-blowing techniques, which resulted in a high production mortality rate and a consequent reduction in the vendor's delivery output.

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[24](1) MIRCOM AHR, FY 77, p. 145. (2) SHILLELAGH Missile System Annual Assessment Report, Rept No. QW-MR-79-2, 15 Feb 79, D/Prod Assur, MICOM, App V, p. 2.

[25](1) MIRCOM AHR, FY 78, pp. 145-46. (2) MICOM AHR, FY 80, p. 212. (3) MICOM AHR, FY 81, pp. 239-40.

(U) Significant procurement difficulties had arisen in May 1974, when the sole qualified manufacturer, Illumination Industries, refused a contract for supplying additional lamps to replenish diminishing military stocks.[26] Subsequent efforts to procure spare lamps revealed there were no other qualified vendors available. Factors contributing to the lack of vendors included the unique expertise required in the fabrication and testing of the lamp; significant initial capital outlays for manufacturing facilities; and the trend towards obsolescence of the SHILLELAGH lamp design. Recent state-of-the-art improvements in arc lamps had led MICOM engineers to conclude that other designs or configurations could offer more reliable methods of generating infrared signals, with fewer attendant production problems and at lower cost. Among the possibilities considered were sapphire/xenon lamps, and a solid state source for the transmitter.[27]

(U) A program to qualify a new vendor capable of producing the quartz envelope arc lamp was begun in May 1975 under a $375,000 task order (DAAH01-75-A-0030) awarded to Aeronutronic. Aeronutronic selected the Optical Radiation Corporation as the lamp manufacturer in August 1975. Because of the critical supply posture, Aeronutronic was awarded a contract, in December 1976, for a limited quantity of 400 lamps. Following Government acceptance tests, MIRCOM released the lamps for issue in July 1977. Aeronutronic received another production contract (DAAH01-78-C-0430) in FY 1978 for 1,696 additional lamps, delivery of which was completed in October 1979. The contractor had started efforts in December 1976 to qualify a vendor for manufacture of a sapphire envelop transmitter lamp, but unresolved technical problems and funding restrictions forced an early cancellation of the project.[28]

(U) As directed by the MIRCOM Commander, a special study had been initiated in FY 1978 to investigate the feasibility of a solid-state source for the transmitter, as a backup or possible replacement for the xenon lamp. Results of the study showed that a solid state transmitter would meet SHILLELAGH system performance requirements and be cost effective. A solid-state version, eliminating the xenon lamp and its attendant problems, would provide greater reliability, reduce repair parts costs, guarantee multiple sources for the component items, and prevent near-term obsolescence.

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[26]DF, H. M. Bartlett, Contr Off, Proc Div, D/P&P, MICOM, to Chf, ADCCS/LCSS/SHILLELAGH Div, SSMO, 21 Jun 74, subj: SHILLELAGH Lamp Subassembly, APN 11433676, Illumination Industries (Successor to PECK Inc.) (No-Quote - RFP DAAH01-74-R-1159) PRON D1-4-11964.

[27](1) Product Improvement Proposal No. 1-76-03-006, 3 Feb 75, SSMO, MICOM, pp. 15-16, 24. (2) Incl 1 & 2 to CMT 2, Chf, Engrg Svc Div, Sys Engrg Drte, MRDEL, to Chf, ADCCS/LCSS/SHILLELAGH Div, SSMO, MICOM, 18 Oct 74, subj: Information on SHILLELAGH G&C Problems.

[28](1) SHILLELAGH Missile System Master Plan, Feb 76, SSMO, MICOM, p. 48. (2) MIRCOM AHR, FY 77, pp. 145-46. (3) MICOM AHR, FY 78, p. 147. (4) MICOM AHR, FY 79, p. 283.

(U) In FY 1979, a MIRADCOM* prototype solid-state transmitter, packaged in an existing SHILLELAGH transmitter housing with the xenon lamp and modulator removed, underwent extensive static field and guided flight feasibility tests. Mounted on an M60A2 tank, the transmitter was subjected to the usual flight conditions of launch shock and vibration and to the smoke and missile plume obscuration found in normal firings. Because of an apparently inadequate captive beam angle in the solid-state breadboard model, the first two missiles failed to capture. After modification of the beam size, six missiles were fired which scored highly accurate hits. The flight test program successfully demonstrated the feasibility of the solid-state transmitter in the fully operational mode. However, because of the SHERIDAN/M60A2 phasedown, the solid-state development program was discontinued in FY 1980.[29]

Laser Beamrider Improvement

(U) In April 1975, MICOM initiated a 5-year product improvement program for application of newly developed laser beamrider technology to the SHILLELAGH missile system. The proponent engineers claimed that conversion to an optical beamrider guidance unit would extend the life of the SHILLELAGH weapon system, provide increased hardening against enemy countermeasures, reduce logistic and maintenance support, and result in an improved hit capability at extended ranges. Under the PIP, six of the seven existing infrared source G&C "black boxes" (major subassemblies) would be replaced with two principal components—a laser beam projector (transmitter) and a simplified test checkout panel. The total cost of the beamrider PIP was estimated at $126.5 million.[30]

(U) Aeronutronic was awarded a contract in September 1975 to modify 16 SHILLELAGH missiles to laser beamrider guidance, retrofit M551 vehicle and M60A2 tank firing platforms, and conduct a flight demonstration program. During July-October 1976, 15 test missiles were fired at 2,000-3,000-meter ranges, all striking the target within 30 inches of its center. Critical issues relating to the laser beam projector unit's survivability and boresight retention were adequately resolved, as well as the system's capabilities to fire from defilade, through tactical smoke conditions, and with the sun in the missile receiver's field of view. The MIRADCOM-sponsored laser beamrider demonstration program was completed in August 1977.[31] A short time later, however, the Army began

*Army Missile Research and Development Command.

[29](1) MIRCOM AHR, FY 78, p. 147. (2) MICOM AHR, FY 79, p. 283. (3) MICOM AHR, FY 80, p. 212. (4) SHILLELAGH Missile System Annual Assessment Report, Rept No. QW-MR-79-2, 15 Feb 79, System Performance Assessment Div, D/Prod Assur, MICOM, Appendix V, p. 3.

[30]Product Improvement Proposal 1-77-03-016, Revision A, 23 Apr 75, SSMO, MICOM, pp. 3, 7-8, 27. (Appendix B to SHILLELAGH Missile System Master Plan, Feb 76, SSMO, MICOM.)

[31]MIRADCOM AHR, FY 77, pp. 173-74.

the phaseout of M551 SHERIDAN vehicles,[32] and the laser beamrider improvement was never released for production.

Welded Module Redesign

(U) By the mid-1970's, repair parts procurement for SHILLELAGH electronic modules with welded leads had become increasingly more difficult and expensive, as only three manufacturers were identified who could assemble them. During FY 1978, MIRCOM started a packaging redesign and engineering qualification program, during which 13 modules having the highest frequency of repair were to be converted from welded to solderable lead configuration. The goals of the program were to lower costs, increase reliability, eliminate obsolescence of piece parts, and enhance competitive bidding without changing the missile system's performance characteristics. Teledyne, Incorporated, received a contract to build test units for nine modules, while MIRADCOM would fabricate the remaining four on an in-house basis. Contractor deliveries were completed in FY 1979. During the following year, the Test and Evaluation Directorate of MICOM's Army Missile Laboratory qualified the nine Teledyne-constructed test units and released technical data packages for competitive procurement. Work was discontinued on the four modules planned for in-house development because of design and fabrication problems.[33]

Other Improvements During Deployment

(U) During night firings of early-production SHILLELAGH missiles, gunners complained of their visual acuity being temporarily impaired by bright light from the missile's tungsten beacon (infrared source light). In March 1969, an optical filter was installed on the missile beacon to eliminate the distracting visible light. After a 2-year test program which included over 20 missile firings in varying weather conditions, the Test and Evaluation Command determined that the filtered source beacon caused no missile failures and did not significantly degrade tracking link performance. The DA approved the modification of all SHILLELAGH missiles with the beacon filter commencing in FY 1971. The installation work, completed in 1974, was performed on CONUS stockpiles by the Anniston Army Depot and in Germany by the Miesau Army Depot. The model number of the modified SHILLELAGH missile was changed from MGM/MTM-51C to -51C-1.[34]

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[32] See above, pp. 102-03.

[33] (1) MIRCOM AHR, FY 78, p. 146. (2) MICOM AHR, FY 78, p. 284. (3) MICOM AHR, FY 80, p. 212. (4) SHILLELAGH Missile System Annual Assessment Report, Rept No. QW-MR-79-2, 15 Feb 79, System Performance Assessment Div, D/Prod Assur, MICOM, Appendix V, pp. 3-4.

[34] (1) MICOM AHR, FY 69, p. 38. (2) MICOM AHR, FY 70, p. 35. (3) MICOM AHR, FY 72, p. 88. (4) SHILLELAGH Missile System Annual Assessment Report, Rept No. AW-MR-79-2, Feb 79, System Performance Assessment Div, D/Prod Assur, MICOM, Appendix I, p. 2.

(U) In 1972, the red silicone rubber rings on the missile aft caps were found to be incompatible with the modified closed breech scavenger system (CBSS) used on the M60A2 tank. Analysis by MICOM engineers identified the source of the problem as high pressure air from the CBSS injected behind the missile aft caps, causing them to stick in the gun breech. A black neoprene ring was designed which could adequately withstand the CBSS pressure. Installation of the new rings on the SHILLELAGH stockpile began in 1973 and was completed in February 1976. No missile model change was required.

(U) Four accidental missile firings in 1972-73 were traced to shorted firing circuits in worn and damaged missile test stand components (cables, connectors, and radio frequency interference filters). To eliminate the problem, MICOM redesigned those components to provide greater durability, and contrived a test stand missile support tube locking mechanism. The design changes were incorporated in the field hardware by the Anniston Army Depot in 1977-78 under PIP's 1-76-03-0602A and 1-78-03-0601W1.[35]

Conduct-of-Fire Trainer

(U) The conduct-of-fire trainer (COFT) was designed to allow gunners to develop and maintain their proficiency in SHILLELAGH missile firings without actually launching live missiles. The requirement for the COFT stemmed from both technical and economical reasons: the differences in firing the missile as opposed to conventional ammunition and the high cost of the live missile. The conduct-of-fire trainer provided a visual simulation of missile ejection and flight, performed the computing functions required to score the gunner properly, and housed the controls and indicators needed to control and monitor the training mission. It consisted of two major subsystems—a launch vehicle and a target vehicle.

(U) On the launch vehicle subsystem were the instructor control unit (ICU) and the visual effects simulator (VES), both of which were electrically connected to the operational guidance and control system of the SHERIDAN vehicle. The ICU, mounted on the top of the SHERIDAN turret forward of the tank commander's hatch, contained the controls and displays which permitted the instructor to establish the training exercise and to monitor the gunner's performance. It also had the necessary electronics for computing range, hit-miss distance, and gunner's tracking performance, and for displaying the results to the instructor. The VES, mounted forward of the gunner's telescope on the gunshield of the SHERIDAN vehicle, housed the electrical, optical, and mechanical assemblies necessary to produce the missile simulation effect. The VES responded to inputs from the ICU and the G&C equipment.

(U) The target vehicle subsystem, mounted on another SHERIDAN or other suitable vehicle, consisted of a tower, tower base, prime power supply, and

[35] Ibid.

power control unit. The tower assembly contained two xenon lamp assemblies which provided the necessary signals to the launch vehicle subsystem.[36]

(U) The requirement for a conduct-of-fire trainer had been established when R&D work commenced on the SHILLELAGH system in 1959. The SHERIDAN/SHILLELAGH Project Manager at WECOM subsequently delegated COFT development to the Army Participation Group, US Naval Training Device Center (NTDC), the agency responsible for the evolution of that type training equipment within DOD.* In June 1964, the NTDC awarded a $400,000 contract to the Reflectone Division of Otis Elevator Company for the development and delivery of seven prototype COFT units.

(U) Limited production of 67 trainers was approved in October 1965, 3 months before the TECOM ET/ST's were scheduled to begin. Reflectone received a $3.75 million production contract for the first 67 units in February 1966. Upon completion of the ET/ST program the following September, TECOM reported that the SHERIDAN trainer, designated as the XM35, was deficient in reliability and ruggedness and was unsuitable for Army use. Another TECOM test of the COFT 2 months later, using units from the first-year production buy, also yielded unsatisfactory results. Check tests of a modified COFT in January 1967 indicated that the trainer was sufficiently reliable; however, Fort Knox observers insisted that several training effectiveness modifications be applied. Limited production was then extended for a second year buy of 127 trainers. Reflectone received a $4.08 million contract for these units in January 1967.

(U) After training effectiveness modifications were added to the SHERIDAN trainers, the units were retested in October 1967. The results again indicated poor reliability, durability, and maintainability. An ad hoc investigative committee, appointed by the NTDC, reported in late January 1968 that the poor performance of the trainer resulted from design shortcomings, inadequate quality assurance and reliability, and maintainability problems. Testing of the COFT was suspended pending correction of the deficiencies.[37]

(U) Meanwhile, early in 1966, CONARC established a requirement for a COFT to use with the SHILLELAGH/M60A1E1 system. This trainer, designated as the XM38, was identical to the XM35 SHERIDAN COFT, except for installation hardware, cable connections, and the visual effects simulator, which was modified to accept the larger focal length of the M60 optics. The XM38 was type classified as limited

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*When the SHILLELAGH Project Office was established at the Army Missile Command in September 1964, the SHERIDAN Project Office at WECOM retained overall responsibility for the COFT.

[36]AMCTC Item 8012, 24 Jun 70, subj: Type Classification as Standard "A" of the Trainer, Launcher, Conduct-of-Fire: SHERIDAN Weapon System M41; Target, Conduct-of-Fire Trainer: SHERIDAN Weapon System M42. DA Project 1X579191D33502. Type Classification Standard "A" of the Shop Equipment, Conduct-of-Fire Trainer Semitrailer Mounted, AN/MSM-97. RSIC.

[37]SHILLELAGH Missile System Master Plan, SSMO, MICOM, Feb 76, pp. 23-24.

production in September 1966, and Reflectone received a $2.2 million contract for 57 trainers.[38]

(U) Pursuant to recommendations of the SHERIDAN and SHILLELAGH Project Managers and the Commander of MICOM, the Army Materiel Command transferred responsibility for the XM35 and XM38 conduct-of-fire trainers from WECOM to MICOM on 25 March 1968. The SHILLELAGH Project Manager worked with the SHERIDAN Project Office at WECOM on a plan to correct the design deficiencies, and in April 1968 authorized the contractor to modify seven trainers for testing. In July 1968, after their performance had been evaluated, the SHILLELAGH Project Manager released the XM35 COFT's for ET/ST and committed additional trainers to modification, to satisfy upcoming overseas deployment of the SHERIDAN/SHILLELAGH. The ET/ST was about 85 percent complete in November 1968 when the SHILLELAGH Project Manager included the XM35 COFT in his request for conditional release of the SHILLELAGH equipment overseas deployment. The Army Missile Command approved this release on 26 November 1968.[39]

(U) In the ET/ST, conducted from August 1968 to mid-April 1969, the conduct-of-fire trainer met all but 3 of the 47 test requirements. These three involved missile grounding, line-of-sight obstacles, and trainer ruggedness. The Test and Evaluation Command waived the military characteristics for the first two requirements and approved the ruggedness of the item. On 31 March 1970, DA type classified the conduct-of-fire trainer as standard A.[40]

(U) Meanwhile, in response to a recommendation from the SHILLELAGH Project Manager, DA, in November 1968, reduced the basis of issue for the COFT to 2 launch units and 1 target unit per 27 SHERIDAN vehicles. Previously, 9 launch units and 3 target units per 27 vehicles had been authorized. This reduced density lowered the total requirement for trainers from 656 to 194.[41]

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[38](1) Service Test of Trainer, Conduct of Fire: 152mm, Gun Launcher, XM38 for M60A1E1 Tanks, USATECOM Project No. 1-4-2040-35, Test Plan, US Army Armor and Engineer Board, 23 Feb 68, p. 2-3. (2) Fact Sheet, Mar 69, subj: Status of Funds Paid to the Contractor on the COFT Contracts.

