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HISTORY OF THE

LACROSSE GUIDED MISSILE SYSTEM (U)

1947 — 1962

(U) S E C U R I T Y

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HISTORY

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LACROSSE GUIDED MISSILE SYSTEM (U)

1947 - 1962

Mary T. Cagle

Approved by: HOWARD P. PERSONS, JR.
Brigadier General, USA
Deputy Commanding General
Guided Missiles

Published by

Helen Brents Joiner
Chief, Historical Division
Administrative Office
U. S. Army Missile Command
10 September 1962

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(U) PREFACE

(U) This historical monograph chronicles the evolution of the LACROSSE Guided Missile System from inception of the project in September 1947 to the present time. It was prepared in accordance with Ordnance Corps Order 12-58, OCTI 150-1-58, and AMC Directive 870-1.

(U) The scheme of treatment of the LACROSSE story is basically chronological. The first chapter traces the origin of the project and the events leading to the formal development effort that began in February 1951. Chapter II deals with the organization and management aspects of the program, with primary emphasis on weaknesses and deficiencies which blocked effective control and coordination of the over-all effort. The next two chapters describe the overlapping weapon system development and production effort, along with the funding and technical problems encountered and their impact on the program schedule. Chapter V deals with the LACROSSE training program and Chapter VI with deployment, field support, and system improvement program. A very brief account of the program cost appears in Chapter VII, followed by a retrospective view of the over-all program in the final chapter.

(U) Unless otherwise indicated, the references cited in footnotes are on file in the Historical Division, Administrative Office, U. S. Army Missile Command.

10 September 1962 Mary T. Cagle

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I. (S) EVENTS LEADING TO LACROSSE SYSTEM DEVELOPMENT (U)

(U) Origin of the Project

(U) The basic concept of the LACROSSE Guided Missile System was conceived by the U. S. Marine Corps early in the postwar period to supplement conventional artillery in close support of ground troops. Specifically, the Marine Corps needed a highly accurate weapon capable of destroying enemy strong-points such as concrete pillboxes and reinforced bunkers that could not be readily attacked or eliminated by conventional artillery weapons. This guided weapon would also serve as a useful supplement to naval gunfire and aerial bombardment in close support of landing forces, as well as general support of ground operations against troop concentrations, supply columns, and staging areas.

(U) Like other guided missile programs of the late 1940's, the LACROSSE was originated as a result of battle field experiences during World War II. The need for a more effective close support weapon was repeatedly demonstrated in virtually all campaigns of the war, but particularly in the heavily fortified islands of the South Pacific. Here, the Marines had to overrun fanatic resistance from swarms of Japanese firmly entrenched in a honeycomb of pillboxes and fortified caves.

(U) One of the strongest defensive systems encountered by American forces was on the island of Iwo Jima. The Japanese had transformed this island of eight square miles into a rugged fortress with interlocking underground strong-holds, thousands of steel-reinforced concrete blockhouses and pillboxes, and fortified caves, all cleverly camouflaged. Before the assault troops landed on 19 February 1945, the island was softened up by 74 consecutive days of naval and aerial bombardment, then plastered with tons of explosives by a task force of battleships and a screen of cruisers and destroyers.

(U) The naval and aerial bombardment was not very effective. American Marines not only found themselves up to their ankles in loose volcanic ash, but they also became the targets for an enveloping fire from narrow apertures only a few inches above ground level. It took

them more than three days to cover 700 yards up sloping ground through the flaming defenses. In an area only 1,000 yards long and 200 yards deep the Marines smashed some 800 enemy pillboxes one by one, often in hand-to-hand combat. Even with the continuing support of naval and aerial bombardment, the battle lasted a full 26 days. Three Marine Corps divisions suffered 20,196 casualties, including 4,189 killed.[1]

(U) It was, no doubt, with this battle in mind that the Marine Corps began to formulate specifications for a more effective artillery weapon shortly after the war ended. Indeed, the strong defensive system encountered on Iwo Jima exemplifies the tactical mission for which the LACROSSE missile system was later designed.

(U) Tentative Weapon System Characteristics (U)

(U) While the state of guided missile technology had not advanced to the point where detailed military characteristics (MC's) could be predicted with any certainty, the basic weapon system concept originally envisioned by the Marine Corps was to remain unchanged. The initial specifications were necessarily restrictive and somewhat arbitrary, but they did provide a definite goal for the feasibility study program that followed.

(U) Briefly, the missile would be launched from a rearward position (on the ground or a nearby ship) and caused to fly with preset controls in the general direction of a target specified by a forward observer. At an appropriate time, the observer would take over terminal control of the missile and direct it by Command Guidance to the target.* The weapon would have a circular probable error (CPE) of not more than five yards.**

---

* (U) It was this guidance technique that gave the weapon system the code name LACROSSE. In the game Lacrosse, goals are scored in much the same manner, with the ball being passed downfield to a man in position to hurtle it into the net.

** (U) In available source material the required accuracy or CPE is cited interchangeably as 5 yards and 5 meters (5 meters = 196.85 inches or 5.468 yards).

1. (U) Snyder, Louis L., The War - A Concise History 1939-1945 (New York, 1960), pp. 472-75.

(U) The missile would have a maximum range of not less than 20,000 yards and a minimum range of not more than 1,000 yards. Anti-jam devices and means for destruction of the missile in flight were to be incorporated. The warhead would weigh about 100 pounds.

(U) Target identification would be made by a forward observer located on the ground or in an observation type aircraft or in an off-shore craft. Forward guidance station equipment was to weigh no more than 150 pounds and be capable of operation in front line position by not more than two operators. Inclement weather or poor visibility was not to limit operation.[2]

(U) Project LACROSSE Established

(U) Early in 1947, members of the Marine Corps presented plans for investigating the feasibility of such a weapon to the Bureau of Ordnance (BuOrd), U. S. Navy. These plans eventually culminated in BuOrd approval of feasibility study proposals submitted by the Applied Physics Laboratory, Johns Hopkins University* (APL/JHU).

(U) Project LACROSSE was established at APL/JHU on 15 September 1947. The Cornell Aeronautical Laboratory, Inc. (CAL) was brought into the initial study program to investigate various means of achieving the necessary guidance accuracy.[3] Cornell was later selected as prime contractor for weapon system development—after some 41 months of feasibility studies and predevelopment effort.

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* (U) The Applied Physics Lab, Silver Springs, Md., was organized in its present concept in 1944, when wartime efforts on the VT fuze program were phased out and the Ofc of Scientific Research & Development was abolished. A true non-profit institution, its financial support is derived solely from funds made available from Govt-assigned tech programs and from such fees as may be allowed under the operating contract with the Navy BuOrd. (Complete history of APL-JHU is given in: Hearings Before a Subcommittee on Government Operations, House of Representatives, Eighty-Sixth Congress, First Session, Feb/Mar 59, pp. 439-40.)

2. (U) For full text of initial MC's, see Document 1.

3. (U) "LACROSSE - An Investigation of the Feasibility of a Guided Missile for Close Support," APL/JHU and CAL, 1 Jul 48, p. 2, Redstone Scientific Information Center (RSIC).

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(U) Feasibility Study Program (U)

(U) The primary objective of the initial LACROSSE study was to determine the feasibility of the proposed missile system in light of the existing state of the art. Investigations of unknowns involving basic research were considered beyond the scope of this program. For study purposes, it was postulated that the observer would be about 1,000 yards from the target with the missile launching point from 10,000 to 20,000 yards to the rear. It was also assumed that the observer would have lightweight, portable equipment with which he could either mark the target in some manner so that the missile could home on the marker, or direct the missile onto the target by a command system technique.

(U) From the outset of the program in September 1947, the LACROSSE study group was guided by two fundamental observations. First, the accuracy specification (CPE not to exceed 5 yards) was recognized as the "dominant requirement." And second, the "stringency of this figure suggests at once that the problem of guidance may be the most difficult."[4] Accordingly, the bulk of the study effort was devoted to possible methods of achieving the desired guidance accuracy. The APL study group investigated the feasibility of homing as a means of terminal guidance for LACROSSE, while the CAL group concentrated on the non-homing (radar) guidance technique. Subsequent CAL effort dealt with design studies of a combination rocket-helicopter (or Shuttlecock) missile for LACROSSE.

(U) The results of these studies, published in a combined APL/CAL report on 1 July 1948, showed that there were several possible ways of achieving the guidance accuracy required for LACROSSE. Those believed to be the most promising and therefore deserving of prime consideration were: Homing, Guidance Along a Way established by Cycle-Counting (or phase-comparison), and Shuttlecock development. However, each of these techniques would involve secondary problemsof considerable importance

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4. (U) Ibid., p. 5. These observations were remarkably sound and prophetic, for problems still existed in the LACROSSE guidance system more than a decade later.

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and of a character requiring a different approach for their solution than that used so far. The study group thus concluded that the choice of a guidance system for intensive development should be postponed until practical laboratory and field tests had given the answers to a number of questions having both tactical and technical aspects. In this connection, it was recommended that further investigations be conducted in three specific areas, as follows:

1. ~~(C)~~ U Field tests by the Marine Corps which would attack the problems of target survey and missile let-down, and which would attempt to assess the maneuverability and vulnerability of the proposed rocket-helicopter (Shuttlecock) missile under combat conditions.

2. ~~(C)~~ U Follow-up of other projects (Kingfisher, Meteor, Raydist, etc.), making arrangements for tests of particular significance to LACROSSE.

3. ~~(C)~~ U Modest development programs to determine whether the remotely controlled helicopter would be feasible, and whether suitable beacons could be built for marking or surveying-in a target.[5]

(U) Analysis of Feasibility Study Results

(U) For some unknown reason, the project remained dormant for the better part of a year after completion of the initial feasibility study. A program for continuing the LACROSSE investigation was discussed between the Bureau of Ordnance and the Cornell Aeronautical Laboratory, Inc., early in 1949, but work was not resumed until the middle of that year.

(U) Under BuOrd Contract NOrd-10629, June 1949, Cornell was assigned the task of selecting a guided missile system suitable for development and conforming to LACROSSE specifications. In the course of this Task I effort, Cornell was to analyze the results of the feasibility study; select from two to four of the most promising systems for complete evaluation; and submit a detailed plan for further development

5. (U) Ibid. See extract from report, Document 1.

of the system believed to be the most suitable for the LACROSSE mission.

(U) Systems Evaluated

(U) From a review of the initial feasibility study and a limited study of the general problem, a number of missile systems, incorporating the best features of those previously analyzed, were selected for evaluation in the Task I program. Two types of guidance systems were chosen: 1) command system - using angle tracking and radio ranging to the missile, and 2) homing system - assuming the missile homing on a beacon fired onto the target by a mortar. A secondary type of command system using only angle measurements was postulated for development in the event that range measurement proved impractical.

(U) An analysis of the guidance systems showed that their fundamental problems could be classified into five categories common to all systems. These components of the general LACROSSE problem were:

Target Survey Problems Investigation
Warhead Investigation
Airframe Investigation
Guidance Intelligence Systems Investigation
Dynamic Behavior of Complete Missile System

With the data from these five investigations, the LACROSSE missile systems selected for consideration under Task I effort were to be investigated.[6] Significant results of these investigations follow.

(U) Target Survey Investigation

(U) The problem of surveying or marking the target with the required precision was considered one of the most difficult of the LACROSSE program. The main difficulty encountered was that of either determining the target range from the forward station or of firing a beacon onto the target with the required range accuracy. Possible solutions investigated were the use of optical range finders, firing

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6. (U) Donovan, A. F., "LACROSSE Summary Report ... June 1949-March 1950," CAL Rept Nr. BE-635-S-2, 22 Mar 50, pp. 2-4, RSIC. This document hereinafter referred to as: Donovan Rept BE-635-S-2.

a beacon from a mortar, and firing a shell containing radio distance measuring equipment at the target.

(U) Results of the target survey study showed that marking the target with a mortar-fired beacon or ranging it in this manner would require an excessive number of mortar shells and beacons. In addition, the development of suitable beacons would be an extremely difficult problem and the cost appeared to be excessively high.

(U) Target location by means of an optical range finder and sight was considered practical in both ranging accuracy and cost. A study of this problem indicated that a range finder of two-meter base length would yield a probable error of two yards at a 1,000-yard range. It was estimated that a range finder of two-meter base length would have a minimum weight of about 125 lbs., less supporting base. Development would take from two to three years and cost about $250,000.[7]

(U) Warhead Investigation (U)

(U) Survey of the warhead problem indicated that the size of the warhead should be increased from the original concept of 100 lbs. to 500 lbs. This weight increase would yield a substantial gain in payload with an increase of less than 35% in gross missile weight. Moreover, a 500-lb. warhead would allow some margin even if the impact angle were not proper for obtaining the maximum effect of the shaped charge. Studies indicated that the shaped charge would give the best results against various types of stationary targets, especially point targets such as pillboxes, concrete fortifications, bunkers, caves, etc., prescribed in the MC's.[8]

(U) Airframe Investigation

(U) In conducting the airframe investigation, it had been planned to study both the helicopter and conventional subsonic guided missiles. The helicopter type vehicle, investigated during the initial feasibility

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7. (U) Ibid., pp. 4-6.

8. (U) Ibid., pp. 6-7.

study, appeared to have many promising advantages both from the standpoint of tactical application and the simplicity and accuracy of guidance. Obvious disadvantages were greater vulnerability, a potentially greater development cost, and lower reliability. It was originally thought that optical command guidance would probably be practical for a conventional drone type missile, but impractical and extremely difficult for a conventional drone type missile. However, dynamic analyses of the command drone missile system proved this concept to be incorrect. The study showed, in fact, that optical command guidance of a drone could be made to have a high degree of accuracy. It also revealed that the change in warhead weight did not greatly increase the complexity of the drone type missile, but increased the helicopter problem several fold. Consequently, investigation of the helicopter type missile was abandoned in favor of the conventional subsonic type missile.[9]

(U) The earliest concept of the LACROSSE drone was embodied in the three designs presented in the initial feasibility study report. All three of these were open to criticism on the ground that they were tail-controlled configurations whose response to control signals, particularly in yaw, was much too slow. An alternate design using cruciform wing control was thus adopted. As originally conceived, this missile was based on the Navy's LARK* surface-to-air missile system for which extensive design and test data were available.[10] A sketch of the

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* (U) The LARK, a guided weapon with command mid-course control and a semi-active homing system, resulted from a Navy anti-kamikaze program that began in late 1944. The Navy awarded the Fairchild Engine & Airplane Co. a LARK development & production contract in Mar 45, and later initiated a back-up LARK program at Consolidated Vultee Aircraft Corp. The LARK eventually became a test vehicle (CTV-N-9) designed to help solve problems relating to radar, guidance systems, stability, control, and launching. Ordway, Frederick I., III, and Wakeford, Ronald C., International Missile and Spacecraft Guide (New York, 1960), pp. 100-101.

9. (U) Ibid., p. 7.

10. (U) Donovan, A. F.: "LACROSSE Final Report - Task I, June 1949 - March 1950," CAL Rept Nr. BE-635-S-3, 1 Aug 50, pp. 57-59, RSIC. This document hereinafter referred to as: Donovan Rept BE-635-S-3.

proposed (500-lb. warhead) missile is shown in Figure 1. The LACROSSE missile configuration later adopted for development is shown in the inset for comparison.

(U) Guidance Intelligence Systems Investigation

(U) Effort in this phase of the Task I study was chiefly expended on one command system and a homing system. Investigations started on other guidance intelligence systems were abandoned when major defects were discovered.

(U) Investigation of homing intelligence systems was limited to units developed in other missile programs. Data derived from this study indicated that a conventional interferometer homing system such as those developed by MIT* and the University of Texas would be best suited to LACROSSE if homing missiles were to be used. The dynamic analyses of complete LACROSSE missiles, using the MIT flight simulator, showed that guidance by homing on a beacon was extremely accurate, an error of only seven feet being anticipated. However, errors in placement of the beacon and in the observer's knowledge of its position were so great as to rule out the homing system for LACROSSE application. Another unfavorable factor was the high cost estimate for development of an adequate beacon.[11]

(U) The command guidance concept investigated—and finally recommended for development—was the Sight Tracking, Electronic Equipment Ranging (or STEER) system. As implied by its title, this system used a combination of optical angular tracking by the forward observer and electronic range measurement by Raydist** equipment. In the STEER guidance scheme, the data derived from the angular tracking unit and the range measurement equipment are fed to a computer from which commands are transmitted by radio link to the missile control system.