[39](1) SHILLELAGH Missile System Master Plan, SSMO, MICOM, Feb 76, pp. 24-27. (2) Ltr, SHILLELAGH PM to CG, WECOM, 26 Sep 67, subj: SHILLELAGH Conduct of Fire Trainer. (3) Ltr, CG, MICOM, to CG, WECOM, 3 Jan 68, subj: SHILLELAGH Conduct of Fire Trainer. (4) Ltr, CG, WECOM, to CG, MICOM, 14 Feb 68, subj: Transfer of Conduct of Fire Trainers, XM35 and XM38. (5) Fact Sheet, E. R. Edmondson, Dep SHILLELAGH PM, to ACSFOR, DA, 11 Mar 69, subj: Initial Deployment of Conduct of Fire Trainer (COFT) XM35.

[40]AMCTC Item 8012, 24 Jun 70, subj: Type Classification as Standard "A" of the Trainer, Launcher, Conduct-of-Fire: SHERIDAN Weapon System M41; Target, Conduct-of-Fire Trainer: SHERIDAN Weapon System M42. DA Project 1X579191D33502. Type Classification Standard "A" of the Shop Equipment, Conduct-of-Fire Trainer Semitrailer Mounted, AN/MSM-97. RSIC.

[41]Fact Sheet, Mar 69, subj: Total Number of SHERIDAN/SHILLELAGH COFT's Required under Revised BOI, atchd to Ltr, ACSFOR, DA, to CG, AMC, 4 Nov 68, subj: Basis of Issue of Conduct of Fire Trainer (XM35).

(U) By the end of FY 1969, about 40 XM35 COFT's had been deployed with SHERIDAN/SHILLELAGH units in Germany, Korea, Hawaii, and CONUS. In April 1969, AMC authorized modification of the XM38 COFT's used with SHILLELAGH-equipped M60A2 tanks. The contractor, Reflectone, completed deliveries of 160 launch units and 99 target units for the SHERIDAN and 49 launch units and 24 target units for the M60A2 during FY 1971. At that time, 108 launch units and 81 target trainer units were deployed with SHERIDAN systems worldwide. The M60A2 trainers were issued to CONUS schools at Fort Knox and Redstone Arsenal. Maintenance support for the COFT's was provided by direct and general support shop sets in semitrailer vans.[42]

Improved Conduct-of-Fire Trainer

(U) Following deployment of the COFT, users in tactical units and training agencies identified several major performance deficiencies which limited the effectiveness of SHILLELAGH gunner training. One limitation cited was the lack of realism in simulated firings—the COFT did not allow for the one-second delay between closing the fire switch and launching the missile, and it did not simulate the launch recoil or acoustic noise. Another significant drawback was the lack of data provided to the instructor for accurately evaluating gunner performance. Moreover, the gunner did not receive direct feedback on a miss and what caused it. The instructor had to extrapolate this information from an oscillograph recording. Since the COFT did not require the gunner to maintain his line of sight on the target during the entire launch and flight simulation, he could be tracking significantly off-target during most of the simulation, then place the line of sight on the target at the last instant and get credit for a hit. The trainer provided line of sight error information for only the last half of the flight simulation. Reliability and maintainability of the COFT constituted additional problem areas. The bulk and weight of the components, along with stiff cabling, made installation of the equipment cumbersome and time-consuming.[43]

(U) Because of these defects, the Missile Command, in December 1973, initiated efforts to redesign the trainer under an engineering services memorandum funded by the 1969 engineering services contract with Aeronutronic. Under this contract, Aeronutronic delivered a demonstration unit of a redesigned COFT in September 1974. SHILLELAGH-equipped units at Fort Bliss and Fort Knox trained with this prototype in September and October 1974, and judged it a major improvement in realism, ease of operation, reliability, and maintainability.

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[42](1) Fact Sheet, E. R. Edmondson, Dep SHILLELAGH PM, to ACSFOR, DA, 11 Mar 69, subj: Initial Deployment of Conduct of Fire Trainer (COFT) XM35. (2) MICOM Anl Hist Sum, FY 69, p. 40. (3) MICOM Anl Hist Sum, FY 70, pp. 37-38. (4) MICOM Anl Hist Sum, FY 71, pp. 121-22.

[43]DF, Chf, ADCCS/LCSS/SHILLELAGH Div, SSMO, MICOM, to Sys Engrg Drte, MRDEL, 29 Oct 73, subj: SHILLELAGH Conduct of Fire Trainer.

(U) In March 1974, MICOM submitted a product improvement proposal for the improved trainer to AMC; however, in July 1975, DA decided that the PIP should be classified as new development work rather than a product improvement. The "new start" effort was funded in August 1975, and Aeronutronic received a $2.8 million contract (DAAH01-76-C-0221) in January 1976 to develop the improved COFT (I-COFT).[44]

(U) The contractor redesigned the trainer to reduce size and weight of the major components (visual effects simulator, instructor's control unit, and target assembly), and improve reliability, availability, maintainability, and operability. Other changes provided more realistic gunner training and better feedback to the gunner and the instructor on simulated firing exercises. An additional advantage offered by the I-COFT was that the same visual effects simulator and mounting hardware could be used on either the M551 SHERIDAN vehicle or the M60A2 tank.[45]

(U) In September 1977, the I-COFT was classified as limited production and Aeronutronic received a production contract (DAAH01-77C-0975) for 45 launchers and 45 targets. Later additions to this contract increased the production buy to 103 launchers, 60 targets, 25 field support test equipment units, and 10 maintenance van modification kits. An engineering services contract (DAAH01-77C-1012) was also awarded to Aeronutronic in September 1977. In April 1980, the I-COFT was type classified as standard and approved for release to the field. The first trainers became operational at Fort Bragg in May, and worldwide deployment was completed in August 1980. The contractor provided engineering services support for the I-COFT through September 1980. Thereafter, MICOM's Army Missile Laboratory assumed that responsibility.[46]

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[44] (1) Fact Sheet, Mgr, SSMO, to Cdr, MICOM, 13 Jan 76, subj: SHILLELAGH Conduct of Fire Trainer Redesign. (2) MIRCOM AHR, FY 77, p. 144.

[45] (1) Ibid., p. 144. (2) SHILLELAGH Missile System Master Plan, SSMO, MICOM, Feb 76, pp. 27-28. (3) Statement of Need, p. 3., Incl 1 to Ltr, Chf, Drte of Training, US Army Armor School, TRADOC, to HQ, DA, 4 Aug 75, subj: SHILLELAGH Conduct of Fire Trainer.

[46] (1) Fact Sheet, Mgr, SSMO, to Cdr, MICOM, 7 Aug 78, subj: Improved Conduct of Fire Trainer (I-COFT) SHILLELAGH. (2) MIRCOM AHR, FY 77, pp. 144-45. (3) MIRCOM AHR, FY 78, p. 145. (4) MICOM AHR, FY 79, p. 283. (5) MICOM AHR, FY 80, pp. 211-12. (6) MICOM AHR, FY 81, p. 239. (7) SHILLELAGH Missile System Annual Assessment Report, Rept No. QW-MR-79-2, 15 Feb 79, System Performance Assessment Div, D/Prod Assur, MICOM, Appendix V, p. 1.

CHAPTER VII

CONCLUSION

Program Summary

(U) Throughout the entire course of the SHILLELAGH missile subsystem development program, an inordinate number of problems and uncertainties surfaced and persisted in a convoluted fashion. In the program's early years (1959-1964), a fragmented management structure generated different concepts of how research and development should be carried out and under whose aegis. Since the SHILLELAGH missile was designated as a subsystem of various combat vehicle weapon systems, the missile developer at Redstone Arsenal was required to report to the overall vehicle system manager at a distant location. Those arrangements prevented the effective integration of program management and control, and led to the establishment of multiple, overlapping lines of authority and responsibility which in turn caused pervasive decisionmaking and coordination difficulties, as well as duplication of effort. Before the activation of the SHILLELAGH Project Management Office at MICOM in September 1964, development work on the missile proceeded largely on a makeshift and piecemeal basis.

(U) During the initial research and development stages, the prime contractor (Aeronutronic) encountered numerous unforeseen technical problems, which caused extensive redesign of major components and resultant schedule slippages and cost increases. Upon completion of the initial feasibility study in May 1958, Aeronutronic had expressed confidence that the proposed missile subsystem could be made operational in 54 months at a total development cost of $33,922,000 (excluding facility costs). At the beginning of the formal development program early in FY 1960, the Army projected a total RDTE cost of $57,550,000 for the FY 1960-63 period, with a planned system availability date of December 1963.* The contractor, however, had grossly underestimated both the complexity and magnitude of the development effort. In late 1961, the SHILLELAGH program had to be reoriented to an applied research effort to resolve major design deficiencies. Following the resumption of full development early in 1963, a series of successful R&D flight tests indicated that the military characteristics were essentially being met. The Department of the Army thereafter approved the release for limited production in August 1964 and type classified the system as Standard A in May 1966. The SHERIDAN/SHILLELAGH system finally reached the field in June 1967, representing a slippage of some 42 months, and the total RDTE cost, including subsequent product improvements, eventually came to $151.2 million.

(U) While the SHILLELAGH was in full production, from November 1964 until May 1971, the contractor developed and applied major modifications to overcome reported deficiencies, increase the missile's range, and adapt the system to

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*See above, pp. 15, 17. Also see Appendix C.

the M60A2 tank platform. A program to incorporate the SHILLELAGH system in the joint US/German Main Battle Tank (MBT-70) prototype, which began in 1965, was discontinued when the MBT-70 project was terminated in mid-1972.

(U) Early in 1978, when worldwide deployment reached its peak, there were 1,570 SHERIDAN/SHILLELAGH systems in service, over half of which were assigned to armored cavalry units in Germany. A total of 540 M60/SHILLELAGH systems had also been deployed beginning early in 1975, the bulk of them in Europe. In February 1978, the Army decided to replace the SHERIDAN vehicles in nearly all armored cavalry units with the improved M60 series main battle tanks armed only with conventional guns. Primarily because of turret and other hardware deficiencies in the M60A2 tank, the Army then decided in February 1980 to phase out that model from the Army inventory. By FY 1982, there were no M60/SHILLELAGH systems in service and only a residual fleet of 140 SHERIDAN/SHILLELAGH systems remained in the inventory.

SHILLELAGH Subsystem Cost Summary

(U) Excluding the cost of feasibility studies in FY 1958-59, the US Army invested about $664.6 million in development, procurement, and support of the SHILLELAGH missile subsystem, $509,886,000 or about 76.7 percent of which went to Aeronutronic, the prime developer and producer of the subsystem. Following is a summary of the funding program (in millions).

Recipients	RDTE	PEMA	OMA	Total
Various Contractors	$134.1	$454.7	$ .2	$589.0
In-House Government Support*	17.1	54.9	3.6	75.6
	$151.2	$509.6	$3.8	$664.6

*Charges through FY 1971 when the SHILLELAGH Project Office was closed.

(U) Of the $134.1 million in RDTE funds expended under contracts, Aeronutronic received $131,355,000 or about 97.9 percent. Included in the latter were 3 contracts totaling about $100.3 million for applied research, development, and research engineering, and 11 other contracts totaling $31,055,000 for product improvements and other effort, such as extended range missile flight testing ($1 million); adaptation of the missile to the M60 tank ($3.7 million) and the MBT-70 ($7.5 million); advanced development ($9.9 million); counter countermeasure research ($2.3 million); advance production engineering ($3.8 million); and system improvement study ($1.7 million).

(U) The bulk of the $509.6 million in PEMA funds was expended under production contracts with Aeronutronic and Martin/Orlando, the former receiving $378,384,000 under some 22 contracts and the latter $38,425,000 under 3 contracts. All but $147,000 of the $3.8 million in OMA funds went for in-house Government support through FY 1971. Aeronutronic conducted depot training under a $147,000 contract during the period June 1970 to June 1971.[1]

[1]SHILLELAGH Fact Book, pp. B-8, C-1, C-2-1, and Summary of Shillelagh Contracts (Sec F). File: SAIMS Group, Land Combat Cost & SAIMS Analysis Br, Cost Analysis Div, Comptroller.

APPENDIX

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APPENDIX A

OTCM 36753*
APPROVED - 10 APR 58

WJMorawski/PDDenn/53749

DEPARTMENT OF THE ARMY
Office of the Chief of Ordnance

13 February 1958

FROM: The Subcommittee on Artillery and Vehicle Systems

TO: The Ordnance Technical Committee

SUBJECT: COMBAT VEHICLE WEAPON SYSTEM (PENTOMIC) - Initiation of Department of Army Project No. 5W45-07-034, Ordnance Project TW-413 (U)

1. REFERENCES:

References pertinent to this project are contained in the attached Appendix I, Project Card (Combat Vehicle Weapon System (PENTOMIC).)

2. DISCUSSION:

a. A brief history, statement of requirements, and general characteristics for Combat Vehicle Weapon System (PENTOMIC) are contained in Appendix I.

b. The objective of this project is to provide a long range development of weapon systems (armament-ammunition-fire control combination) for use in combat vehicles of the Pentomic and future Armies.

c. This project is included in the Fiscal Year 1958 Research and Development Program and will be included in the Research and Development and Procurement Programs for succeeding Fiscal Years.

3. RECOMMENDATIONS:

The Subcommittee recommends:

a. That the information outlined in Appendix I (Project Card Combat Vehicle Weapon System (PENTOMIC) applicable to this project be approved.

b. That Department of Army Project No. 5W45-07-034, Ordnance Project TW-413 be authorized for the purpose of development of Combat Vehicle Weapon Systems (PENTOMIC).

c. That this project be assigned Department of Army Priority 1A and Technical Objective LC-1b.

d. That approval be granted to perform studies, investigations, evaluations and development, as necessary, to accomplish subject program objectives.

*Formerly SECRET - Group 4 (AMCTC 3978, 4 Nov 65). Downgraded to Unclassified April 1970.

e. That the item or items developed under this project be assigned Modernization Code DEV-Z.

f. That this action be classified SECRET and the Combat Vehicle Weapon System (PENTOMIC) be classifed in accordance with attached Appendix II (Consolidated Ordnance Item Security Check List).

SUBMITTED FOR CONSIDERATION:

/s/ M. A. KINLEY
M. A. KINLEY
Colonel, Ord Corps
Chairman, Subcommittee

RDB Project Card (DD Form 613)
Project No. 5W45-07-034
26 March 1958

EXTRACT

* *

20. Requirement and/or Justification: A requirement exists during the mid-range period for a direct-fire, guided missile type weapon system for armored combat vehicles, the system to be distinguished by its capability of destroying the heaviest enemy armored vehicles and to be characterized by a significant improvement over conventional gun type tank armament in its probability of hitting and its adapatability to vehicular installation and employment. A further requirement exists for the long range period for a missile type weapon system for combat vehicle installation and employment, the system to be capable of rapidly engaging and efficiently destroying a wide variety of close in and distant ground and sub-sonic air targets at ranges up to 5000 meters.

a. Brief: The objective of this project is to develop an armored combat vehicle weapon system which in combination with other weapons will provide the protected mobile offensive and defensive fire power now associated with gun type tank armament. The mid-range weapon system is required as expeditiously as feasible, to offset the quantitative and perhaps qualitative superiority of Soviet armored vehicles. The mid-range weapons system is distinguished from the long-range system to the extent that the latter imposes an additional requirement for a combat vehicle type system which is capable of performing many more of the offensive and defensive roles of the primary and secondary armament of the family of tanks. The mid-range direct fire system will embody weapons development beyond the present rifled and smooth-bore conventional tubes now reaching the point of diminishing return and would eventually replace the high pressure light, medium and heavy class of tank guns. The long-range system will be employed on a combat vehicle to engage targets during the assault, support, pursuit and exploitation missions by armored units and combined arms teams. It will be the primary offensive weapon to exploit and counter the use of tactical mass-destruction devices and for seeking out and destroying the enemy mobile offensive strength, to include low altitude sub-sonic flying elements. It is desirable that this weapon be capable of being armed with a low yield atomic warhead.

b. APPROACH:

(1) Mid-Range

(a) It is required that the guided missile be capable of destroying the heaviest armored vehicle likely to be encountered on the battlefield. It is desired that it be employable efficiently and effectively against other targets.

(b) It also is required that the probability of hitting a stationary and moving target with each guided missile must be markedly better than that achievable with gun or rocket-type projectiles and must be attained without either resulting in a rate of aimed fire unduly lower than that of existing medium gun tanks or requiring more than one on-vehicle controller-gunner. It is desired that this capability extend from near 0 to 5,000 meters, the approximate limits of direct fire associated with tanks. It is further desired that this capability be retained when the vehicle in which the missile system is mounted is moving and when operating during the hours of darkness and under conditions of poor visibility.

(c) Finally, it is required that loading and reloading be carried out by one man and that the unassisted rate of loading not restrict the rate of aimed fire. Moreover, it is desirable that the weight, size, and configuration of the missile system and its components be such that the vehicle characteristics are substantially independent of the physical characteristics of the former.

(d) In order that the mandatory portions of the above listed requirements can be met quickly, it is accepted that:

1 Defeat of 150mm rolled homogeneous armor at 60° and associated equivalent targets with a shaped charge warhead will provide a satisfactory level of terminal performance at the outset.

2 Use of a guided missile against unarmored targets may prove inefficient from the standpoint of cost and supply. Therefore, consideration during the initial concept study phase should be given to the feasibility of a weapon capable of not only launching a guided missile but also firing relatively low velocity unguided gun-type projectiles. If, however, it is established that attainment of this dual capability will penalize unduly the basic guided missile system or delay materially the latter's introduction into service, it further is accepted that companion free rockets or different and more conventional weapons will have to be used in non-armor defeating roles.

3 Reduction in the direct fire range limits of near 0 to 5,000 meters may prove necessary and that a maximum range of approximately 2,000 meters is adequate initially.

(e) Concept studies of the complete Armored Combat Vehicle (ACV) missile system to include weapon, guided missile, weapon mount, fire control equipment, weapon controls and firing gear, will be completed by 31 Dec. 1958.

(f) Studies will be evaluated to determine which concepts, if any, will be pursued.

(g) Upon selection of one or more promising concepts, subsequent steps in development will be determined in order to establish the practicability of the basic weapon - missile - fire control combination at the earliest possible date and preparatory to developing ancillary equipment and to fabricating prototypes of complete operational systems for ACV applications.

(h) Concurrent with this weapon system development every consideration will be given to the compatibility of the weapon system with appropriate vehicular concept employing new developments in armor, suspension, propulsion and other elements of the combat vehicle systems.

(2) Long-Range

(a) The long range requirement is for a greatly refined and improved system which includes characteristics which cannot be clearly foreseen at this time and are doubtful of attainment with present technological development. This second system will succeed the initial system and should not be permitted to complicate its development. Capabilities and characteristics will be determined as development progresses on the mid-range requirement.

(b) Feasibility studies for the long range system will be initiated in FY59, based upon areas of profitable investigations revealed during the studies and development of the mid-range system.

c. SUB-PROJECTS:

Appropriate sub-projects will be established to implement recommendations contained in Reference 21-h(3) by subsequent Ordnance Technical Committee action concurrently with establishment of military characteristics now being formulated by CONARC. It is expected that this project will be divided into two (2) major sub-projects; "A" Mid-Range Weapon System, and "B" Long-Range Weapon System.

d. FISCAL ESTIMATES:

Period	Total Estimate	Army R&D	Proc & Prod Funds	Other Agency Funds
Sub-Project Funding				
FY59 (A)	3,500 M	1,500 M	2,000 M	None
FY59 (B)	500 M	500 M	None	None
Total Project Funding				
FY58 (A) only	659 M	659 M	None	None
FY59 (A) + (B)	4,000 M	2,000 M	2,000 M	None
FY60 " "	4,000 M	2,000 M	2,000 M	None
FY61 " "	4,000 M	2,000 M	2,000 M	None
FY62 " "	4,000 M	2,000 M	2,000 M	None

e. OTHER INFORMATION

(1) This project will be coordinated by a single Ordnance Corps agency. However, assignment of specific tasks will be made to appropriate arsenals or commands in accordance with mission responsibilities as defined in OCO 15-55 through 22-55.

(2) No basic research contracts are contemplated in this program.

(3) This project is not presently included in an international standardization program.

(4) Operational availability date: Unknown

(5) Several feasibility studies initiated by Redstone and Frankford Arsenals under DA 545-03-029, "Airborne Assault Weapon", will be reviewed for applicability to this project.

f. BACKGROUND AND PROGRESS:

(1) Cumulative History

(a) In early 1954, Project 545-01-002 (TT2-810), "Astron", was initiated in order to fulfill a requirement for long-range development leading to vastly improved types of medium tanks. The Project Directives indicated that emphasis should be placed on preliminary design of a complete end item. The activity on this project consisted of two contracts with commercial facilities and design efforts by Detroit Arsenal. "Astron" was terminated in 1956 to preclude end item development due to unsatisfactory concept development, and inability to project sufficient improvement over current developments.

(b) In July 1956, Project 545-03-029 (TT2-829)(Now TW-402), "Airborne Assault Weapons Systems", was initiated to conduct research, investigation and study leading to the solution of the medium tank problem. This program differed from Astron in that the emphasis was placed on investigation in four sub-system areas. These sub-system areas were designated as chassis, power package, armament and ballistic protection. Funds were allocated to various commands and arsenals to conduct investigations, feasibility studies, and development in the armament and ballistic protection sub-system areas. No work was conducted in the other sub-system areas, under this specific project. The "Airborne Assault Weapons Systems" project is being terminated, until such time as satisfactory improvement in the weapon system can be assured.

(2) Discussion:

(a) Detailed military characteristics for these weapon systems will be recorded by future OTCM action.

(b) Discussion pertinent to this project is contained in DOD Ad Hoc Report on Armament for Future Tanks or Similar Combat Vehicles (Ref. 3.) and CONARC Statement of Materiel Requirements (Ref. 4.).

g. FUTURE PLANS:

It is planned to utilize the mid-range and long-range weapon systems developed under this project in future armored combat vehicles.

h. REFERENCES:

(1) CDOG, par. 336-a(1 thru 5), 336-B, (9, 10).

(2) OTCM Item 36240 dated 6 April 1956, "Airborne Assault Weapons Systems."

(3) DOD Ad Hoc Group Report on Armament for Future Tanks or Similar Combat Vehicles (forthcoming).

(4) U. S. CONARC Letter ATSWD - G451.6/9 (C) dated 18 March 1958, subject: "Qualitative Material Requirements for Missile System Armored Combat Vehicle (U)."

* *

Complete concurrence in this report has been received from all members of the Ordnance Technical Committee.

/s/ E. DERICKSON
Executive Secretary

APPROVED BY ORDNANCE TECHNICAL COMMITTEE
10 APR 58

/s/ J. F. KREITZER, Lt Col, Ord Corps
Chairman Pro Tem and Secretary

APPROVED BY ORDER OF THE
SECRETARY OF THE ARMY

/s/ L. R. PATRICK, Lt Col, GS
For the Chief of Res. and Dev., OCS

APPENDIX I to OCTM 36753

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APPENDIX B

OTCM 37039*
READ FOR RECORD - 2 APRIL 1959

DEPARTMENT OF THE ARMY
Office of the Chief of Ordnance

READ FOR RECORD

Hayer/cas/73916
4 March 1959

References: OTCM 36753, 10 April 1958-Initiation for Development of Combat Vehicle Weapon System (PENTOMIC)
OTCM 36791, 8 May 1958-Assignment of Staff Supervision and recording of project number TU1-2051 to Pentomic System File 00/8C-10871, September 25, 1958 containing military characteristics for Armored Combat Vehicle Weapon System (Midrange)

MEMORANDUM FOR SECRETARY, ORDNANCE TECHNICAL COMMITTEE

SUBJECT: MILITARY CHARACTERISTICS FOR ARMORED COMBAT VEHICLE WEAPON SYSTEM (MIDRANGE)

1. The PENTOMIC Weapon system was initiated by OTCM 36753. Included in the OTCM were an R&D project card (DD Form 613) and Security check List (00 Form 1889).

2. The inclosed military characteristics approved by the Department of the Army supplement the information contained in OTCM 36753.

3. The following security classifications are assigned:

a. READ FOR RECORD w/Appendices: SECRET*

b. READ FOR RECORD without Appendices: Unclassified

c. Appendix I (MC'S): SECRET*

d. Appendix II (Requirement for Training Devices): Unclassified

/s/ Edward Hayer for
B. J. LEON HIRSHORN
Colonel, Ordnance Corps

READ FOR RECORD BEFORE ORDNANCE TECHNICAL COMMITTEE
2 APR 59

/s/ J. F. KREITZER, Lt Col, Ord Corps
Chairman Pro Tem and Secretary

*Formerly SECRET - Group 4 (AMCTC Item 7290, 21 Oct 69). Downgraded to Unclassified April 1971.

OTCM 37039 continued

DEPARTMENT OF THE ARMY MILITARY CHARACTERISTICS
FOR
ARMORED COMBAT VEHICLE WEAPON SYSTEM (MIDRANGE)

I - GENERAL

1. Statement of the requirement. -A direct fire, guided missile-type weapon system for armored combat vehicles, the system to be distinguished by its capability of destroying the heaviest enemy armored vehicles and to be characterized by a significant improvement over conventional gun-type tank armament in its probability of hitting and its adaptability to vehicular installation and employment. The system will include a capability to utilize alerting and target acquisition information from the combat surveillance system. (MR)(CDOG) subparagraph is 336b(9).)

2. Operational concept. -The Armored Combat Vehicle Missile System, in combination with other weapons, will provide the protected, mobile offensive and defensive fire power now associated with gun-type armament.

3. Organizational concept. - The new missile system will be organic to all units equipped with armored combat vehicles requiring an agile, direct fire, armor-defeating capability.

4. Consideration of tripartite, Navy, Air Force, and Marine Corps development activities.

a. Tripartite. - Both the United Kingdom and the United States have anti-tank guided weapons under development. The Fourth Tripartite Conference on Armor agreed to a meeting later this year to write tripartite military characteristics and agree on standard terminology and battlefield employment. To date this meeting has not been held.

b. Other services. - No similar development by other services is known at this time.

5. Feasibility of development. - If, during the development phase, it appears to the design agency (the Ordnance Corps) that the characteristics listed herein require the incorporation of certain impracticable features and/or unnecessarily expensive and complicated components or devices, costly manufacturing methods and processes, critical materials or restrictive specifications which negate mass production techniques and controls of the item, such matters should be brought to the immediate attention of Chief of Research and Development, and the Commanding General, United States Continental Army Command, for careful consideration before incorporation in a final design.

6. Background. - Reason for requirement - A significant and immediate increase in mobile protected fire power is required to offset the quantitative and, perhaps, qualitative superiority of Soviet armored vehicles. Since tank gun development appears to be reaching the point of diminishing returns and a new parallel approach is essential, the potential of the guided missile should be

exploited in order that a direct fire, armored vehicle-mounted missile system can be available for operational use at the earliest possible date.

II - OPERATIONAL CHARACTERISTICS

7. Configuration.

a. The configuration of the system including the missile(s) should be compatible with installation on present standard and both current and future development combat vehicles. However, the primary requirement for system effectiveness must not be compromised to obtain vehicle compatibility. In addition to the missiles the system is considered to include: Launcher or projector, weapon mounting, fire control components, equipment for controlling movement of the weapon and/or its mounting, and firing gear.

b. The weapon system should be as lightweight as practicable without compromise of the required performance characteristics. The overall combination weapon system-armored vehicle weight should show a marked improvement over the weight of conventional gun-type armored vehicles.

8. Performance.

a. The system shall be capable of firing at targets located up to and including 20° above and 10° below the horizontal, when the vehicle mounting the system is level. Extension to 40° above the horizontal is desirable.

b. The system must be capable of being operated by one gunner-controller and of being served by one loader, both crewmen to be located inside an armored combat vehicle and to be able to perform their duties without exposing themselves. The rate of loading must not restrict the rate of aimed fire. The rate of aimed fire should be on the order of 6 to 8 missiles per minute at varying ranges up to 2,000 meters.

c. The weapon system should be simple to operate; excessive training time should not be required. Special selection of crew members to operate the system is not desirable.

d. The missile should be capable of destroying the heaviest armored vehicle likely to be encountered on the battlefield. However, defeat of 150-mm of rolled homogeneous armor at 60° obliquity and associated equivalent targets at ranges up to 2,000 meters will provide a satisfactory initial level of performance.

e. The same basic missile with appropriate warheads shall be employable efficiently, economically, and effectively against unarmored targets, including personnel, material, and field fortifications. If this is infeasible, it is mandatory that means of firing preferably a ballistic type high explosive projectile be provided. Maximum practicable effectiveness in attack of personnel and unarmored materiel, including field fortifications, is desirable. The attainment of this capability must not delay or unduly penalize achievement of the armor-defeating capability of the system.

f. Hitting ability.

(1) The ultimate engagement objective for this system is to achieve with a given load of ammunition, the largest number of successful engagements, each in the shortest possible time; time required to realize these ultimate objectives cannot be accurately predicted. Any interim solution may necessitate compromises among delivery accuracy, rapidity of engagement at various ranges, and number of rounds to kill. Such compromises must result in systems which are practical from the standpoint of cost, maintenance, training, and simplicity of operation and must inspire soldier confidence.

(2) The weapon-ammunition-fire control system must produce significant improvements in engagement capabilities by independently or collectively increasing the effect, decreasing the time to hit, or increasing the delivery accuracy of the projectile without prejudicing the practicality of the system. The ability of a system to provide such a capability will be determined by testing comparatively against the best equipment in being at the time.

(3) Direct fire range limits must extend from near 0 to at least 2,000 meters. Extension of the maximum limit to 3,500 meters is desirable without compromise of the required near 0 to 2,000 meter capability. An indirect fire capability for the missile is not required.

g. As much of the capability as is practicable should be provided when either the Armored Combat Vehicle or the target or both are moving, and during hours of darkness or under conditions of limited visibility.

h. In the event a new turret is required in order for the system to be mounted on present and current development type combat vehicles the armor protection of the turret shall be equal to the armor protection of the vehicle to which the system is adapted. The exterior components of the missile system should be protected against small arms projectiles and artillery shell fragments.

i. Preoperation checks and other stops preparatory to firing must be held to a minimum.

9. Durability and reliability. - The system shall be capable of firing 1,000 missiles and withstanding 2,500 miles of vehicle operation with no greater than organizational maintenance and 2,000 missiles and 4,000 miles of vehicle operation without requiring major overhaul or replacement of major components.