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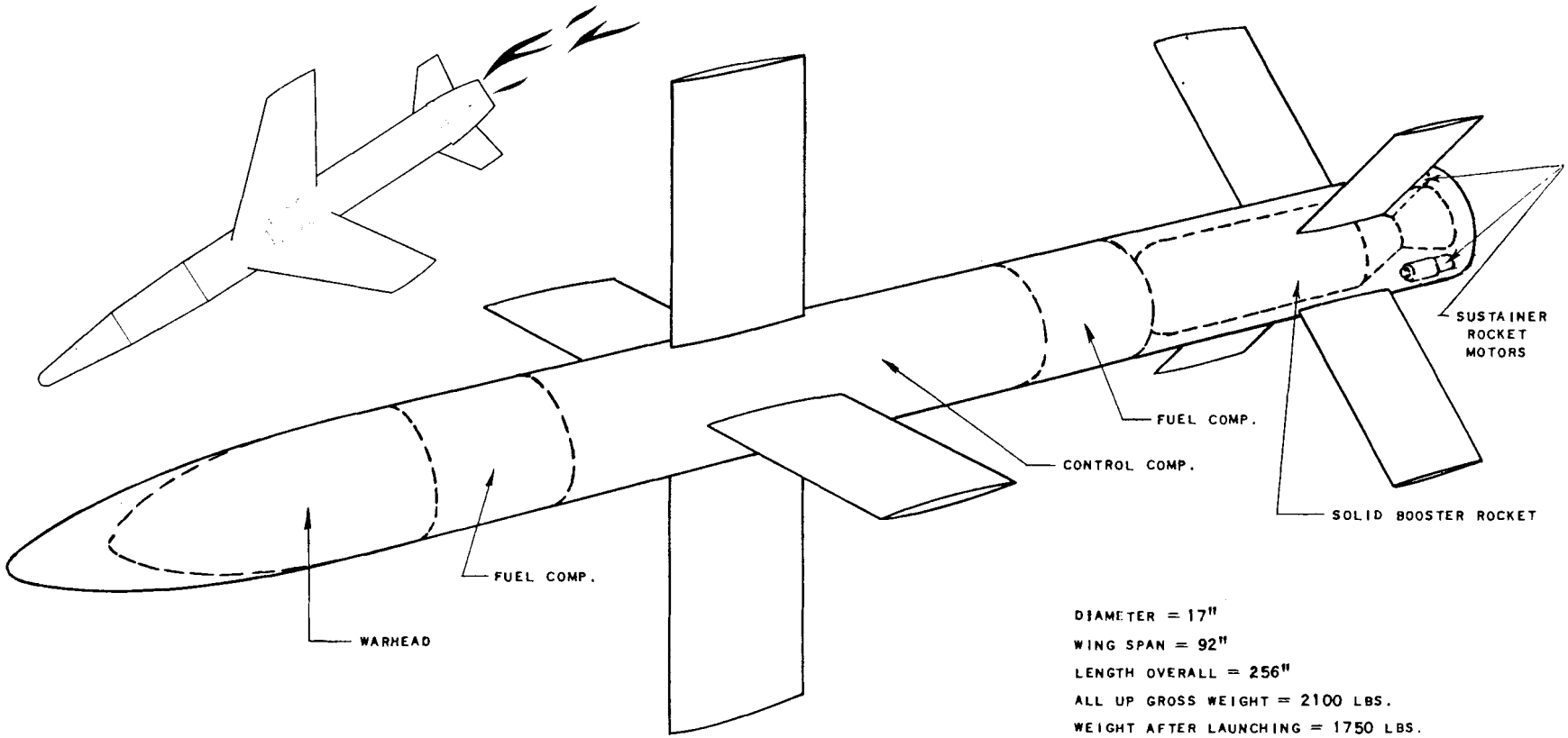
* (U) Massachusetts Institute of Technology.

** (U) A Radio Navigation & Tracking System developed and manufactured by the Hastings Instrument Company (HICO).

11. (U) Donovan Rept BE-635-S-2, op cit., pp. 10, 11, & 13.



DIAMETER = 17"
WING SPAN = 92"
LENGTH OVERALL = 256"
ALL UP GROSS WEIGHT = 2100 LBS.
WEIGHT AFTER LAUNCHING = 1750 LBS.
WEIGHT AFTER BURN-OUT = 1420 LBS.
GUIDANCE AND CONTROL SYSTEM WEIGHT = 150 LBS
BOOSTER THRUST = 18000 LBS. FOR 2.5 SECONDS
SUSTAINER THRUST = 440 LBS.
POWERED RANGE = 20,000 YARDS AT M = .6
MAXIMUM MANEUVERING ACCELERATION = 4 g

PROPOSED LACROSSE MISSILE
(March 1950)

Figure 1

Range to the target is assumed to have been initially determined by an optical range finder, while azimuth and elevation are determined using the same scope employed for tracking the missile. This target survey information is then set into the computer which computes the appropriate command signals from the missile track and range data.[12] An artist's sketch of this operation is shown in Figure 2.

(U) Performance of the LACROSSE STEER command system was determined by combining results of investigations of the effects of optical tracking errors made on a Reeves analogue computer with data on the effects of other errors in this system obtained from the MIT simulator. The dynamic analyses showed a potential error of about ±6 yards. The difficulty in achieving this result was likely to arise from the requirement that the measurement of the missile range by the radio range system be improved in accuracy. At the same time, there appeared to be considerable probability that the accuracy could be improved by better tracking and better smoothing of the tracking data.[13]

(U) STEER System Evaluation

(U) The STEER command system did not lend itself to all-weather operation, but all LACROSSE systems required that the forward observer at least be able to see the target. For night operation, it was presumed that tracking a light on the missile would be possible. Operation under low ceiling conditions would become possible in the future, with development of small, lightweight radar tracking heads of sufficiently high accuracy. On the other hand, it was recognized that substitution of radar tracking could result in lower accuracy compared to optical techniques. Possibilities for accuracy improvement existed in automatic optical tracking and in modifications to the system whereby the observer would feed data to the computer only at the times that his tracking is good. The command guidance equipment used by the forward observer could be kept to less than 150 pounds. The range

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12. (U) Ibid., p. 8.

13. (U) Ibid., pp. 11-13.

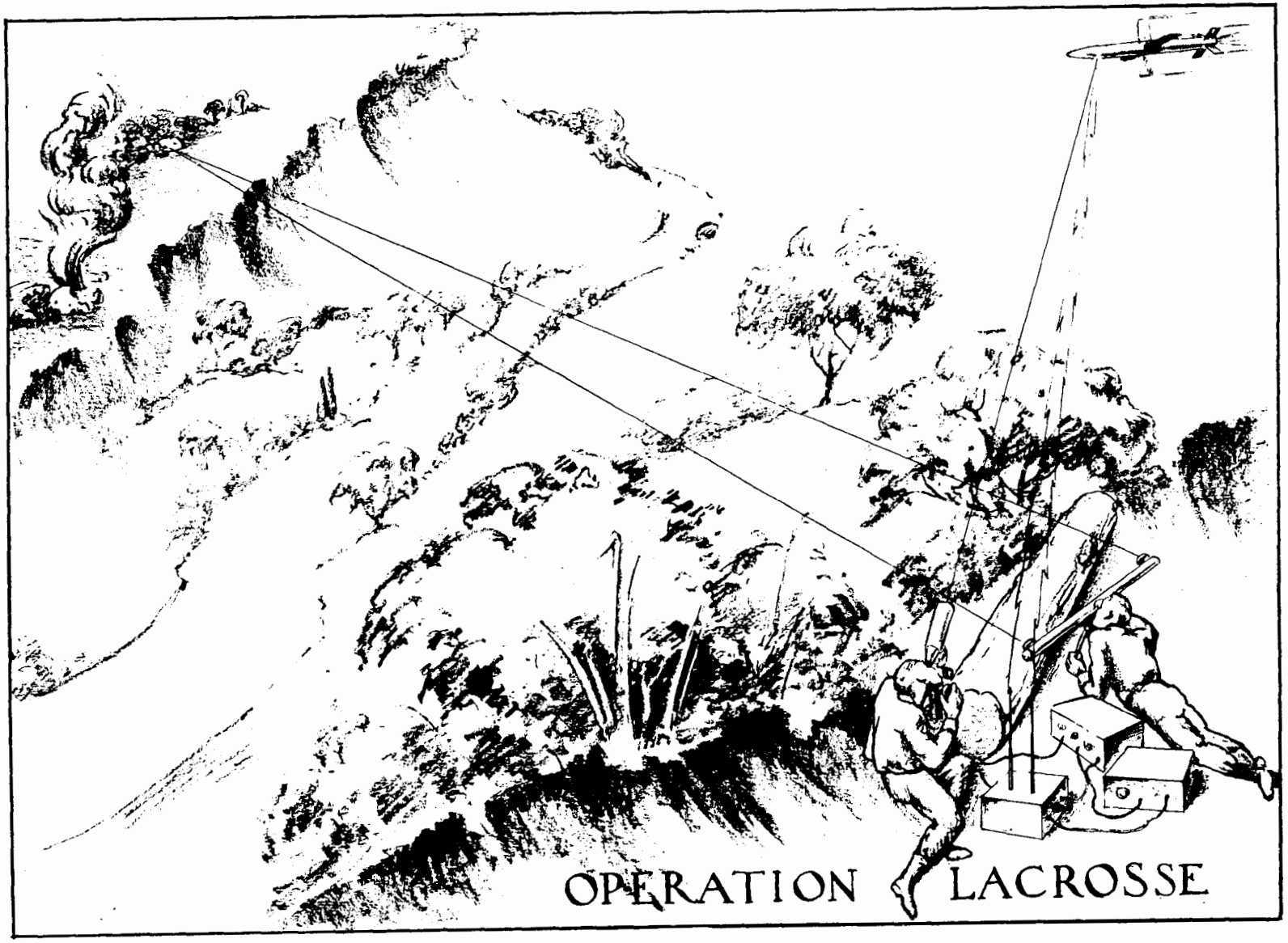

Figure 2

finder would have a total weight of about 200 pounds, including its base. Both units could be broken up into smaller packages for ease of transportation.