10. Transportability. - The system and the parent vehicles should be transportable by rail and/or water in fighting condition and within the limitations of the Berne-International Agreements for unrestricted rail movement. The missile system shall not be adversely affected in cases where the vehicle on which the system is mounted is transported by air.

11. Associated equipment.

a. Ammunition stowage. - The stowage should be compatible with the parent vehicles. Maximum stowage is desired and must be within the carrying vehicle.

b. Interference. - Interference between adjacent systems and disclosure of firing positions should be avoided to the greatest practical extent. The command guidance must be substantially independent of enemy countermeasures.

c. Optics. - Any optical components which may become damaged should be readily replaced by the crew from inside the vehicle.

III - SPECIAL CHARACTERISTICS

12. Environmental and terrain requirements. - Same as for the vehicle in which it is mounted.

13. CBR and atomic requirements. - Same as for the vehicle in which it is mounted.

14. Kit requirements. - None.

15. Maintenance and interchangeability requirements. - The frequency of maintenance and the time, skills, and number of tools required to carry out preventive maintenance will be kept as low as practicable.

IV - ORDER OF PRIORITY OF CHARACTERISTICS

16. Order of priority. - If any of the required characteristics are incompatible with each other to the extent that significant compromises are required, the CG, USCONARC will be consulted as to the degree of compromise acceptable and the merits of revising the relative priorities which are as follows:

A. Performance.

B. Durability, reliability, and ease of maintenance.

C. Configuration.

D. Associated equipment.

E. CBR and atomic requirements.

F. Transportability.

G. Environmental and terrain requirements.

V - ITEMS SUPERSEDED BY THIS ITEM

17. It is contemplated that this item will replace tank gun systems currently employed for the defeat of armor.

OTCM 37039 continued

Appendix

REQUIREMENTS FOR TRAINING
EQUIPMENT AND TRAINING DEVICES

1. Training equipment. - Components of the missile system itself will be used as training equipment.

2. Training Devices.

a. A requirement exists for a simple, rugged, and reliable trainer for the guided missile type weapon system for armored combat vehicles of a design that will facilitate training of armored combat vehicle crewmen in all aspects of missile firing. The trainer will replace current turret trainers, and will be used to facilitate training in all phases of operation from initial familiarization through crew training to include sequence of operation, firing, tests, adjustments, maintenance, and replacement of parts. The trainer shall contain all the operating controls, firing controls, and interim fixtures associated with the operational equipment, each component being in its correct relative position.

b. A requirement exists for a training device to be used in teaching conduct of fire and in testing crew reaction to simulated targets under simulated tactical conditions.

c. A requirement exists for a modification of Device 17-AR-1, Trainer Tank Platoon Leaders to make it compatible with the missile system.

d. Manuals, training equipment, and aids to include inert warheads, should be available prior to and must be available coincident with the issue of the production item.

UNCLASSIFIED

APPENDIX C

OTCM 37245*
APPROVED 5 NOV 1959
DEPARTMENT OF THE ARMY
Office of the Chief of Ordnance

S.Weiss/P.D.Denn/D.M.Roeck/lel/54137
19 August 1959

FROM: Subcommittee on Artillery and Vehicle Systems

TO: The Ordnance Technical Committee

SUBJECT: COMBAT VEHICLE WEAPON SYSTEM (SHILLELAGH) - Reorientation of Department of Army Project 545-07-034, Initiation of Development of Gun-Launcher, Ammunition and Fire Control; Continuation of Development of Guided Missile; Initiation of Research on COMBAT VEHICLE WEAPONS SYSTEM (LR)

1. REFERENCES:

References pertinent to this project are contained in attached Appendices.

2. DISCUSSION:

a. A brief history, statement of requirement, and general characteristics for Combat Vehicle Weapon System (SHILLELAGH) and Combat Vehicle Weapon System (LR) are contained in Appendix I.

b. The objective of this project is to provide for the development of a weapon system during the midrange period (1963) consisting of a gun-launcher, guided missile, conventional type ammunition and fire control for use in armored combat vehicles.

c. A further objective of this project is to provide for the continuation of research leading to a greatly refined and improved system for use on combat vehicle during the long-range time period.

d. The requirements for these weapons systems are established in CDOG, par. 336b(9) for the midrange system and paragraph 336b(10) for the long range weapons system.

e. This project has been included in the R&D program for FY 58, 59 and 60, and will be included in the R&D procurement programs for succeeding fiscal years.

3. RECOMMENDATIONS: The Subcommittee Recommends:

a. That the information contained in project and task cards applicable to this overall project be approved.

*Formerly SECRET - Group 4 (AMCTC 6265, 26 Jun 68). Downgraded to Unclassified November 1971.

b. That the Department of Army Project No. 545-07-034 be retained on this project for both the midrange and long range systems.

c. That Ordnance Project TW-413 be assigned for the midrange system, and that Ordnance Project TU1-2053 be authorized for the long range system.

d. That this project be assigned Department of Army Priority 1A and Technical Objective LC-02.

e. That approval be granted to perform studies, investigations, evaluations, development and manufacture of a sufficient number of R&D pilots of gun-launchers, guided missiles, conventional type ammunition, fire control sets and associated test and check-out equipment, and improvised turret installations to achieve a completely developed and accepted weapon system to fulfill the midrange requirement.

f. That approval be granted to perform research studies, evaluations, and laboratory development, as required, to accomplish the long range program objective.

g. That the following project tasks and nomenclatures be approved:

(1) Task A - CANNON, 152MM GUN-LAUNCHER: XM81. (This designation to be reserved for prototype design).
CANNON, 152MM GUN-LAUNCHER: XM81E1. (ballistic gun-launcher).
(2) Task B - GUIDED MISSILE, ARMOR DEFEATING: XM13
(3) Task C - CARTRIDGE, 152MM HEAT-MP, XM409
(4) Task D - CARTRIDGE, 152MM WP, XM410
(5) Task E - CARTRIDGE, 152MM practice, XM411
(6) Task F - Fire Control
(7) Task G - Combat System Vehicle Weapon System (LR)

h. That this action be classified SECRET, and the Combat Vehicle Weapon System (SHILLELAGH) and Combat Vehicle Weapon System (LR) be classified in accordance with the attached appendix (Consolidated Ordnance Items Security Check List).

SUBMITTED FOR CONSIDERATION:

/s/ J. L. Quinnally, Lt Col O. C.
for N. S. GLASSMAN
Acting Chairman, Subcommittee

R&D Project Card (DD Form 613)
Project No. 547-07-034
19 Aug 1959

EXTRACT

1. Project Title:
Combat Vehicle Weapon System (SHILLELAGH)
Combat Vehicle Weapon System (LR)

* *

19. This reorientation project card supersedes Project Card 545-07-034, dated 26 March 58.

20. Requirement and/or Justification: A requirement exists during the mid-range period for a direct-fire, command guided missile type weapon system for armored combat vehicles, the system to be distinguished by its capability of destroying the heaviest enemy armored vehicles and to be characterized by a significant improvement over conventional gun type tank armament in its probability of hitting and its adaptability to vehicular installation and employment. A further requirement exists for the long range period for a missile type weapon system for armored combat vehicle installation and employment, the system to be capable of rapidly engaging and efficiently destroying a wide variety of close-in and distant ground and sub-sonic air targets at ranges up to 5,000 meters.

21. BRIEF OF PROJECT AND OBJECTIVE:

a. BRIEF: The objective of this project is to develop an armored combat vehicle long-range weapon system which in combination with other weapons will provide the protected mobile offensive and defensive fire power now associated with gun type tank armament. The midrange weapons system is required to be in the hands of troops by December 1963 to off-set the quantitative and perhaps qualitative superiority of Soviet armored vehicles. The mid-range weapons system is distinguished from the long-range system to the extent that the latter imposes an additional requirement for a armored combat vehicle type system which is capable of performing many more of the offensive and defensive roles of the primary and secondary armament of the family of tanks. The mid-range direct fire system will embody weapons development beyond the present rifled and smooth-bore conventional tubes now reaching the point of diminishing returns and would eventually replace the high pressure light, medium and heavy class of tank guns. The long-range system will be employed on a combat vehicle to engage targets during the assault, support, pursuit and exploitation missions by armored units and combined arms teams. It will be the primary offensive weapon to exploit and counter the use of tactical mass-destruction devices and for seeking out and destroying the enemy mobile offensive strength, to include low altitude sub-sonic flying elements. It is desirable that this weapon be capable of being armed with a low yield atomic warhead.

b. APPROACH:

(1) Mid-range

(a) A contract has been executed with Aeronutronic, Division of Ford Motor Company, on 11 June 1959 for the engineering, design and development of a direct fire guided missile to be fired from the 152MM closed breech gun-launcher. The scope of the contract with Aeronutronic also includes the design and development of the guidance and fire control components, not only to allow firing and controlling the guided missile, but also to allow firing the conventional type ammunition from the 152MM gun-launcher. This contract also includes the installation design to mount this system in existing T95 turrets in order that they may be used as improvised test beds to allow complete development and final engineering and user testing of the weapons system.

(b) The guided missile being developed will be considered the primary round and it will be capable of defeating armored targets at all ranges up to 2,000 meters, with a very high probability of a first round kill. The conventional type HEAT-MP round will be considered the secondary anti-tank round, as well as the primary soft target round. It will be the primary armor defeating round at ranges up to 800 meters and the principal HE round for defeat of soft targets at all ranges. The lethality of the HEAT-MP round in defeating soft targets will be greater than existing tank armament HE type rounds.

(c) Concurrent with this weapon system development, utilization of this system will be integrated into separate vehicle projects currently being approved, in order to supply pilot vehicle and/or turrets to meet specific vehicular materiel requirements. It is currently planned that this weapons system will be utilized on the AR/AAV, the New Main Battle Tank.

(2) Long-Range

(a) The long range requirement is for a greatly refined and improved system which includes characteristics which can not be foreseen at this time and are doubtful of attainment with present technology. This long range period system will succeed the mid-range system and will not be permitted to complicate or delay its development. Capabilities and characteristics will be determined as development progresses on the mid-range system and as a result of research and theoretical investigations.

(b) Feasibility studies for the long range system will be initiated in FY 60.

c. <u>SUB-PROJECTS</u>:

The following task areas are established in order that development may proceed in consonance with established Ordnance mission assignments. Tasks A - D are under the cognizance of ORDTW on Project TW-413. Task E is under the cognizance of ORDTU.

(1) Design and development and manufacture of pilot models of cannon 152MM gun-launcher, XM81. Feasibility studies and development work on this

task were previously conducted under DA Project 501-04-076, Ordnance Project No. TW-411.

(2) Guided missile, anti-tank: XM13, feasibility studies and development on this task was formerly being conducted under DA Project 545-07-034, Ordnance Project TU1-2051.

(3) Cartridge, 152MM: HEAT-MP, XM409
Cartridge, 152MM: WP, XM410
Cartridge, 152MM: Practice, XM411, feasibility studies and preliminary development of all conventional type ammunition for the 152MM gun-launcher was previously conducted under DA Project 504-03-040, Ordnance Project TW-430.

(4) Design and development of all components in the fire control system suitable for firing and guiding the guided missile, as well as firing the conventional type ammunition.

(5) To conduct research investigations and laboratory development of the CVWS (long range system).

d. FISCAL ESTIMATES:

	Total Est.	Army R&D	T&E Funds	Other Agency Funds
Prior	5188	3029	1500	None
FY 60*	12310	8890	3420	"
FY 61	12425	9675	2750	"
FY 62	12915	4565	8350	"
FY 63	19900	7550	12350	"

*Funds to be supplied for gun and ammunition development under Project Nos. DA 501-04-076 and DA 504-03-041 are included.

e. OTHER INFORMATION:

(1) This project will be coordinated in the field by a single Ordnance Agency (OTAC). However, assignment of specific tasks will be made to appropriate arsenals or commands in accordance with mission responsibilities as defined in OCO 15-55 through 22-55.

(2) No basic research contracts are contemplated in this program.

(3) This project is currently included in an international standardization program, Tripartite Category List 1-8-102-2 as CVWS (Pentomic).

(4) Operational Availability Dates:

(a) CVWS (SHILLELAGH) - December 1963
(b) CVWS (LR) - Cannot be determined at this time.

(5) Same or related items. No other work in this field is being done by either the Navy, Air Force, or other Army development agencies.

f. BACKGROUND AND PROGRESS:

(1) Cumulative History:

(a) The SHILLELAGH Weapon System is an outgrowth of the Combat Vehicle Weapon System (Pentomic) and the New Tank Main Armament System.

(b) The "Pentomic" project, approved by OTCM action (36753) in April 1958, initiated development for a radically improved tank armament system. Field responsibility for this project was assigned to the Ordnance Tank-Automotive Command. Technical responsibility of the study contracts was handled by ARGMA. A working committee, chaired by OTAC, was formed to evaluate the feasibility studies being conducted by Aeronutronic, Sperry, Chrysler and Gilfillan. As a result of this evaluation and Staff directive, contracts for continuation of effort were awarded to Sperry and Aeronutronic. After a final evaluation of the two proposed systems by the committee and subsequent reviews by OCO and OCRD, Staff approval for the selection of Aeronutronic as development contractor was forwarded on 10 April 1959. A contract with Aeronutronic for the development of the missile and guidance equipment was executed on 11 June 1959.

(c) Feasibility studies of the conventional type ammunition and gun-launcher were initiated in August 1958 and were based on a BRL study for a new concept tank armament system for the main battle tank. The system envisioned was a moderate pressure, lightweight, large caliber, short overall length gun, launching a spin stabilized multi-purpose projectile. In authorizing these studies, OCRD indicated the additional requirement that this system be capable of launching a direct fire wingless (or folding fin) guided missile.

(d) During March 1959, by DF from CofOrd to CRD, Ordnance advised of the feasibility of such a system and recommended initiation of development of the New Tank Main Armament System that would be capable of firing both guided missiles and conventional type ammunition.

(e) In June 1959, CRD approved the Ordnance recommendations and officially identified the Combat Vehicle Weapon System (Pentomic) as the SHILLELAGH Weapon System, which is to incorporate the gun-launcher, the guided missile, conventional ammunition and suitable fire control.

(f) By direction of the Chief, R&D Division, Office, Chief of Ordnance, in June 1959, OCO R&D Staff supervision of the SHILLELAGH missile, in the Office, Chief of Ordnance was transferred from ORDTU to ORDTW, thereby integrating the complete system in ORDTW.

(g) On 19 June, ORDTW in a letter to OTAC, requested the implementation of this program.

(2) Discussion:

(a) Detailed characteristics for the mid-range weapon system (SHILLELAGH) have been approved by the Dept of Army and were recorded by Read for Record OTCM 37039 in April 1959.

(b) Discussion and background information leading to a specific materiel requirement for these weapon systems are contained in DOD AD HOC report on Armament for Future Tanks or Similar Combat Vehicles, dated 20 January 1958, Log No. 58-356.

g. FUTURE PLANS:

(1) It is planned to utilize the mid-range weapon system (SHILLELAGH), being developed under this project, on the future Main Battle Tank and on the AR/AAV.

(2) The long range weapon system will be carried out as a separate development from the midrange weapon system.

h. REFERENCES:

(1) CDOG, paragraph 336-B(9, 10)

(2) OTCM Item 36753, dated 13 Feb 58 (Combat Vehicle Weapon System) (Pentomic).

(3) Report of AD HOC Group Advisory Panel on Ordnance, Transport and Supply, Office of the Assistant Secretary of Defense, Research and Engineering "Armament for Future Tanks or Similar Combat Vehicles", dated 20 January 1958, Log No. 58-356.

(4) Read for Record OTCM 37039, April 59, recommending military characteristics for the Combat Vehicle Weapon System (SHILLELAGH) mid-range.

R&D Task Card E (DD Form 613)
Project No. 545-07-034
19 Aug 1959

EXTRACT

1. Task Title:

Combat Vehicle Weapon System (LR)

* *

19. This task was previously included on superseded Project Card 545-07-034, dated 26 March 1958.

20. Requirement and/or Justification: A requirement exists for the long range time period for a missile type weapon system for armored combat vehicle installation and employment which is capable of rapidly engaging and efficiently destroying a wide variety of close-in and distant ground and subsonic air targets at ranges up to 5,000 meters with an option of utilizing an atomic warhead. The system will include a capability to utilize alerting and/or target information from the combat surveillance system and the Army Air Defense warning net.

21. a. BRIEF: This system will be employed on armored combat vehicles to engage targets during the assault, support, pursuit and exploitation missions by armored units and combined arms teams. It will be the primary offensive weapon to exploit and counter the use of technical mass-destruction devices and for seeking out and destroying the enemy mobile offensive strength, to include low altitude subsonic flying elements. It is desirable that this weapon be capable of being armed with a low yield atomic warhead.

b. APPROACH: Research effort and feasibility studies will be initiated in FY 60 to investigate profitable areas revealed during the studies and development of the SHILLELAGH system to include a complete theoretical analysis of the electromagnetic spectrum to determine the ultimate possibility of achieving a homing device. Capabilities and characteristics which cannot be clearly foreseen at this time and which may be doubtful of attainment with present technical development will be determined as results of investigation and research effort are realized on this task.

* *

R&D Task Card D (DD Form 613)
Project No. 545-07-034
19 Aug 1959

EXTRACT

1. Task Title:

Fire Control for SHILLELAGH

* *

19. New Task Card

20. Requirement and/or Justification: A requirement exists for fire control equipment including guidance devices to allow launching and controlling the guided missile as well as firing the conventional type ammunition being developed as other tasks within this project.

21. a. BRIEF: The objective of this task is to develop the guidance and control devices required for the SHILLELAGH system to include the missile tracking device, the computer, the missile transmitter, the sight ballistic drive, ranging device, and other miscellaneous associated equipment.

b. APPROACH: The components of the fire control required for guidance of the missile and conventional type rounds will be designed, if possible, for end item use. Other components, such as the ranging device and ballistic drive may be designed for end item use if already standard or development components can not be used in their present or modified form. The sight will not be designed for end item use inasmuch as this would require the incorporation of night firing capabilities. It is believed that the incorporation of this firing capability might seriously delay the achievement of the primary objectives of the project. Plans have been established to initiate development of an integrated sight as part of a new program currently being approved. Close coordination must be accomplished with the user during all phases of this program.

c. SUB-TASKS: Sub-tasks have not been separated, inasmuch as this area is completely under contract with Aeronutronic, under the technical supervision of AOMC(ARGMA) with other arsenals supplying consulting services.

d. FISCAL ESTIMATES: Fiscal estimates for this task have not been separated from the overall project requirements.

e. OTHER INFORMATION:

(1) This task will be coordinated with other tasks under the complete system. Responsibility for development will be assigned in accordance with mission responsibilities as defined by OCO 15-55 through 22-55.

(2) No basic research contracts are contemplated in accomplishment of this task.

(3) This task is currently included in an international standardization program, Tripartite Category List 1-8-102-2 as CVWS (Pentomic).

(4) Operational Availability: This item is scheduled to be available to troops in December 1963.

f. BACKGROUND, HISTORY & PROGRESS: See Basic Project Card.

g. FUTURE PLANS: It is planned to continue the development of the fire control and guidance equipment by Aeronutronic. Incorporation of night firing capability is being developed under a separate project.

h. REFERENCES: See Basic Project Card.

R&D TASK CARD B(DD Form 613)
PROJECT NO. 545-07-034
19 Aug 1959

EXTRACT

1. Task Title:

Guided Missile, Armor Defeating, XM13.

* *

19. New task card

20. Requirement and/or Justification: A requirement for the development of a direct fire, command guided missile for the SHILLELAGH Weapons System.

21. a. BRIEF: The objective of this task is to develop a direct fire, command guided missile incorporating a HEAT war-head of sufficient size to defeat the Tripartite heavy tank targets. It is intended that this guided missile will be the primary anti-tank defeating capability of the SHILLELAGH missile system and will be fired from the 152MM gun-launcher indicated as a separate task on this project.

b. APPROACH: As a result of feasibility studies by several contractors it has been determined advantageous to develop a command guided missile in order to achieve greater first round hit probabilities, particularly at longer ranges, against hard targets which are significantly higher than those normally associated with gun type armament systems.

c. SUB-TASKS:

The proposed guided missile, anti-tank XM13 is the only task listed on this task card.

d. FISCAL ESTIMATES:

Fiscal estimates are included in those listed on the basic project card.

e. OTHER INFORMATION:

(1) The missile propulsion will be provided by a solid propellant rocket motor which will accelerate the missile to a peak velocity of approximately 1050 feet per second. It is intended that the missile will glide to the target after burn-out to a maximum range of 2,000 meters. Static stability is obtained by means of four fins at the rear of the missile which are extended after the missile leaves the launcher. The missile is stabilized in roll and controlled in pitch and yaw by a system of hot gas reaction jets in the nose of the missile. Hot gas flow is provided to the pitch, yaw and roll control jets by burning a solid propellant in a gas generator. The missile carries on-board

receivers and electronics with which to receive IR control signals from the guidance equipment and translate them into pitch, yaw and roll control signals to the hot gas jet controls. The missile is tracked from a modulated IR source in the base of the missile. It is expected that physical characteristics will approximate the following:

Length	42 inches
Diameter	6 inches
Gross Weight	45 pounds
Warhead	12.8 pounds

Significant changes in the physical characteristics particularly changes which would increase the weight, diameter, and length of the missile, must be immediately coordinated with the user.

(2) No basic research contracts are contemplated in this program.

(3) This project is currently included in an international standardization program, Tripartite Category List 1-8-102-2 as CVWS (Pentomic).

(4) Operational availability date: The guided missile anti-tank, XM13 is scheduled to be available and in the hands of the troops in combination with other items of the SHILLELAGH Weapon System by December 1963.

f. BACKGROUND HISTORY AND PROGRESS:

See Basic project card.

g. FUTURE PLANS:

It is planned to continue development of this guided missile under the technical direction of AOMC (ARGMA).

h. REFERENCES:

References pertinent to this task are included on the basic project card.

R&D Task Card A
Project No. 545-07-034
19 Aug 1959

EXTRACT

1. Task Title:

Cannon, 152MM Gun-Launcher, XM81 (Series)

* *

19. New Task

20. Requirement and/or Justification: A requirement exists for the development of 152MM gun-launcher capable of firing both conventional type ammunition and a guided missile. It will be characterized by its lightweight, short length and adaptability to vehicular installation and employment.

21. a. BRIEF:

(1) The objective of this project is to develop a Gun-Launcher for a Tank Main Armament System characterized by moderate to low pressure, lightweight, short tube, small chamber volume and capable of launching a spin-stabilized chemical energy HEAT shell having a spin-compensated liner for the shaped charge. The caliber of this armament system is to be of sufficient size to penetrate the armor of all existing or future enemy heavy tanks and to provide adequate residual damage after penetration to insure destruction.

(2) This armament system must serve as a launcher for the delivery of direct fire, guided missiles, as a gun to deliver conventional type ammunition.

b. APPROACH:

(1) In the past, a chemical energy HEAT shell was considered as a secondary round in a high velocity kinetic energy system. In the proposed armament system, sole reliance is placed on chemical energy for the defeat of armor. Since terminal performance of the shaped charge is independent of striking velocity, the HEAT projectile need only be launched at a speed consistent with good flight characteristics, hence pressure and velocity can be relatively low when compared to current high velocity kinetic energy cannon. Such a combination of characteristics allows the design of a compact, lightweight gun type launcher most adaptable to vehicle installation.

(2) The new Gun-Launcher will employ the separable chamber breech design and will be constructed of high physical, cold worked components. The breech will utilize a self-sealing or obturating device to accommodate combustible cased ammunition.

(3) Gun-Launcher design will be such as to permit the launching of the guided missile currently being developed.

c. SUB-TASKS: The proposed Cannon, 152MM Gun-Launcher XM81 Series is the only task listed on this task card.

d. FISCAL ESTIMATES: Fiscal estimates for this task are included on the basic project card. During FY 60 funds will be utilized from Project No. DA-501-04-076, Ordnance Project TW 411 for this development work. In following years the funding will be incorporated into DA Project No. 545-07-034.

e. OTHER INFORMATION:

(1) Design Characteristics:

Proposed characteristics for the 152MM Gun-Launcher are:

Caliber	152MM (6.00" Bore)
Bore Length	17.53 calibers
Projectile Travel	96 Ins.
Chamber Volume	285 cu. Ins.
Max. Rated Pressure	32,000 p.s.i. (cu)
Total Est. Weight	870 lbs.
Twist of Rifling	1/43.6 - RH

(2) Scientific Research -- No basic research contracts are contemplated in this program.

(3) Standardization -- This task is currently included in an international standardization program, Tripartite Category List 1-8-102-2 as CVWS (Pentomic).

(4) Engineering Test -- Critical materials to be used in this program are alloying elements for high strength gun steels such as chromium, nickel, molybdenum, manganese, etc. There is no anticipated lack of critical materials.

(5) Operational Availability Date -- It is estimated that the "New Tank Main Armament System" can be operationally available to the User, by December 1963.

(6) Same or Related Items -- No other defense agencies are performing work in this area.

f. BACKGROUND, HISTORY AND PROGRESS:

(1) Cumulative History:

(a) In April 1958, the Ballistic Research Laboratory at Aberdeen Proving Ground published Technical Note 1183 (Ref. 1) proposing a concept tank armament system utilizing a gun characterized by its large caliber combined with short travel and moderate pressure to provide a lightweight component for launching a spin-stabilized dual purpose shell having a spin-compensated liner for the shaped charge.

(b) In July 1958, the Chief of Research and Development requested that a technical study be conducted to determine the practicability of development, and the design parameters for a "New Tank Main Armament System" capable of defeating the heaviest known or projected Soviet tanks in substantially all attack conditions, whether utilizing compound, special or spaced armor arrangements. In addition, the system should be capable of launching direct fire, wingless, guided missiles for extreme battle ranges.

(c) Under the direction of the Chief of Ordnance, a committee was formed of representatives from BRL, OTAC, Picatinny and Watervliet Arsenals to conduct the study outlined in (b) above. The mission was completed in January 1959 and presented to Staff, USCONARC and interested Ordnance agencies early in February. The completed report was published in March by Watervliet Arsenal (Ref. 5).

(2) DISCUSSION:

(a) Detailed military characteristics for the proposed Gun-Launcher will be recorded by future OTCM action.

(b) Discussion pertinent to this project is contained in Watervliet Arsenal technical report, "A new Tank Main Armament System" (U), dated March 1959.

g. FUTURE PLANS: It is planned to utilize the Gun-Launcher developed under this project in future armored combat vehicles in connection with CVWS (SHILLELAGH).

h. REFERENCES:

(1) BRL Tech. Note 1183, "A Concept Armament System for the Main Battle Tank" (U), April 1958.

(2) File 00/8S-6402, CRD/C-6042, Comment Nr. 2, C/R&D to Chief of Ordnance, Subject: "Future Tank Production," dated 24 July 1958.

(3) Letter from OCO (ORDTW) 00/8S-8894 to Watervliet Arsenal, dated 12 August 1958.

(4) 1st Ind to 00/8S-8894, Watervliet Arsenal to OCO (ORDTW), dated 22 August 1958.

(5) Technical Study, "A New Tank Main Armament System" (U), Watervliet Arsenal, March 1959.

* *

SUBJECT: COMBAT VEHICLE WEAPON SYSTEM (SHILLELAGH) - Reorientation of Department of Army Project 545-07-034, Initiation of Development of Gun-Launcher, Ammunition and Fire Control; Continuation of Development of Guided Missile; Initation of Research on COMBAT VEHICLE WEAPONS SYSTEM (LR)

Concurrence in this report has been obtained from members of the Ordnance Technical Committee, in accordance with AR 705-9.

/s/ E. Derickson
Executive Secretary

APPROVED BY ORDNANCE TECHNICAL COMMITTEE
5 Nov 1959

/s/ E. L. Weible, Major, Ord Corps
Chairman Pro Tem and Secretary

APPROVED BY ORDER OF
THE SECRETARY OF THE ARMY

/s/ Russell C. Peeples, Jr.
For the Chief of Res and Dev, OCS

APPENDIX D

AMSMI-W 17 Aug 1964

Major General W. B. Bunker
Deputy Commanding General
U. S. Army Materiel Command
Washington, D. C. 20315

Dear General Bunker:

As you may know, I submitted a letter to AMC on 7 July 1964 in which I outlined the problems that exist between MICOM and WECOM regarding the management of the Shillelagh subsystem and recommended that it be projectized at the Missile Command. I understand the contents of that letter are currently being studied.

I would like, at this time, to emphasize my concern and strong convictions in this matter. I am convinced that the current arrangement, which in essence uses my people as a technical management labor pool, is not working and will not work satisfactorily, even as modified by a recent proposal by General Anderson. What I want most is to be given the total doing job for the missile. My recommendation that the Shillelagh be projectized is of secondary importance, although I do feel that such action would place the whole matter in the best perspective with respect to clarity, simplicity, efficiency, and effectiveness.

Recognizing that my 7 July letter hit only the highlights of the problem, I asked my people to put together a presentation that would appropriately elaborate on the details. I had in mind that at a proper time it would be given at AMC. After having thought further on this subject, I felt that it would be better to present the content of that presentation in written form to you for your personal perusal.

Your consideration of my position in this matter will be greatly appreciated.

Sincerely yours,

1 Incl
as

/s/ John G. Zierdt
JOHN G. ZIERDT
Major General, USA
Commanding

MICOM Briefing on Shillelagh Subsystem

Gentlemen:

1. The fundamental problem that exists between the Missile Command and the Sheridan/Shillelagh Project Manager has already been presented. However, it is felt that some elaboration is appropriate in order that the MICOM viewpoint is thoroughly understood. To accomplish this I will present, first, an evaluation of the current task order arrangement; second, a discussion of the new WECOM/Project Manager proposal; and, third, an examination of the commodity command role in relation to project management.

2. In summary, the disadvantages of the current arrangement are reflected on this chart.

CHART #1

3. At this point it is believed that these disadvantages can be placed in proper perspective by providing a few illustrations.

4. Our first illustration involves the acquisition of the manufacturing facility. Late last summer, MICOM officially submitted a facility plan to the Project Manager which, in essence, stipulated that the contractor would furnish the required facility plus 20% of the necessary capital equipment. From the point of having submitted this plan to the Project Manager until mid-July (an elapse of about ten months), the Missile Command was not further officially involved in this area. Unofficially, however, we understand that the plan was not considered acceptable by the Project Manager. Apparently the Project Manager subsequently developed and received approval of a plan which would utilize a government owned facility at Lawndale, California; he then submitted a project request to rehabilitate the Lawndale facility and as a result received approval, in principle, whereupon program authority in the amount of about $679,000 was set aside for the project. We further understand that, because the project request did not contain cost verification by the Corps of Engineers, only $25,000 was released until such time as the verification was received.