(U) One important advantage of the STEER system was that no warning of attack would be given the enemy by mortar fire (as required by the homing system). Therefore, the forward observer was less likely to be subject to enemy counteraction while performing the operations necessary to deliver the missile. The optical features of the guidance system would not be vulnerable to jamming except by smoke screens or other means detrimental to enemy operations, while the radio command link and ranging system could be made relatively jam-resistant for the few seconds of operation during flight of the missile.

(U) The majority of the components and the technical knowledge required for development of the STEER system were either already in existence or attainable by a moderate expansion of existing techniques. One possible exception to this was the radio range measuring unit which required considerable improvement in accuracy. A logical approach to this improvement appeared to be available, and while it would necessarily involve considerable development, it was not of a radical or unknown nature. Experimental information showing that a complete missile system analogous to STEER had performed approximately according to LACROSSE specifications was available in the results of the HERMIT project conducted by the Army Air Forces near the end of World War II. In the HERMIT project, radio controlled airplanes were flown into ground targets on the basis of optical tracking information with miss distances of only a few feet. Although the optical tracking was done from two stations, there was no reason to suspect that one station could not be eliminated if suitable range information and command computer could be provided.[14]

(U) System Recommended for Development

(U) Based on the results of the investigation and evaluation

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14. (U) Ibid., pp. 13-14.

described above, Cornell recommended that the STEER command guidance missile system be developed for LACROSSE and that a similar all-weather (AW) system using a radar tracker be developed for LACROSSE AW operation. The total recommended system included an optical range finder (two-meter base length); an optical tracking sight; missile-to-observer radio range measuring units; a computer; radio command system; and a high subsonic speed winged-type missile carrying a 500-pound shaped charge warhead. Since the system containing the optical tracking unit could be put into operational use more quickly than that containing the radar tracking unit, it was concluded that the former system should be developed and tested and then extended to include the radar tracking feature.[15]

(U) While a sufficiently thorough investigation had not been possible to positively preclude that some missile system might be conceived which would be better than the LACROSSE STEER system, it was believed highly improbable that any more effective system could be achieved within the same time and cost in the current state of the guided missile art. The Task I investigation was deliberately limited to those systems that previous work showed to be the most promising, the object being to find a system—though not necessarily the best possible system—which could be developed to meet or exceed LACROSSE specifications. Since the STEER command system appeared to meet this requirement, Cornell concluded that development should be commenced immediately, rather than search further for an ideal system.[16]

(U) Pursuant to provisions of the Task I contract, Cornell submitted a proposed program schedule for development and flight test of prototype LACROSSE missiles and guidance equipment. The suggested program covered a three-year period beginning in July 1950 (FY 1951) and ending in June 1953 (FY 1953). This time scale, shown in Figure 3, was considered the minimum achievable with reasonably constant and efficient effort applied

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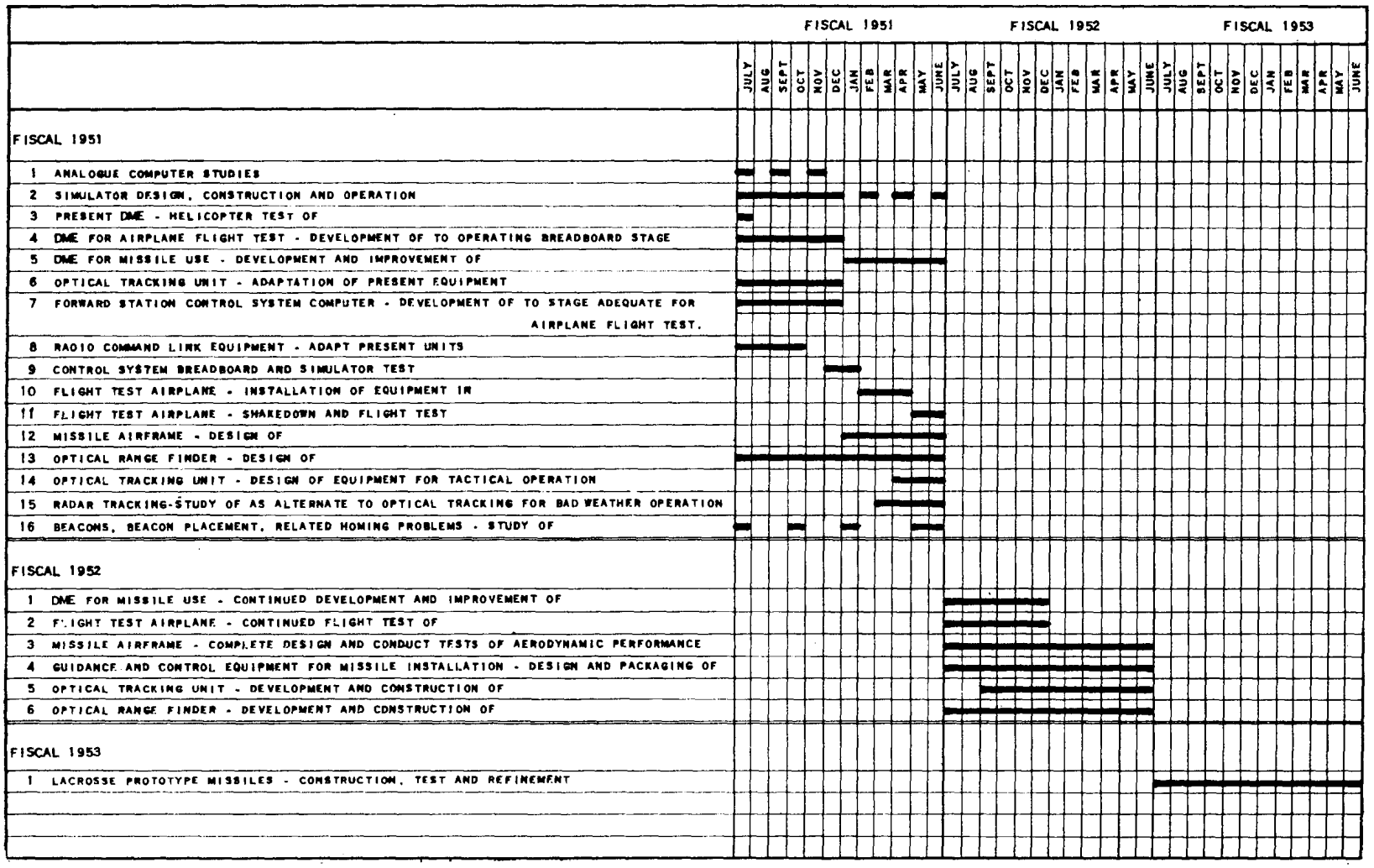
15. (U) Donovan Rept BE-635-S-3, op. cit., pp. 1-2.

16. (U) Ibid., p. 27. Also see Donovan Rept BE-635-S-2, op. cit., p. 14.

PROPOSED LACROSSE PROGRAM SCHEDULE



SOURCE: CAL Report Nr. BE-635-S-2, 22 Mar 50.

Figure 3

to the resolution of known problem areas. In establishing the proposed program schedule, Cornell made no allowance for such contingencies as unforeseen development difficulties, contractual delays, and budgetary limitations, but stated that these factors could "easily extend the time scale by one to three years."[17] With the proposed development program was an itemized cost estimate of $460,000 for first-year (FY 1951) effort.[18]

(U) Later developments proved this early plan to be overly optimistic. Funds spent for FY 1951 effort nearly doubled the estimated cost, the total expenditure amounting to some $800,000.* The three-year period envisioned for the LACROSSE R&D program also doubled, chiefly because of funding deficiencies, continuing technical difficulties, and delay in phasing in the production contractor. These aspects of the program are treated in a later chapter.

(U) LACROSSE Project Assigned to the Army

(U) Late in 1949, while the second LACROSSE study was still in progress, the Joint Chiefs of Staff (JCS) laid down a new policy governing the development and use of guided missiles by the armed services. As a general rule, guided missiles were to be employed by each armed service in the manner and to the extent necessary to accomplish its assigned mission, and each service would be authorized to develop its own weapons. Under this policy, Army Ordnance was assigned responsibility for antiaircraft guided missiles and for ground-launched, short-range, surface-to-surface guided missiles supplanting or extending the capabilities of conventional artillery.[19] The LACROSSE

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* (U) Navy funds spent in the three prior years (FY 1948-50) amounted to $410,000, making a total contract cost of $1,210,000 through FY 1951.

17. (U) Donovan Rept BE-635-S-2, op. cit., p. 16.

18. (U) Ibid., pp. 15-17. For full text of the suggested development program, see extract from rept, Document 2.

19. (U) JCS Memo 1620/12 for Secretary of Defense, 17 Nov 49, subj "Assignment of Responsibility for Guided Missiles," cited in Report of Army Field Forces (AFF) Board No. 4, Project No. GM-350, 3 Oct 50, "Military Characteristics for Surface-to-Surface Missiles." Also see DA Pamphlet 70-10, "Chronological History of Army Activities in the Missile/Satellite Field, 1943-1958," Sep 58, p. 23.

project—then sponsored by the Navy—fell in the latter category.

(U) Shortly after Cornell finished the Task I effort in March 1950, the Joint Chiefs of Staff recommended that the LACROSSE project be transferred from the Navy to the Department of the Army (DA). The Secretary of Defense approved the transfer early in August 1950 and the project was formally assigned to Army Ordnance on August 31st. Research and development (R&D) effort was to be continued with the view of producing "as early as possible" a tactically acceptable missile system for employment in close support of amphibious and/or ground operations. The program was assigned a DA priority of 1B and designated as Project TU1-2001 (DOA Number 516-05-003).[20]

(U) Meanwhile, the Korean War erupted in June 1950 and American troops were committed to the battlefield with outmoded weapons of World War II. Barely four months earlier, Senator Lyndon B. Johnson (D-Tex.) had warned that the United States was far behind Russia in developing modern weapons and demanded an immediate review of the entire rocket research program, either by the Secretary of Defense "or if necessary by Congress." Pointing out that the bulk of defense spending, five years after World War II, was "still going for weapons originally designed to help us win the war," he declared:

> ...We must not tie our future security to our past successes.
>
> If guided missile warfare should begin within the next two or three years, we—at our present rate—would be very feeble participants. For a push-button war, we have neither the push nor the button.[21]

(U) Senator Johnson's observation was profoundly accurate, for American participation in the Korean action was indeed feeble. The short-range artillery rockets and guided missiles which could have completely transformed the fighting in Korea were still in scale models, in prototype stage, or on the drawing boards. With the postwar

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20. (U) Ordnance Technical Committee Meeting (OTCM) Item 33399, 31 Aug 50, "Surface-to-Surface Guided Missile (LACROSSE)."

21. (U) Quoted in The Huntsville Times, 14 Feb 50.

reductions in military spending, the missile program simply had taken a back seat to the less expensive conventional weapon programs and remained a minor, almost obscure item in the defense budget. But in the wake of the Korean emergency, Representative Carl Vinson (D-Ga.) ended the partisan fight over defense reductions and won a standing ovation when he declared: "Our great need right now is to get the ox out of the ditch—not to spend a lot of time and effort trying to find out who pushed him in."[22]

(U) Interim Army LACROSSE Program

(U) With the impetus thus sparked by the Korean emergency, Army Ordnance moved out on the LACROSSE project and started an interim program at Cornell in July 1950, some 30 days before the transfer was formally effected.[23]

(U) This interim Army program was primarily concerned with further investigation of the STEER guidance system selected in the previous study and development of the command computer, optical tracker, and radio link through the breadboard stage. Work performed under the interim contract generally reaffirmed the technical feasibility of the LACROSSE system, particularly with respect to the three key guidance components, which were developed through the breadboard stage. Cornell therefore recommended that Ordnance continue the LACROSSE project and that "full effort be applied to the development of a prototype missile system based on the STEER and STEER-1 concepts."[24] The basic STEER guidance system would use the optical tracking sight for fair weather

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22. (U) Quoted in The Reader's Digest, Mar 61, p. 132.

23. (U) Contract DA-30-115-ORD-11 was initially awarded for $75,595.50 and extended thru 10 Mar 51. This date was later moved up to 15 Feb 51 by Supplemental Agreement Nr. 1, and the cost was reduced by $1,180.12 under Agreement Nr. 2, leaving a basic contract total of $74,415.38. Technical Report, "Ordnance Guided Missile & Rocket Programs, Vol. VI - LACROSSE," inception thru 30 Jun 55, p. 81. (This document hereinafter cited as "LACROSSE Blue Book.")

24. (U) Ahlin, A., "Summary Report Project LACROSSE," CAL Rept Nr. BE-712-S-1, 15 Feb 51, p. 33, RSIC.

operation, while the STEER-1 would employ a radar tracking head for all-weather operation.[25]

(S) Formal Development Contract Awarded

(U) Having thus reaffirmed the feasibility of the proposed guidance scheme, Ordnance officials decided to continue LACROSSE system development with the Cornell Aeronautical Laboratory, Inc., as prime R&D contractor. Actual development work was initiated early in February 1951 by Letter Order Contract DA-30-115-ORD-47, which was later definitized on a cost-plus-fixed-fee (CPFF) basis.[26]

* * * * * *

(U) During this formative period, from September 1947 to February 1951, the LACROSSE had progressed from a mere idea on paper, to extensive studies and evaluations, thence to a brief pre-development effort which reaffirmed the tactical feasibility of the proposed guidance scheme.

(S) A review of the reams of paperwork and voluminous reports generated in the ensuing decade reflects a moderately successful but costly development and production program which managed to survive many technical and administrative crises. Throughout the eight and a half years preceding system development, the LACROSSE program was characterized by funding restrictions, unsolved technical problems, schedule slippages, increasing contractor costs, mounting user criticism, and gradual loss of confidence in the LACROSSE system as a tactically useful weapon.

(S) Although the LACROSSE I missile system failed to meet all the criteria for a completely reliable, field-worthy weapon, it was finally accepted for interim Army use in July 1959, pending availability of the

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25. (U) Ibid., p. 4. A general outline of recommendations made to OCO is presented in Document 3.

26. (U) Letter, Rochester Ordnance District to CAL, re Letter Order Contract No. DA-30-115-ORD-47, RAD Order No. ORDTU-1-12833, 5 Feb 51; and LACROSSE Blue Book, op. cit., p. 12.

improved MOD I* system then under development. The deficiencies fielded with the LACROSSE I (at one time numbering over 100) were neither new nor surprising, for they were directly related to, or stemmed from, the original design concepts which turned out to be much more complex, time-consuming, and expensive than initially anticipated. The Army had already invested some $325 million in the LACROSSE, and needed an additional $66.1 million to correct existing deficiencies and satisfy all safety and reliability requirements.

(U) Yet, the MOD I development program—which had already cost over $11.4 million and which would have provided a weapon acceptable to both the Army and Marine Corps—was cancelled by DA Staff in August 1959, shortly after LACROSSE I deployment. This decision led to the immediate withdrawal of Marine Corps support and later to a "kill or cure" operation which left the LACROSSE program in a reduced-strength, buy-out, terminal status. Army LACROSSE units deployed in the Continental United States and overseas were thus stuck with an interim, admittedly deficient, and potentially dangerous weapon which the original customer (U. S. Marine Corps) refused to accept.

(U) To answer all the thorny questions obviously evoked by the foregoing brief would be extremely difficult, if not downright impossible. In the succeeding chapters of this study, an attempt is made to cover as many of the crucial issues as possible within the bounds of time and available evidence. The broad topics of system development, production, and deployment will be treated in sequence after first considering the organization and management concepts used in prosecution of the program.

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* (U) MODIFICATION I or MOD I was the designation for a radically different guidance system designed to decrease LACROSSE's vulnerability to enemy countermeasures and detection, and to provide multiple use capabilities.

II. ~~(C)~~ U PROGRAM ORGANIZATION AND MANAGEMENT (U)

(U) The complications that thwarted the timely execution of the LACROSSE program stemmed partly from the continuing technical problems, most of which had been recognized and clearly identified in the feasibility study phase. But there were other deterring influences that probably had an even greater impact on the over-all program. Among these were vacillating financial support, unrealistic program planning, indecision at top management levels, and inadequate control and supervision of production engineering effort during the transition period.

~~(C)~~ U Contract Philosophy (U)

(U) Since the inception of its rocket and guided missile program, Army Ordnance had depended upon American industry to perform the bulk of R&D work, rather than build and staff new laboratories of its own. Normally, the policy was to contract an entire weapon system program with a prime contractor, one not only willing and able to develop the system, but also capable of initial production. The prime contractor, in turn, was free to subcontract as much of the work as considered necessary, but there was one organization that could be held responsible—one firm to praise or to blame. This "system contract" philosophy was first applied with unqualified success to the NIKE AJAX Guided Missile program in September 1945, and later to other major programs such as the NIKE HERCULES and HAWK weapon systems.