5. On 21 July of this year, the Missile Command was again officially brought back into the act. Our job was to work with the Corps of Engineers and all others concerned to finalize all necessary plans, receive Corps of Engineer verifications, obtain final project approval, and take necessary implementing actions in such a manner as to preclude schedule slippages if at all possible. As things now stand, we find ourselves in a very awkward and critical situation in that we are obligated to take every action possible to circumvent time in order to make the facility available as near to the scheduled date as is possible. It appears that even under the most optimistic conditions the availability of the facility to the contractor will slip at least two months.

CHART 1

DISADVANTAGES OF CURRENT SHILLELAGH ARRANGEMENT

I. PROJECT MANAGER DEVIATES FROM TASK AGREEMENTS.

II. EFFORT IS DUPLICATED.

III. MICOM PERSONNEL CANNOT BE COMPLETELY KNOWLEDGEABLE.

IV. STIFLES "SENSE OF URGENCY" OF MICOM PEOPLE.

V. CREATES "VOIDS" AND "UNNECESSARY DELAYS" WHILE AWAITING DECISIONS

UNCLASSIFIED

6. Having very briefly presented the particular illustration, I would like to relate these events to the stated disadvantages previously shown. First, let me emphasize that we are in no way raising the question as to the propriety of using a government owned facility versus a contractor facility. Our biggest single point in this illustration is that the Project Manager chose to put the Missile Command out of the act late last year and pursue the matter himself.

7. It is obvious from the example here that the Project Manager, to one degree or another, duplicated the capability and staffing of the Missile Command because he was able to put personnel to work on the project in the intervening months. Obviously, the Missile Command's people were not kept knowledgeable of what transpired and when given the job back on 21 July found themselves at a considerable disadvantage - including a lack of documentation to back up our current and future actions. Although we intend to pursue required actions with the greatest of vigor, we must admit to having a feeling of being called upon for technical management "labor pool" services because of an emergency which could not be handled within the resources immediately available to the Project Manager. This obviously affects the morale and sense of urgency of our people. Finally, and most important, the delay exemplified here, we feel, would not have occurred had the Missile Command been handling the job continuously.

8. Another illustration, closely related to our previous one, concerns itself with required reprogramming actions and the letting of the hardware contract. Funds were programmed and approved for hardware and facilities on the basis of the original plan submitted to the Project Manager last summer. During the intervening time, when the facility concept was being changed, no one took action to correlate with this endeavor the requirement for reprogramming funds based upon utilization of the Lawndale facility. Utilization of Lawndale has resulted in increased hardware costs and a reduction in facilities costs, thereby requiring a reprogramming action. This action cannot be completed until all facilities requirements (including the missile firing range) are finalized and costed. The Missile Command is presently developing the cost for the manufacturing and assembly plants. However, we have not been given the responsibility for developing the cost of establishing a firing range. Thus, even having been brought back into the picture on 21 July, we still are not doing the total job and, consequently, we cannot provide the data necessary for the reprogramming action.

9. The hardware contract scheduled for execution on 1 Sep 64 cannot be let until all reprogramming action has been accomplished. Again, since we are not aware of all of the actions which must necessarily precede reprogramming, we are unable to predict, at this time, a specific date when the hardware contract will be executed. Certainly there will be a significant slippage from the scheduled date.

10. This example vividly illustrates duplication, lack of knowledge, and, more significantly, the creation of a void which will cause schedule slippage. Again, the Missile Command feels confident that had we been doing the total job the system would not be in the trouble which it currently finds itself - even with the rejection of our initial plan.

11. These are but two of many examples wherein the Project Manager utilizes the Missile Command on an intermittent basis, leaving us with the distinct impression that we are called upon only as a technical management labor pool. Certainly he is not utilizing the integrated capability of the Missile Command to get a missile job accomplished.

12. We, of course, have pursued this matter with WECOM and the Project Manager. These discussions have culminated in a proposal by WECOM and the Project Manager. This proposal is unacceptable to the Missile Command. Although the new WECOM plan would reduce the number of tasks from 70 to 10, this is in reality only a superficial improvement. The more important question remains, "What is to be the actual job of the Missile Command and the concept of management with respect thereto?" Essentially, the latest proposal does not alter the previous concept and we have no reason to believe that we will be used other than intermittently as a technical management labor pool. Our reasoning is as follows:

a. Although the proposal purports to give us the P&P and S&M mission activities, we, in fact, find that this cannot be so because, in essence, the Project Manager would retain direct control over the contractor-both generally and on site at the plant. The proposal, however, is vague in that it recognizes that MICOM can give certain undefined direction to the contractor in order to accomplish its assigned supporting activities, but under restrictions so severe that we are at a loss to understand what directions we may give. In principle, the contractor may be directed by two or more sources. It is our considered opinion that sound practices of procurement require that there be a single focal point for directing a contractor. This is not meant to imply that the Project Manager could give no direction to the contractor. To the contrary, he could give any direction desired but normally through the Missile Command as his managing agent. In fact, at a recent meeting between General Zierdt and Aeronutronics, Mr. Lawson, the top executive of Aeronutronics, "urged that somebody be in charge." The ultimate test which, in reality, determines who directs the contractor is the source of the funds. Since funds would go direct from the Project Manager to the procuring agency and thus to the contractor, it is obvious that the contractor would not consider the Missile Command as being in charge.

b. With respect to funds, the Project Manager must unquestionably control these along with associated program authority. The new proposal would leave it as it has been in the past, i.e., that each action, except MICOM in-house work, would go back to the Project Manager for issuance of funds and program authority. This command strongly urges a relationship similar to that with major contractors who control funds and authority for sub-contractors. This could be accomplished under whatever controls the Project Manager needs.

c. The WECOM proposal specifies that the Missile Command will have responsibility for all P&P and S&M mission activities. It also specifies that the mission of the Project Manager's Missile Engineering Division, located at Redstone Arsenal, would execute those functions specified in an attachment. The function of that Division as written includes "plan, direct, evaluate, and/or execute the entire engineering processes required to develop, produce, and maintain the Shillelagh missile system." This, of course, includes all production and maintenance engineering, which theoretically would be given to the Missile Command as a part of the P&P and S&M activities, thus the proposal conflicts with itself and does not indicate anything other than a continuation of the undesirable situation we have already substantially illustrated.

d. If the Missile Command is to be used to best advantage, we feel strongly that we should be given the total missile job to do including the development engineering. Certainly there will be continued development effort exerted - for example - the extended range version. These development efforts will have to be meshed in an effective manner with the production and field support aspects of the current missile. Concurrency in this dimension will involve factors which require active participation and timely coordination of many people with many different skills involved in many different areas. This requires a well organized, experienced, and tested team which has demonstrated a capability of working in unison to get a job done effectively - in short - the Missile Command.

13. Possibly the various factors which have been discussed up to this point may be summarized graphically.

CHART #2

14. This chart depicts graphically the management interfaces which currently exist with respect to the missile. It is noted that the operations are divided and require numerous horizontal interfaces between the respective operational groups. Such interfaces require learning, necessitate extensive communication, consume time, cause delays, subject the parties concerned to misunderstandings, and require a circumventing of normal internal organizational interplay. Of course, these horizontal interfaces are in addition to the normal vertical interfacing.

15. The contractor is in the confusing position of receiving direction from two sources. The question mark indicates a lack of understanding on the part of all concerned as to specifically who gives what direction.

16. It is the Missile Command's belief that a stronger and more effective total structure would evolve if we would eliminate the numerous horizontal interface requirements between two missile operational groups and provide a single focal point for directing the contractor activities.

CHART #3

17. This next chart illustrates this desired situation. One could contend that even though we merged the two operations, horizontal interfacing would still be required. In one sense this is true. However, the basic theory of organizing to get a job done recognizes that the object of any organizational system is to provide a framework of structure, procedures, and

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CHART 3

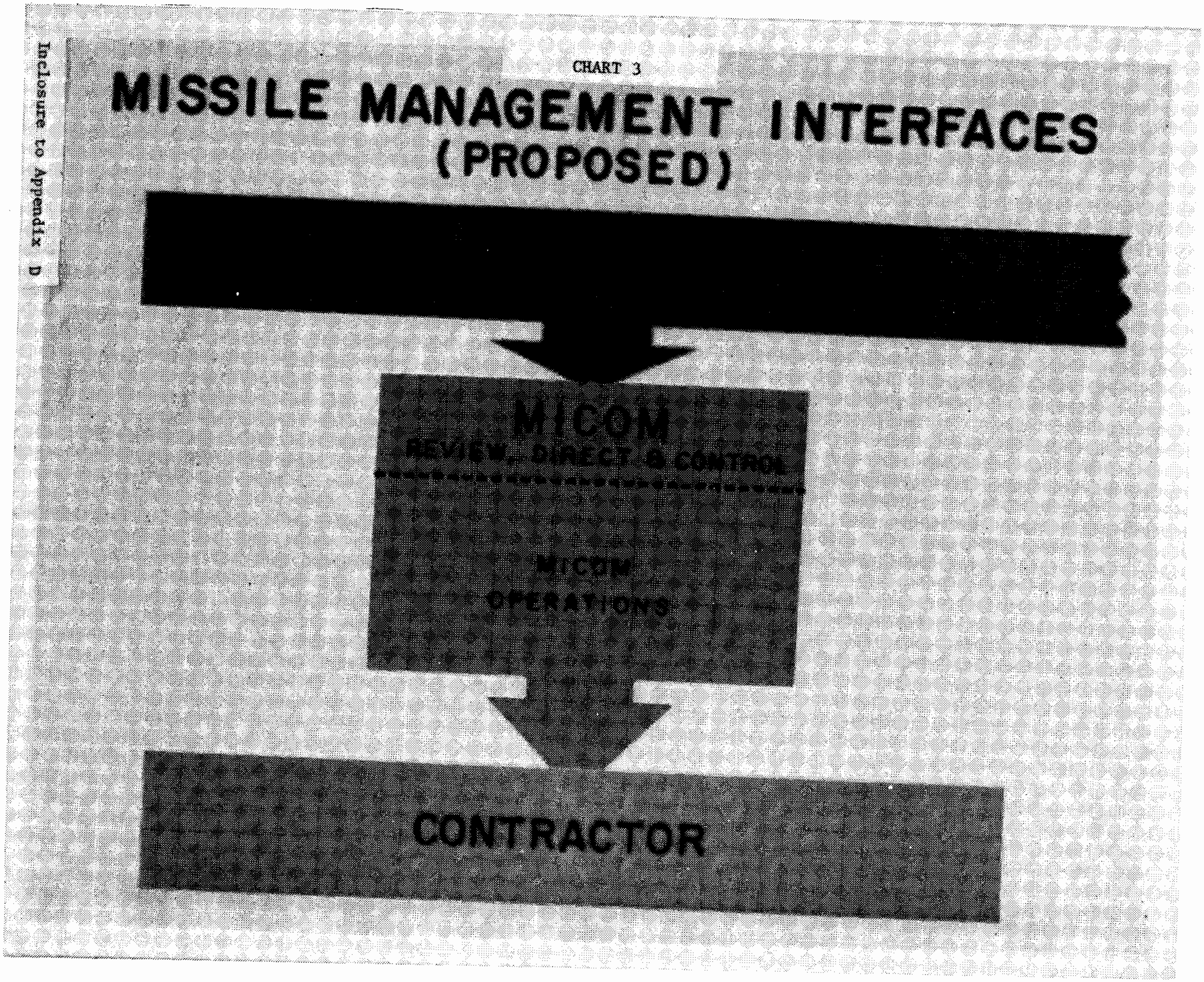

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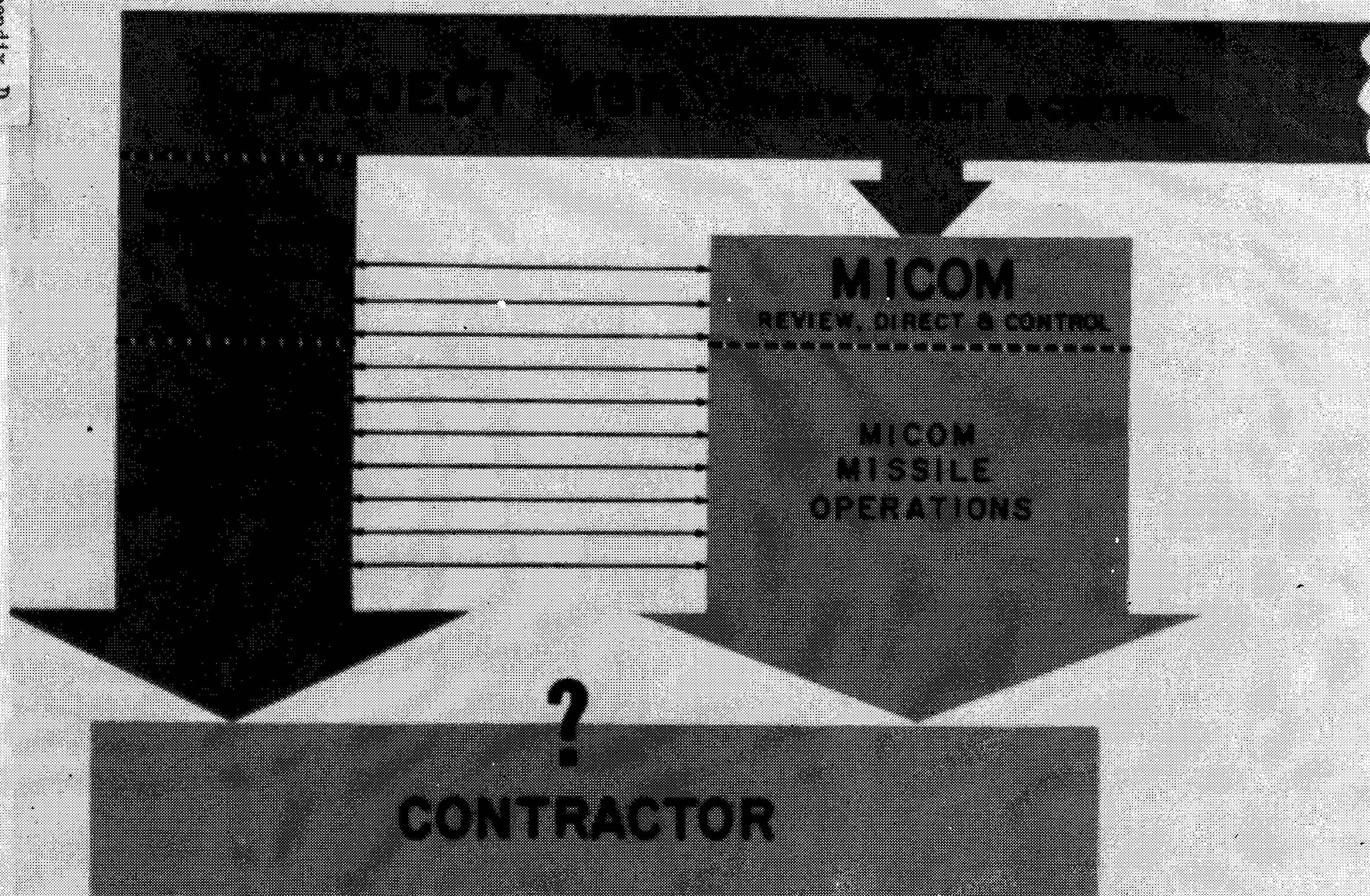
CHART 2

MISSILE MANAGEMENT INTERFACES
(PRESENT)



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communication integrated in such a fashion that individuals involved, after gaining experience, respond to the system so spontaneously that when viewed as a whole one sees only the efficient functioning of a sophisticated machine. In this sense, interfacing, as such, is eliminated and the team, based upon the experience of having worked together in a disciplined manner, tends to automatically respond in an integrated fashion to all requirements at the right time and in the right fashion. The Missile Command feels that it has such a team expertly oriented in the missile business and that failure to utilize its total integrated capability renders this command's effectiveness much less than could be realized.