(U) But the circumstances surrounding the LACROSSE program dictated a radical departure from the tried and proved "system contract" philosophy, in that the contractor selected to develop the system had no production capability. It was thus necessary to use the alternate and less desirable "co-contractor" method, wherein the system contract responsibility was split between two prime contractors, one being charged with system development and the other with initial production. Even under ideal programming conditions, certain interface problems and some duplication of effort were inevitable. As will be noted in more detail later, the programming conditions for LACROSSE were something less than "ideal." Interface problems abounded; duplication of

effort was clearly excessive; program cost trends turned sharply upward; and schedule slippages were soon a matter of fact. The lessons learned from this co-contractor experience with LACROSSE (and similar experience in the SERGEANT program) were almost as numerous as they were expensive. Summing up the situation in an impeccable understatement, the ARGMA Commander later avowed: "Our experience has indicated that this (co-contractor) approach is not generally desirable and we do not intend to use it in the future."[1]

(U) Little is known about the criteria used by Ordnance in selecting the R&D contractor, but it is fairly obvious that the Cornell Aeronautical Laboratory represented the only logical choice. In addition to a well-established reputation in aeronautical research,* Cornell had been engaged in studies of the LACROSSE problem since inception of the program in September 1947. Though primarily an R&D laboratory, it did have a limited capacity for product design and fabrication as required to formalize designs or conduct critical experiments to demonstrate the feasibility of a system. The fact that Cornell was not equipped for full-scale production did constitute a distinct disadvantage, but this, in and of itself, was not the real source of trouble that later beset the program.

(U) In proving the feasibility of the LACROSSE system, it was necessary to establish the accuracy to which the missile could be guided. To demonstrate this point, as well as numerous other critical areas, Cornell had to produce well developed items of special equipment and conduct rather extensive field tests. It was therefore deeply involved in the detail design of equipment and had a somewhat more extensive background in LACROSSE than might be considered normal for a research laboratory. To assure a smooth but rapid transition from development to pilot production, it was thus essential that a qualified co-contractor

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* See Background History of CAL, Document 4.

1. (U) Speech (Managing a Major Missile System R&D Program) by Col John G. Zierdt, ARGMA Comdr, to the DOD Research and Engineering Policy Council 6-8 Jul 60 Meeting, Ft. Monroe, Va.

be phased into the program at a sufficiently early date to participate in the actual R&D design and selection of subsystems making up the tactical LACROSSE system.[2]

(U) Early in 1953—a full year before design of the tactical LACROSSE system was initiated—OCO-ORDTU asked Cornell to prepare a plan for phasing in a co-contractor with R&D capabilities as well as production know-how and potential for possible future industrial contracts. In the schedule submitted on 15 April 1953, Cornell recommended that the co-contractor be selected and phased into the program by January 1954, in order to assume complete technical responsibility for the system by January 1956.[3] But austere funding in 1953 interfered with this plan. Implementing action was not initiated until April 1954, and phase-in of the co-contractor was delayed until early 1955.

(U) Following a survey of prospective contractors, the Glenn L. Martin Company was approved as the LACROSSE R&D co-contractor and Ordnance was authorized to proceed with contract negotiations in January 1955. By the end of June 1955, the Martin Company had been awarded three CPFF contracts for a total of $13,692,643, including a fixed fee of $951,850. One was a small R&D contract ($699,982), signed on 1 April 1955, which called for design, fabrication, testing, and evaluation of the LACROSSE missile system through 31 December 1955. The other two were large industrial contracts signed on 31 May and 1 June 1955, respectively.[4] (The final weapon system contract structure is depicted in the accompanying charts.)

(U) Meanwhile, Cornell started work on the tactical LACROSSE I system during the early part of 1954, as planned. By the time the co-contractor was named in the spring of 1955, Cornell had essentially completed the design of the tactical model and had successfully

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2. (U) Sacher, R. E., "Project LACROSSE - Final Report (ORD 47)," CAL Rept Nr. BE-745-T-149, 30 Jan 60, p. 212, RSIC.

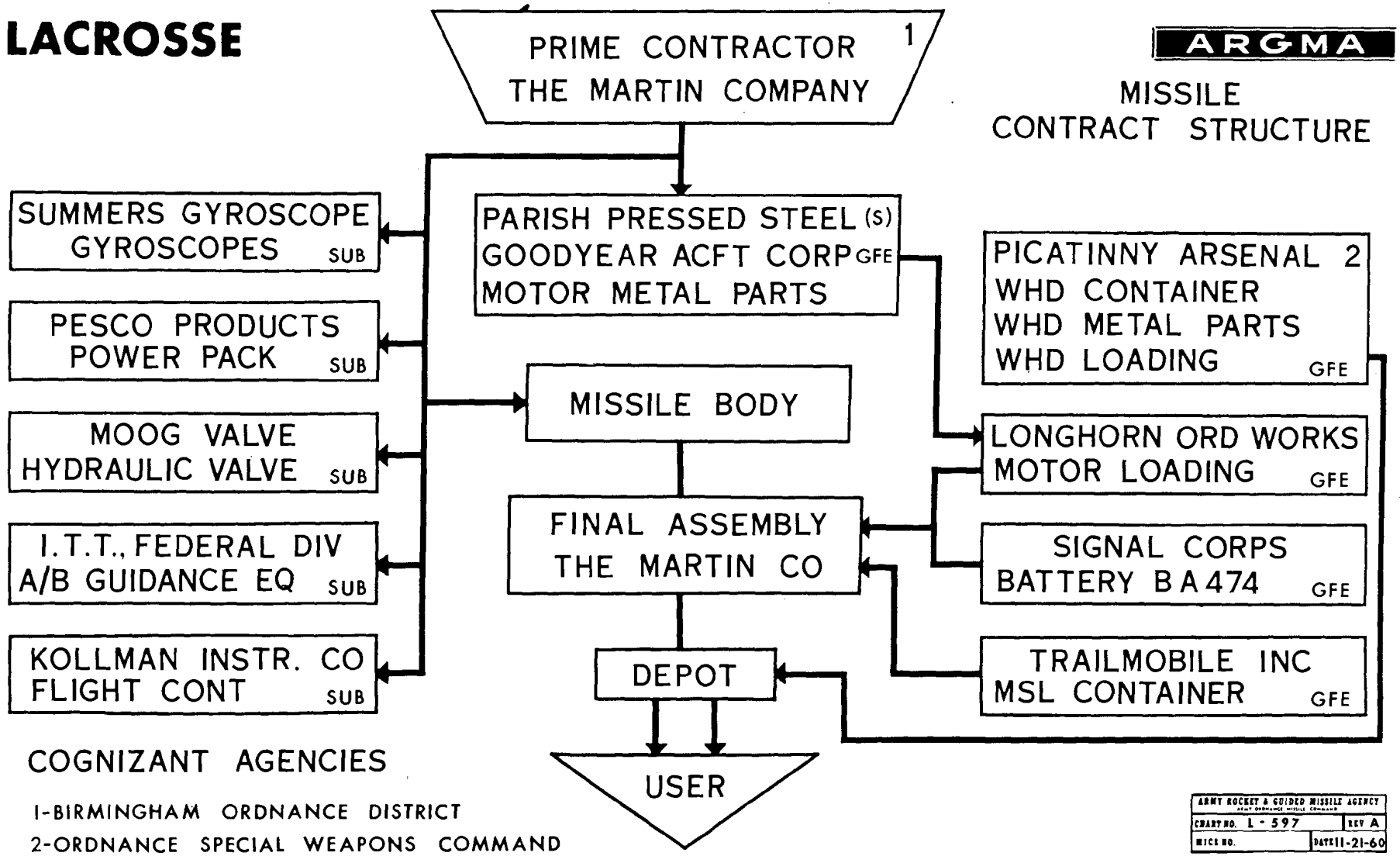
3. (U) LACROSSE Blue Book, op. cit., pp. 12-13.

4. (U) Ibid., pp. 13, 82, 83.