18. I should like now to broadly examine the method of operation within the Army Materiel Command as it relates to the respective roles of the Project Manager and the major subordinate commands. We feel that no one appreciates the concept of project management more than does the Missile Command. It is well established that as it relates to his project, the project manager is solely responsible for his system and that he exercises full-line authority in all planning, direction, and control of the project and associated resources. The primary question is, "How does the Project Manager use the major subordinate commands to accomplish his total job?" We are certain that he can completely control his project and, at the same time, effectively utilize the major subordinate commands in accordance with their assigned missions.

CHART #4

19. This chart depicts the mission of the Missile Command. Mission #1 specifically expresses coverage and extent of the mission. Mission #3, shown at the bottom of the chart, we feel effectively specifies the command's role for commodities that are project managed. This mission statement gives us the total job to do on the Shillelagh subsystem and, at the same time, places the performance of that job in context by specifying that it is in support of the Project Manager and under his direct authority.

20. We recognize this approach in the case of the project managed systems that are located at the Missile Command. This next chart illustrates this.

CHART #5

21. In the Pershing system, the warhead is assigned to MUCOM, the vehicle to MOCOM, the communications pack to the Electronics Command. A similar situation exists for Hawk and for all of our other systems which require performance by other than the Project Manager/MICOM. In all of these cases the total job is given to these commands. Under such an arrangement, each of the commodity commands is able to perform the assigned commodity mission by bringing to bear the total resources of the command in an integrated effort as required to accomplish the job, but under the direction and control of the project manager. To remove the overall management of the commodity from that commodity command would not only weaken its technical capability, but, if carried to the extreme, would destroy the AMC commodity commands.

CHART 4

MISSION OF THE U. S. ARMY MISSILE COMMAND

I. EXERCISE INTEGRATED COMMODITY MANAGEMENT OF MISSILES AND ROCKETS AND OTHER ASSOCIATED EQUIPMENT, INCLUDING:

A. DESIGN AND DEVELOPMENT.

B. ENGINEERING.

C. PROCUREMENT AND PRODUCTION.

D. CATALOGING AND STANDARDIZATION.

E. INVENTORY MANAGEMENT, SUPPLY CONTROL, AND ASSIGNED STOCK CONTROL.

F. NEW EQUIPMENT TRAINING, TRAINING DEVICES, AND TECHNICAL ASSISTANCE.

II. CONDUCT OR MANAGE BASIC AND APPLIED RESEARCH.

III. EXECUTE ASSIGNED MISSIONS IN SUPPORT OF OTHER AMC ELEMENTS HAVING PROJECT MANAGEMENT OR COMMODITY MANAGEMENT RESPONSIBILITY FOR SPECIFIC WEAPON SYSTEMS OR ITEMS.

CHART 5

USE OF OTHER COMMODITY COMMANDS
BY
MICOM PROJECT MANAGERS

SYSTEM	COMPONENTS	RESPONSIBLE COMMAND
PERSHING	WARHEAD	MUCOM
	TRACKED VEHICLE	MOCOM
	COMMUNICATIONS PACK	ECOM
HAWK	WARHEAD	MUCOM
	LOADER	MOCOM

22. As it relates to the warhead for the Shillelagh subsystem, we understand that MUCOM, in effect, has the total job to do - working, of course, under the direction of the Project Manager. We fail to see why the missile itself should be handled any differently.

23. Another analogy can be made. The Project Manager for Aircraft Armament, working out [of] AMC HQ, has defined his system by components and assigned total responsibility for those components to the appropriate commodity subcommands while retaining overall direction, control, and system integration. In this case, the Missile Command has been assigned the job for the XM3 and XM22 missile subsystems.

CHART #6

24. This chart depicts, in principle, the method of management used by the Aircraft Armament Project Manager (with MOCOM supplying the vehicle). It also represents the method we would like to see the Sheridan/Shillelagh Project Manager adopt - giving the missile job to MICOM with control over the contractor and necessary resources. Actually the Sheridan/Shillelagh Project Manager operated generally in this fashion when he was a part of AMC HQ. The reason for changing after transfer to WECOM is not apparent, particularly since MICOM was not contacted in any way at the time of decision.

25. In summary, the primary concern of the Missile Command is that the total doing job for Shillelagh is being withheld. Our strong belief, desire, hope, and plea is that this total doing job be given to the Missile Command.

26. For whom we do the job is of secondary importance. Certainly we have no inhibitions for accomplishing this total job for the Sheridan/ Shillelagh Project Manager. At the time this matter was brought to the attention of AMC, it was deemed appropriate, from a theoretical viewpoint, to request that the Shillelagh be projectized in its own right at the Missile Command. The logic for this is as follows:

a. The Shillelagh will be used for multiple applications. Already it has been selected for two applications and it is a candidate to be used on two additional modes (Direct Support and Aircraft Armament). It appears to the Missile Command that under such multiple applications the projectization of Shillelagh as such would permit the most objective response to all concerned. Admittedly the two uses thus far approved involve WECOM vehicles. WECOM implies that since they have both vehicles there are no new outside factors which should cause additional consideration to be given to placing Shillelagh at the Missile Command. Under existing conditions, interfaces must be accomplished between the Sheridan/Shillelagh Project Manager and the Main Battle Tank Project Manager. This, in essence, specifies that the Sheridan/ Shillelagh Project Manager, established for the purpose of managing the Sheridan/Shillelagh Systems, must now divert some of his energies to the interface problems associated with the Main Battle Tank - which in itself is projectized. This seems to be an unnecessarily awkward situation when a much more straight forward structure could be evolved with the Missile Command doing the missile job, responding to the requirements of each Project Manager who, of course, would have control over interfaces.

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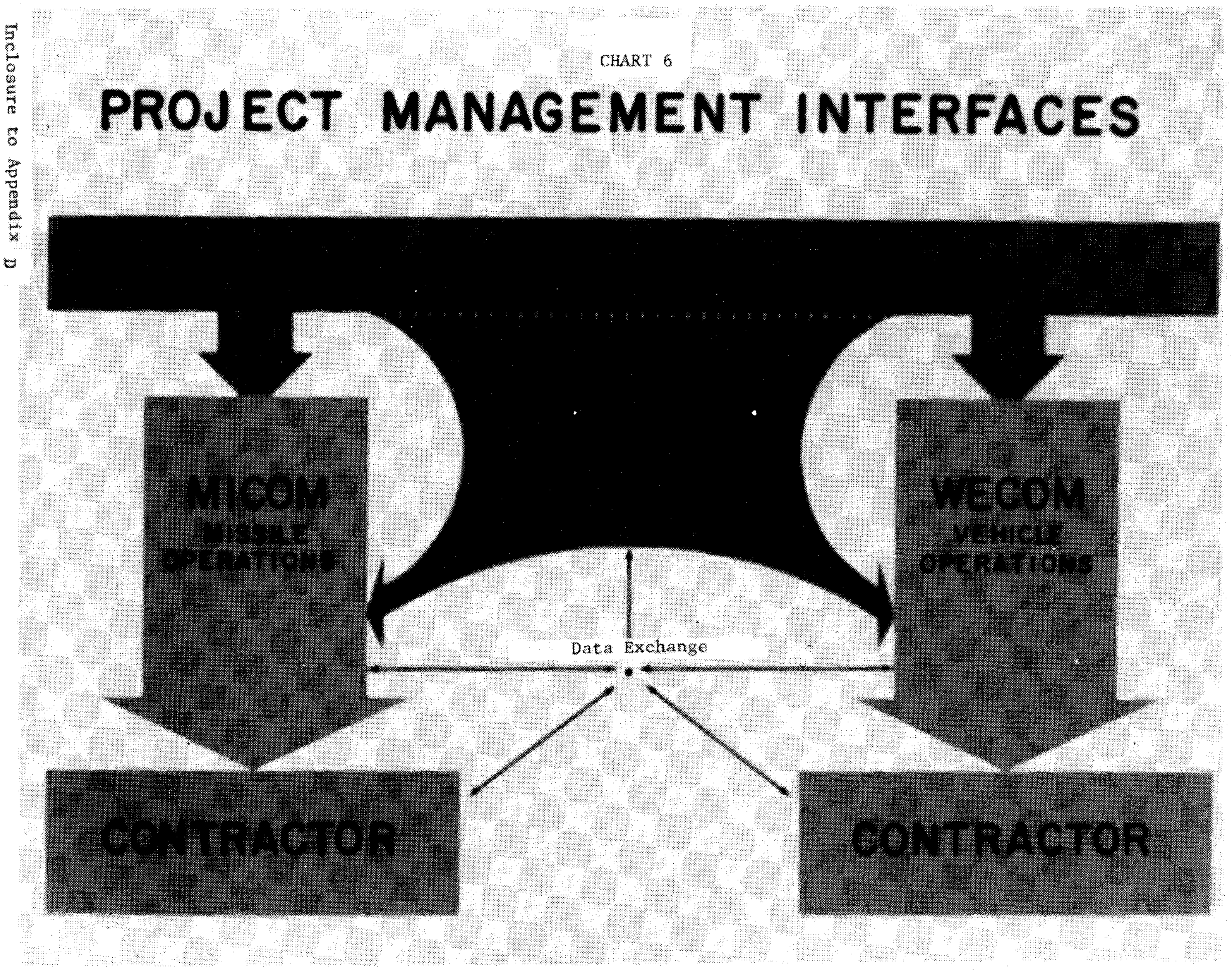

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b. Continuation of the current arrangement seems to set the stage for continued fragmentation of the missile mission in terms of the "commodity command concept." This becomes serious when we recognize that all indications point toward a reduction in the number of types of missile systems and total associated dollars. Under these conditions, it would seem that the strength of the Missile Command can be sustained only by giving it responsibility for all missile activity.

27. In conclusion, we request, first, that the Missile Command be given the total doing job, and, secondly, that the Shillelagh be projectized in its own right at the Missile Command.

APPENDIX E

(U) SHILLELAGH Development Test Firing Data*

(Standard Range)

April 1961 - October 1964

FIRING NO	DATE	OPERATION	OBJECTIVE	SCORE	FAILURE AREA	RANGE TO FIRST TARGET
1	20 Apr 61	I-F1**	Flight Control	Success		N/A
2	3 May 61	I-F-2**	Microphonic Noise Level	Success		N/A
3	10 May 61	I-F-3**	Infrared Transmission	Success		N/A
4	24 May 61	I-F-4**	Infrared Transmission	Success		N/A
5	21 Jul 61	II-F-1**	Command Electronics	Failure	Rocket Motor	N/A
6	4 Aug 61	II-F-2**	Command Electronics	Success		N/A
7	29 Aug 61	II-F-3**	Command Electronics	Success		N/A
8	7 Sep 61	II-F-4**	Command Electronics	Success		N/A
9	15 Sep 61	II-F-5	Command Electronics	Qualified Success	Roll Gyro	N/A
10	22 Sep 61	CL-1	LOS Flight Control	Failure	Misfire - on-board firing circuitry	
11	29 Sep 61	CL-1A	LOS Flight Control	Qualified Success	Fin	N/A
12	6 Oct 61	CL-2	Guidance	Qualified Success	Pitch Gyro	N/A
13	20 Oct 61	CL-3	Guidance	Failure	Caged Yaw-Roll-Gyro	N/A
14	26 Oct 61	CL-4	Guidance	Failure	Pitch Gyro	N/A

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APPENDIX E (CONT'D)

FIRING NO	DATE	TEST OPERATION	OBJECTIVE	SCORE	FAILURE AREA	RANGE TO FIRST TARGET
15	3 Nov 61	CL-5	Guidance	Failure	Smoke	N/A
16	16 Nov 61	CL-6	Guidance	Failure	Tracker	N/A
17	22 Nov 61	CL-7	Guidance	Success		N/A
18	1 Dec 61	CL-8	Guidance	Failure	Misfire-Batteries	N/A
19	6 Dec 61	CL-8A	Guidance	Failure	Noise in Receiver	N/A
20	14 Dec 61	CL-9	Guidance	Qualified Success	Struck Guy Wire	N/A
21	12 Jan 62	TC-1	Tank Launch Mode	Success		N/A
22	30 Jan 62	PE-1	Propellant Compatibility	2.74 M High .0 M Yaw		1520 Meters
23	13 Feb 62	PE-2	Propellant Compatibility	Failure	Plume Meter with Tracking Link	N/A
24	23 Feb 62	PE-3	Propellant Compatibility	.9 M Low .9 M Right		1520 Meters
25	7 Mar 62	PE-4	Propellant Compatibility	.5 M Low .08 M Left		1520 Meters
26	21 Mar 62	PE-5	Propellant Compatibility	.5 M Low .05 M Left		1520 Meters
27	23 Mar 62	PE-6	Propellant Compatibility	.3 M High .15 M Right		1520 Meters
28	30 Mar 62	PE-7	Propellant Compatibility	.7 M High .8 M Right		1520 Meters

APPENDIX E (CONT'D)

FIRING NO	DATE	TEST OPERATION	OBJECTIVE	SCORE	FAILURE AREA	RANGE TO FIRST TARGET
29	24 Apr 62	PET-8	Propellant Compatibility	.7 M High .5 M High		1520 Meters
30	2 May 62	ML-1	Moving Target	.41 M High .36 M Right		980 Meters 27 MPH
31	9 May 62	ML-2	Moving Target	Failure	Tracker Zoom Mechanism	
32	10 May 62	ML-3	Moving Target	.81 M Low .94 M Left		2000 Meters 26 MPH
33	16 May 62	ML-4	Moving Target	.05 M Low .25 M Right		1000 Meters 30 MPH
34	23 May 62	ML-5	Moving Target	Failure	Operator	
35	12 Jun 62	LV-1	Dust	.2 M High .38 M Right		1950 Meters
36	14 Jun 62	ML-6	Moving Target	1.45 M High .81 M Left		2000 Meters 30 MPH
37	6 Jul 62	VT-1	Transportation	Failure	Autopilot	
38	20 Jul 62	SR-1	Sun Angle-Receiver	Failure	Gas Gen Ign	
39	3 Aug 62	SR-2	Sun Angle-Receiver	.0 M Elev .002 M Right		2000 Meters
40	10 Aug 62	EC-1/ ST-1	Sun Angle Tracker/ H Temp	Failure	Missile Not Captured	
41	15 Aug 62	ST-2/ VT-2	Sun Angle Tracker/ Trans	Failure	Pitch Control	

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APPENDIX E (CONT'D)

FIRING NO	DATE	TEST OPERATION	OBJECTIVE	SCORE	FAILURE AREA	RANGE TO FIRST TARGET
42	17 Oct 62	EC-2	Low Temperature	.46M High .04M Right		1000 Meters
43	19 Oct 62	AR-1/ MVT-3	Accuracy/Moving Vehicle Transportation	.43 M High .08 M Right		2000 Meters
44	29 Nov 62	AT-1	Arctic Test of Operability of Command Link	.002 M High .0 M Yaw		1000 Meters
45	6 Dec 62	AT-2	Arctic Test of Operability of Command Link	Failure	One Fin Did Not Erect	
46	29 Dec 62	AT-3	Arctic Test of Operability of Command Link	Failure	Yaw Transmitter	
47	3 Feb 63	AT-4	Arctic Test of Operability of Command Link	Failure	Attenuation of Signal	1000 Meters
48	6 Feb 63	AT-5	Arctic Test of Operability of Command Link	Failure	Attenuation of Signal	
49	11 Mar 63	AT-6	Arctic Test of Operability of Command Link	.15 M Right .61 M High		1000 Meters
50	14 Mar 63	AT-7	Arctic Test of Operability of Command Link	.05 M Right .0 M Elev.		2000 Meters
51	16 Mar 63	AT-8	Arctic Test of Operability of Command Link	Success		SMU-101 No Target
52	16 Mar 63	AT-9	Arctic Test of Operability of Command Link	.05 M Right .76 M Low		2000 Meters
53	13 Sep 63	EC-3	High Temperature	.09 M Right .0 M Elev.		2000 Meters