LACROSSE

ARGMA

MISSILE
CONTRACT STRUCTURE



COGNIZANT AGENCIES

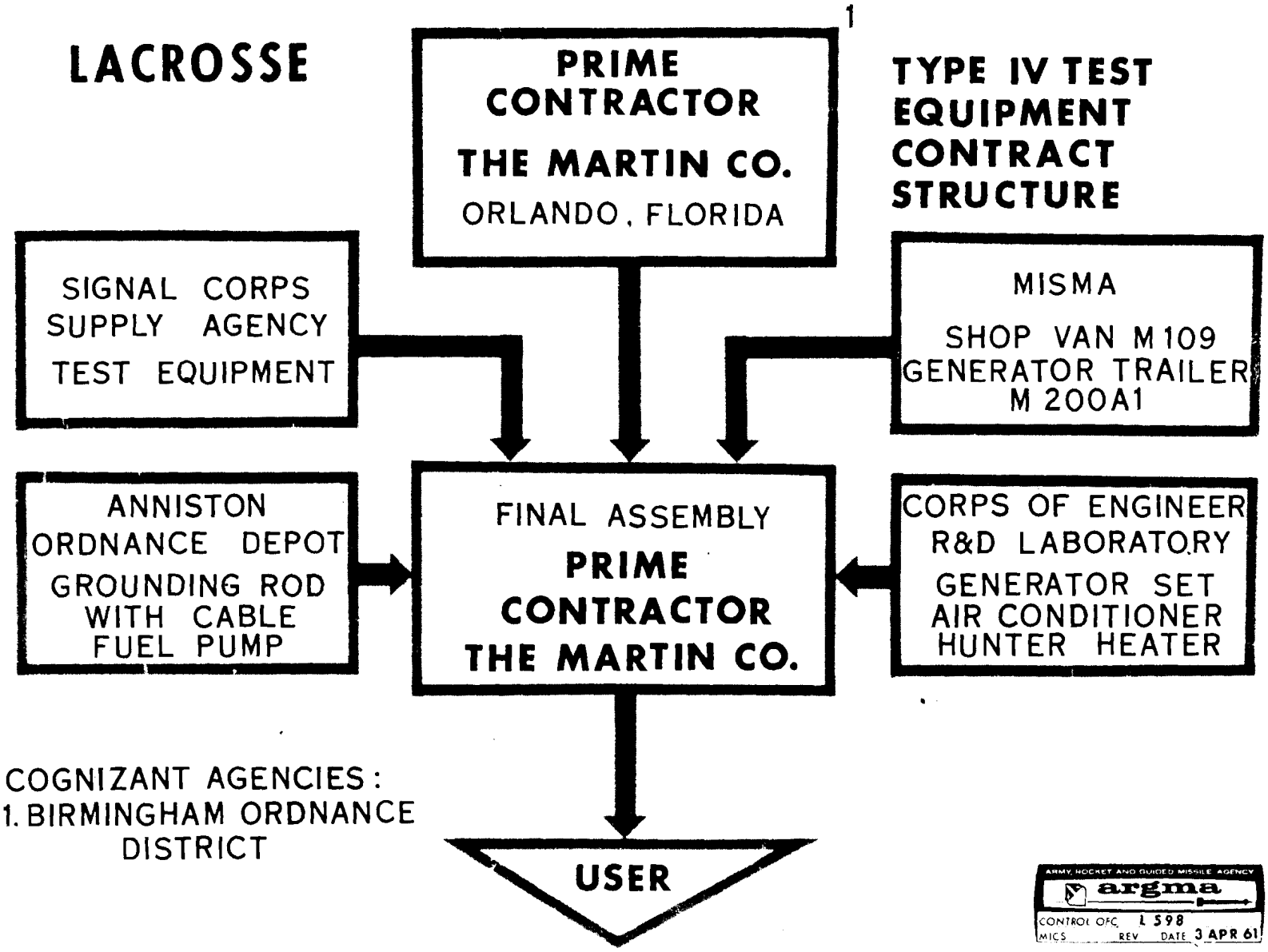
1-BIRMINGHAM ORDNANCE DISTRICT
2-ORDNANCE SPECIAL WEAPONS COMMAND

ARMY ROCKET & GUIDED MISSILE AGENCY
CHART NO. L-597 REV A
WICS NO. DATE 11-21-60

Figure 4

LACROSSE

TYPE IV TEST EQUIPMENT CONTRACT STRUCTURE



COGNIZANT AGENCIES:
1. BIRMINGHAM ORDNANCE DISTRICT

ARMY, ROCKET AND GUIDED MISSILE AGENCY
argma
CONTROL OFC. L 598
MICS REV DATE 3 APR 61

Figure 5

demonstrated system feasibility. This delay in selection of the production contractor, coupled with the lack of adequate control over Martin's initial production engineering effort, naturally led to excessive duplication of effort, serious weapon system deficiencies, and other assorted program complications. The source of the trouble is very aptly described in the following excerpt from a Cornell report:

> It is believed . . . that the co-contractor should have been selected earlier, perhaps in the spring of 1954 when the LACROSSE I design was initiated. This would have proved mutually advantageous to CAL and Martin. The Martin Company engineers would have had an opportunity to participate in the R&D effort that went into the design and selection of the subsystems that make up the LACROSSE I missile system. At the same time CAL engineers would have had an opportunity to benefit from the production know-how of The Martin Company. Much of the duplication of effort that has occurred during the program could have been avoided.[5] (Underline supplied.)

(U) The end result was that Martin underestimated the magnitude of the production engineering effort required. Its initial production proposal failed to cover the complete problem, but only envisioned the copying of equipment fabricated by Cornell under the R&D program. The job of production engineering turned out to be much greater than anticipated, and Martin was caught without an adequate engineering staff to do the work. Martin's engineers then went overboard in the redesign area and reworked the entire LACROSSE I system which Cornell had already developed at a cost of some $15.7 million through FY 1955. The main problem here was not the redesign effort, per se, but rather the lack of adequate contractual coverage to assure effective control and supervision of such effort.

(U) The R&D contract, signed with Martin on 1 April 1955, provided that the design effort would be supervised and controlled by Cornell. However, the larger production engineering contract ($4,934,074), signed on 31 May 1955, did not include a binding supervisory clause.

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5. (U) Sacher Rept BE-745-T-149, op. cit., p. 209.

Consequently, Martin listened to Cornell in work performed under the R&D contract and did most of the redesign work under the production engineering contract without Cornell's advice and guidance. To further complicate matters, the LACROSSE project was shelved in FY 1957, then reinstated in 1958 without funds for production engineering.[6]

(U) The untenable situation which thus developed was largely responsible for the equipment deficiencies fielded with the LACROSSE I system in July 1959. It also caused much apprehension—and probably a few ulcers—among management personnel at all echelons.

(U) In summary, the co-contractor approach did not prove "generally desirable" in the LACROSSE program, but neither could it be blamed for everything that went wrong. On the contrary, the most damaging influences stemmed not from the contracting method, but from certain shortcomings on the part of the Government itself. Perhaps the most singularly damaging influence was the "stop-start" funding philosophy which not only increased the over-all program costs, but also prevented realistic planning and delayed delivery of operational equipment. Also having an adverse affect on the program was the contractual omission that precluded effective control of the redesign effort. These compromising conditions, combined with the built-in weaknesses of the co-contractor concept, presented a formidable challenge throughout the Army's management structure.

(U) Policy and Responsibility

(U) Introduction

(U) At the time of the LACROSSE transfer in 1950, the Army Ordnance missile program was operating at a relatively low level. The Army had started with one project in 1944, and by 1945 had expanded to five. By 1950, the number of programs had been reduced to four, including three weapons and four test vehicles, which the Army was supporting at an

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6. (U) ARGMA Hist Summary, 1 Jan 59/31 Dec 59, pp. 136-38; and LACROSSE Blue Book, op. cit., pp. 82-83.

annual cost of about $36 million.[7] Technical control and supervision of these few R&D projects had been performed by an organization centralized in the Office, Chief of Ordnance. But the rapid expansion of Ordnance missions beginning in 1950 dictated a radical change in management doctrine and a more elaborate management structure.

(U) Realizing that the Ordnance facilities then operational would not be able to handle the projected volume of work, the Chief of Ordnance reactivated Redstone Arsenal at Huntsville, Alabama, on 1 June 1949.[8] In performing its mission as the Ordnance Rocket Center, this World War II manufacturing arsenal was to conduct basic and applied research, development, and testing of free rockets, solid propellants, JATO's, and related items; administer R&D contracts placed with resident contractors* and exercise technical supervision over such projects; exercise technical supervision over Ordnance R&D projects, as assigned; and keep abreast of all scientific and technological developments in the rocket field.[9]

(U) On 1 April 1950, the adjoining Huntsville Arsenal facility, which had been inactivated by the Chemical Corps, was permanently transferred to Redstone Arsenal.[10] Two weeks later, the Ordnance Guided Missile Center was established in the old Huntsville Arsenal Headquarters.[11] The Ordnance guided missile group, headed by Dr. Wernher von Braun, completed the move from Fort Bliss, Texas, in October 1950. Redstone's new mission in the field of guided missiles included component and systems development in aerodynamics, guidance and control, propulsion, assembly techniques, transport, test, and launching.[12]

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* (U) The Rohm & Haas Company and Thiokol Chemical Corporation signed contracts earlier in the year to staff and operate Government-owned R&D facilities within the arsenal.

7. (U) Draft Ms, OCO Hist Div, "Ordnance Guided Missile Program, 1944-1954," pp. 30-31.

8. (U) DA GO 39, 18 Aug 49.