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APPENDIX E (CONT'D)

FIRING NO	DATE	TEST OPERATION	OBJECTIVE	SCORE	FAILURE AREA	RANGE TO FIRST TARGET
54	21 Sep 63	DP-1	Design Proof	.36 M Right .0 M Elev.		2000 Meters
55	3 Oct 63	EC-4	High Temperature	.38 M Left .18 M High		2000 Meters
56	9 Oct 63	DP-2/ HL-1	Design Proof Elevated Line of Sight	.25 M or LOS of 2000 Meters		No Target
57	22 Oct 63	WC-1	Warhead Compatibility	.15 M Right .50 High		2000 Meters
58	23 Oct 63	WC-2	Warhead Compatibility	.07 M Right .50 M High		2000 Meters
59	25 Oct 63	WC-3	Warhead Compatibility	.38 M Right .50 M High		257 Meters
60	5 Nov 63	DP-3/ ML-1	Design Proof Moving Line of Sight	.30 M Left .50 M High		2000 Meters
61	12 Nov 63	DP-4/ ML-2	Design Proof Moving Line of Sight	.07 M Low .31 M Right		2000 Meters
62	20 Nov 63	TS-1	Fixed Target Tank Silhouette	.13 M High .07 M Right		2000 Meters
63	26 Nov 63	TS-2	Moving Tank Silhouette	No Fixed		2000 Meters
64	4 Dec 63	CA-1	Canted Tank	.53 M High .13 M Left		2000 Meters
65	11 Dec 63	WG-1	Gusting Wind	.10 M High .05 M Right		2000 Meters
66	18 Dec 63	PL-1	Programmed Slewing Rate	No Target		N/A

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APPENDIX E (CONT'D)

FIRING NO	DATE	TEST OPERATION	OBJECTIVE	SCORE	FAILURE AREA	RANGE TO FIRST TARGET
67	12 Mar 64	DM-1	Demonstration	.44 above .72 Right		2000 Meters
68	31 Mar 64	RT-1	Simulated Rain	.03 High .344 Right		Fixed 2000 Meters
69	8 Apr 64	SC-1	Sheridan Compatibility	.0 High .483 Left		Fixed 2000 Meters
70	7 May 64	SC-2	Sheridan Compatibility	.23 M High .15 M Left		Fixed 2000 Meters
71	14 May 64	SC-3	Sheridan Compatibility	Missed Target 8.5 M Right 5.5 M High		Moving 2000 Meters
72	20 May 64	SC-4	Sheridan Compatibility	.16 M High 2.34 M Left		Moving 2000 Meters
73	16 Jun 64	SC-5	Sheridan Compatibility	1.19 M High .48 M Left		Moving 2000 Meters
74	19 Jun 64	SC-6	Sheridan Compatibility	.23 M High .81 M Left		Moving 2000 Meters
75	30 Jun 64	SC-7	Sheridan Compatibility	.12 M High .087		
76	9 Jul 64	SC-8	Sheridan Compatibility	.20 M High 1.37 M Left		Moving 1000 Meters
77	4 Aug 64	SC-9	Sheridan Compatibility	.31 M High .38 M Left		Fixed 2000 Meters
78	20 Aug 64	EN-1	Environmental Conditioning	Did Not Hit Target		Fixed 2000 Meters

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APPENDIX E (CONT'D)

FIRING NO	DATE	OPERATION	OBJECTIVE	SCORE	FAILURE AREA	RANGE TO FIRST TARGET
79	21 Aug 64	EN-2	Environmental Conditioning	.050 M High .025 M Left		Fixed 2000 Meters
80	2 Sep 64	TE-1	Turret Evaluation	.25 M High .0 Azimuth		Fixed 2000 Meters
81	2 Sep 64	EN-3	Environmental Conditioning	.32 M High .20 M Right		Fixed 2000 Meters
82	3 Sep 64	TE-2	Turret Evaluation	Failure	Gyro	Moving 2000 Meters
83	9 Sep 64	TE-3	Turret Evaluation	.0 Elevation .89 M Left		Moving 2000 Meters
84	9 Sep 64	EN-4	Environmental Conditioning	.37 M High .0 Azimuth		Fixed 2000 Meters
85	10 Sep 64	ART-1	Aberdeen Road Test	.42 M Low .075 M Left		Fixed 1947 Meters
86	10 Sep 64	ART-2	Aberdeen Road Test	.075 M High .112 M Left		Fixed 1947 Meters
87	10 Sep 64	EN-5	Environmental Conditioning	Failure	Hang Fire	Fixed 1947 Meters
88	14 Sep 64	ART-3	Aberdeen Road Test	.0 Elevation .05 M Left		Fixed 1947 Meters
89	14 Sep 64	HT-1	High Traverse Rate	.075 M High .32 M Right		Moving 1000 Meters
90	15 Sep 64	EN-6	Environmental Conditioning	.35 M High .18 M Left		Fixed 1947 Meters

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APPENDIX E (CONT'D)

FIRING NO	DATE	TEST OPERATION	OBJECTIVE	SCORE	FAILURE AREA	RANGE TO FIRST TARGET
91	15 Sep 64	EN-7	Environmental Conditioning	.0 Elevation .25 M Left		Fixed 1947 Meters
92	16 Sep 64	ART-4	Aberdeen Road Test	.050 H High .125 M Right		Fixed 1947 Meters
93	17 Sep 64	EN-8	Environmental Conditioning	.0 Elevation .0 Azimuth		Fixed 2000 Meters
94	17 Sep 64	TT-1	Transient Target	.175 M High .0 Azimuth		Moving 2000 Meters
95	18 Sep 64	TT-2	Transient Target	.42 M High .53 H Right		Moving 1700 Meters
96	21 Sep 64	MI-1	Military Inspection	.122 M High .05 M Right		Fixed 1947 Meters
97	21 Sep 64	MI-2	Military Inspection	1.2 M High .05 M Right		Moving 2000 Meters
98	22 Sep 64	MI-3	Military Inspection	.05 M Low .15 M Right		Fixed 1947 Meters
99	22 Sep 64	MI-4	Military Inspection	.42 M Low .1 M Right		Moving 2000 Meters
100	23 Sep 64	MI-5/ EN-9	Environmental Conditioning with Mil. Gunner	.075 M High .1 M Left		Fixed 1947 Meters
101	23 Sep 64	MI-6	Military Inspection	.205 M High .360 M Right		Moving 2000 Meters
102	24 Sep 64	MI-7	Military Inspection	.205 M High .154 Left		Moving 1000 Meters

APPENDIX E (CONT'D)

FIRING NO	DATE	TEST OPERATION	OBJECTIVE	SCORE	FAILURE AREA	RANGE TO FIRST TARGET
103	24 Sep 64	MI-8	Military Inspection	.128 M High .128 M High		Moving 100 Meters
104	24 Sep 64	MI-9/ EN-10	Environmental Conditioning with Military Gunner	.076 High .615 Right		Moving 1000 Meters
105	25 Sep 64	MI-10	Military Inspection	.128 Low 0		Moving 1000 Meters
106	25 Sep 64	TT-3	Transient Target	Missed Target	Gunner-Tracker	Moving 1000 Meters
107	29 Sep 64	EN-11	Environmental Conditioning	.154 High .051 Right		2000 Meters
108	30 Sep 64	CA-2	Cant Angle	1.0 M Low .077 Left		2000 Meters
109	2 Oct 64	CA-3	Cant Angle	.282 Low 0		2000 Meters
110	5 Oct 64	EN-12	Environmental Conditioning	Failure	Launcher Shift	
111	6 Oct 64	EN-13	Environmental Conditioning	Failure	Inverted Diode	
112	7 Oct 64	TT-4	Transient Target	0 .642 M Right		1000 Meters
113	14 Oct 64	HT-2	High Traverse Rate	.334 M Low 1.05 M Left		200 Meters
114	22 Oct 64	SP-1	System Performance	.051 M High .308 M Left		2000 Meters
115	29 Oct 64	SP-2	System Performance	.436 M High .310 M Left		2000 Meters

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NOTES:

*Does not include:

9 short range flights conducted November 1960 - May 1961; 5 open breech (Infantry SHILLELAGH) flights conducted August - September 1962; 4 unguided flights to test warhead safety conducted in August 1963; and 12 unguided propulsion reliability flights conducted July - August 1964.

**Unguided flights to evaluate control system.

SOURCE: SHILLELAGH Project Files, RHA, Bx 12-721.

GLOSSARY

ACofS---------------------Assistant Chief of Staff
ACSFOR--------------------Assistant Chief of Staff for Force Development
Act-----------------------acting
ADCCS---------------------Air Defense Command & Control Systems
AEDG----------------------Army Equipment Development Guide
AFF-----------------------Army Field Forces
AHR-----------------------Annual Historical Review
AMC-----------------------Army Materiel Command
AMCMS---------------------Army Materiel Command Mangement Structure
AMCTC---------------------Army Materiel Command Technical Committee
Anl-----------------------annual
AOMC----------------------Army Ordnance Missile Command
App-----------------------appendix
AR/AAV--------------------Armored Reconnaissance/Airborne Assault Vehicle
ARGMA---------------------Army Rocket & Guided Missile Agency
ARMA----------------------Annual Report of Major Activities
ASA-----------------------Assistant Secretary of the Army
ASARC---------------------US Army Systems Acquisition Review Council
ASI-----------------------Aeronutronic Systems, Incorporated
ASPR----------------------Armed Services Procurement Regulation
Asst----------------------assistant
Assur---------------------assurance
ATAC----------------------US Army Tank-Automotive Command
atchd---------------------attached

Bd------------------------board
Bfg-----------------------briefing
Bn------------------------battalion
BOI-----------------------basis of issue
BRL-----------------------Ballistic Research Laboratories

CBSS----------------------closed breech scavenger system
Cbt-----------------------combat
CDC-----------------------US Army Combat Developments Command
Cdr-----------------------Commander
CG------------------------Commanding General
CONARC--------------------Continental Army Command
Chf-----------------------Chief
CMT-----------------------comment
Co------------------------company
CO------------------------Commanding Officer
CofOrd--------------------Chief of Ordnance
COFT----------------------conduct-of-fire trainer
CONUS---------------------Continental United States
CSFOR---------------------Chief of Staff for Force Development
CVWS----------------------Combat Vehicle Weapon System
CY------------------------calendar year

DA------------------------Department of the Army
DCG-----------------------Deputy Commanding General

DDRE--------------------------Director of Defense, Research & Engineering
DF----------------------------disposition form
Dir---------------------------director
Distr-------------------------distribution
Div---------------------------division
Doc---------------------------document
DOD---------------------------Department of Defense
Drte--------------------------directorate
DS----------------------------direct support
DSARC-------------------------Defense Systems Acquisition Review Council
DTG---------------------------date-time-group

Engr(g)-----------------------engineer(ing)
ENTAC-------------------------Engin-Teleguided Anti-Char (missile)
ET/ST-------------------------engineering test/service test
Exec--------------------------executive

FONECON-----------------------telephone conversation
FRG---------------------------Federal Republic of Germany
FY----------------------------fiscal year

G&C---------------------------guidance and control
GO----------------------------General Order
GOCO--------------------------Government-owned and contractor-operated
GS----------------------------general support

HAW---------------------------heavy antitank assault weapon
HEAT-MP-----------------------high-explosive antitank-multipurpose
HEL---------------------------Human Engineering Laboratory
Hist--------------------------History, Historical
HQ----------------------------headquarters

IB----------------------------Infrared Branch
I-COFT------------------------Improved Conduct-of-Fire Trainer
ICU---------------------------instructor control unit
Incl--------------------------inclosure
Ind---------------------------indorsement
Indus-------------------------industrial
IPR---------------------------in-process review
I&S---------------------------Installations & Services

LAOD--------------------------Los Angeles Ordnance District
LAPD--------------------------Los Angeles Procurement District
LCSIMO------------------------Land Combat Special Items Management Office
LCSS--------------------------Land Combat Support System
Log---------------------------logistics
LOS---------------------------line of sight
LP----------------------------limited production
LRF---------------------------laser rangefinder
Ltr---------------------------letter

MBT — Main Battle Tank
MC — military characteristic
MFR — memorandum for record
Mat — materiel
Mgt — management
MICOM(R) — US Army Missile Command (Regulation)
MIRADCOM — US Army Missile Research & Development Command
MIRCOM(R) — US Army Missile Materiel Readiness Command (Regulation)
MLC — Missile Logistics Center
MOU — memorandum of understanding
MRDEL — Missile Research, Development, and Engineering Laboratory
Msg — message
Msn — mission
MTBF — mean-time-between-failure

n.d. — no date
NTDC — US Naval Training Device Center

OCMH — Office, Chief Military History
OCO — Office, Chief of Ordnance
OCONUS — Outside Continental United States
OCRD — Office, Chief of Research & Development
Ofc — office
OMA — Operation & Maintenance, Army
OML — Ordnance Missile Laboratory
OR — operational readiness
Ord — Ordnance
OrdC — Ordnance Corps
Orgn — organization
OSWAC — Ordnance Special Weapons-Ammunition Command
OTAC — Ordnance Tank-Automotive Command
OTCM — Ordnance Technical Committee Meeting

PEMA — Procurement of Equipment and Missiles, Army
PIP — Product Improvement Program
PM — Project Manager
PMO — Project Management Office
PMSO — Project Manager's Staff Office
POMCUS — Prepositioned Organizational Materiel Configured to Unit Sets
P&P — procurement and production
prep — prepared
Prod — product
Proj — project
Pub — publication

RADIAC — radio activity detection, identification & computation
RAM — reliability, availability, and maintainability
RCS — reports control symbol
R&D — research and development
RDTE — research, development, test, and evaluation
Rept — report
Rev — review

RFP-------------------------request for proposal
RHA-------------------------Records Holding Area
RSA-------------------------Redstone Arsenal
RSIC------------------------Redstone Scientific Information Center

SAIMS-----------------------Selected Acquisition Information Management System
SDC-------------------------signal data converter
SECDEF----------------------Secretary of Defense
SHILL-----------------------SHILLELAGH
S&M-------------------------supply and maintenance
SS--------------------------summary sheet
SSMO------------------------Special Systems Management Office
subj------------------------subject
Sum-------------------------summary
Suppl-----------------------supplement
Svc-------------------------service
SWAT------------------------Seeker Weapon Antitank
Sys-------------------------system

TACOM-----------------------US Army Tank-Automotive Command
TARCOM----------------------US Army Tank-Automotive Materiel Readiness Command
TDY-------------------------temporary duty
T&E-------------------------test and evaluation
Tech------------------------technical
TECOM-----------------------US Army Test & Evaluation Command
TIR-------------------------Technical Information Report
TOW-------------------------Tube-launched, Optically-tracked, Wire-guided
TP--------------------------target practice
TRADOC----------------------US Army Training & Doctrine Command

USAECOM---------------------US Army Electronics Command
USAREUR---------------------US Army, Europe
USARPAC---------------------US Army, Pacific

VES-------------------------visual effects simulator
vol-------------------------volume
VP--------------------------vice president

w---------------------------with
WECOM-----------------------US Army Weapons Command
WP--------------------------white phosphorous
Wpns------------------------weapons
WSMR------------------------White Sands Missile Range

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