9. (U) Ord Dept Order 25-49, 18 Jul 49.

10. (U) DA GO 19, 14 Jun 50.

11. (U) RSA GO 1, 15 Apr 50.

12. (U) ARGMA Hist Summary, 1 Apr 58/30 Jun 58, pp. 8-9.

(U) With the Ordnance rocket and guided missile research programs thus combined in a central location, maximum use could be made of the German scientists skilled in these fields and further economies could be effected through the elimination of duplicate or parallel efforts. But the Redstone Commander still had not been delegated adequate authority and responsibility to properly function as the Ordnance commodity center for guided missiles. To do this he needed greater responsibilities in over-all program coordination and increased authority over closely allied phases of the program. National mission responsibilities for industrial and field service activities were delegated to Redstone Arsenal early in 1951; however, responsibility for technical control and supervision of current R&D projects was retained by the OCO R&D Division.[13]

(U) One of the main difficulties affecting the Ordnance guided missile program during the early 1950's was the lack of proper coordination among the divisions of OCO and the various field activities. Personnel possessing the most experience and information on the over-all program were in the Rocket Branch of R&D Division, OCO, but their interest was limited primarily to the R&D aspects of the program. As a result, the industrial, field service, and training elements did not receive the guidance and attention essential in the early phases of such a radically new and highly complicated product. Adding to the confusion was the relatively new "crash" program procedure, whereby the R&D, production, training, and other phases of Ordnance were telescoped to shorten the time required from weapon system conception to availability in quantity in the hands of troops. Such a procedure would have been confusing even with a more orthodox product. With the complexity of modern weapons making the demand for acceleration more and more difficult, improved communication and liaison throughout the Ordnance structure was essential. Referring to the coordination problems that existed early in 1951, one Ordnance administrator stated: "The importance of

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13. (U) Ibid., pp. 9-10; and memo, Lt Col William J. Durrenberger to Maj Gen Alfred B. Quinton, Jr., OCO, 5 Feb 51, subj "Coordination of the Ordnance Effort in the Guided Missile Program."

the guided missile program to the future of the Ord Corps can hardly be overemphasized, and with the program being expedited as it is, we in Ordnance are going to have to move fast if we are to meet our responsibilities in this field."[14]

(U) One of the first steps to improve coordination and control of the expanding Ordnance effort was the formation of an Ordnance Guided Missiles Organization and Training Committee which held its initial meeting on 24 January 1951. This meeting not only pinpointed potential problem areas, but also demonstrated certain management weaknesses that had existed since inception of the guided missile program. For example, it was the first gathering at which key representatives of all Ordnance guided missile activities were present, and many of these individuals had never contacted one another previously, even though Ordnance had been in the guided missile business since 1944. As originally conceived, the mission of this committee was limited to organization and training matters. However, the first meeting showed that much could be gained by broadening the mission to include coordination of all the guided missile functions being performed or contemplated by the Ordnance Corps. This committee was regarded only as an interim solution to the coordination problem and was to be dissolved when sufficient experience had been accumulated to permit the establishment of "normal" channels within the existing Ordnance structure.

(U) The establishment of such channels revolved around the delegation of additional responsibility and authority to Redstone Arsenal (RSA) so that it could properly and efficiently operate as a true Ordnance commodity center for guided missiles. This was partially accomplished with the assignment of industrial and field service missions, as noted above. After a thorough study of the problem, Lt Colonel W. J. Durrenberger of OCO* recommended that responsibility for R&D technical

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* (U) Col Durrenberger was later transferred to RSA and continued to fight the coordination problems that had permeated the entire organization. He served as Dir of Projects from Aug 51 to Sep 52, and as Asst Dir of the Ordnance Missile Laboratories (OML) from Sep 52 to May 53. (See RSA Officer Duty Cards, Hist File.)

14. (U) Memo, Lt Col Durrenberger, Ibid.

supervision be transferred from OCO to RSA as expeditiously as possible, and that such transfer be accompanied by three or four selected individuals from OCO in order to effect a more equitable distribution of the limited supply of qualified personnel. He also recommended that increased efforts be made on the training of Ordnance personnel in the use of new items of equipment.[15]

(U) The basic principles and policies governing the transfer of R&D technical supervision to Redstone were established in June 1951, but the rate at which the projects were transferred was necessarily geared to the arsenal's ability to effectively carry them out without any delay or disruption. The first two projects (NIKE AJAX and CORPORAL) were not actually transferred to Redstone Arsenal until August 1951. (Technical supervision of other R&D projects was assigned in a piecemeal fashion over the next several years, Project LACROSSE being among those transferred early in 1954.)

(U) Under the policy outlined in the transfer letter of June 1951, the RSA Commander became the sole source of instruction to the (NIKE and CORPORAL) contractors and assumed responsibility for monitoring, coordinating, and conducting the technical aspects of the assigned projects. The OCO R&D Division retained responsibility for policy, scope, and objectives of these projects, and for rendering decisions on original approach and major changes in design, performance, and operation of the missiles. Because of this division of responsibility and the semi-vertical organizational structure for guided missiles within the Ordnance Corps, it was essential that the closest possible liaison be maintained between Redstone and the operating branches of OCO.[16] This was not accomplished with any degree of efficiency until after the general reorganization of March 1958. More on this later.

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15. (U) Ibid.

16. (U) Letter, ORDTU-OCO, file 0.0. 682/159, to CO RSA, 26 Jun 51, subj "Transfer of Research and Development Responsibility to Redstone Arsenal."

(U) The initial training function was organized at Redstone in March 1952. The Provisional Redstone Ordnance School, as it was originally known, remained an integral part of RSA's mission and organization until 1 December 1952. At this time it was redesignated as the Ordnance Guided Missile School, a Class II Activity located at Redstone Arsenal and operated under jurisdiction of the Chief of Ordnance. Definitive guidance for commodity managers with respect to new equipment training responsibilities was not issued until August 1953.[17]

(U) Ordnance Policy for Prosecution of R&D Projects

(U) In September 1952, nearly a year after the first two projects were transferred to Redstone, the Chief of Ordnance issued a policy directive which outlined and defined the functional responsibilities involved in the prosecution of Ordnance R&D projects "in order to facilitate the complete understanding of all concerned." Obviously aimed at the continuing problems in management control and coordination, this order divided the various functional responsibilities into four distinct categories, each representing a logical group of duties both with respect to the execution of R&D projects and to the level of command at which the duties were to be performed. These four categories were: Policy Direction and Control; Technical Control; Technical Supervision; and Contract Negotiation, Execution, and Administration. The division of responsibility relating to technical supervision and control of R&D projects followed the same general pattern as that prescribed in the earlier letter of June 1951. This formal directive, however, was much more explicit and gave the OCO R&D Division more latitude for re-delegation of certain authority and responsibility to the field.

(U) Responsibility and authority for policy direction and control was delegated to the Chief, R&D Division, OCO. Duties in this category included the selection of the general approach to be followed;

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17. (U) For background history of RSA's training mission and the mass of management problems encountered, see ARGMA Hist Summary, 1 Jul 60/31 Dec 60, pp. 14-25. LACROSSE training activities are discussed in a later chapter.

determination of priorities and the scale of effort to be applied; establishment of target dates; coordination with related projects or sub-projects and with other interested agencies; preparation of engineering test programs; acceptance or rejection of final prototype designs; and other related functions.

(U) The Chief, OCO R&D Division, was also assigned the responsibility for technical control of all Ordnance R&D projects, with "authority to re-delegate Technical Control of entire projects or sub-projects to the field." (The latter authority was rarely used.) Technical control embraced these important functional responsibilities: 1) selection of potential contractors; 2) determination of the scope of contracts; 3) approval of technical decisions affecting cost, completion date, and priority of competing MC's; 4) approval of proposed solution for satisfying desired MC's; 5) determination of the validity of proposed solution in terms of the established basic design data; 6) within scope of authority, making the decision to proceed with prototype and engineering test models after completion of design; 7) delineation of technical supervision delegated to another agency or agencies; and 8) delineation of the areas of interest of mission arsenals jointly concerned with the prosecution of the project.

(U) In the area of technical supervision, it was the policy of the Ordnance Corps to assign technical work and the detailed supervision of technical work to field installations. (In the case of rockets and guided missiles, of course, the field installation was Redstone Arsenal.) Duties in this category were primarily concerned with assisting, advising, and directing the work of Ordnance contractors; establishing contacts between the contractors and Ordnance and non-Ordnance agencies qualified to contribute to the projects; and making "day-to-day" technical and administrative decisions not affecting cost, delivery dates, or satisfaction of MC's. In short, the technical supervisor or commodity manager served more or less as a medium between the contractors and OCO, the authority for all major policy decisions being vested in the OCO R&D Division.

(U) Finally, the responsibility for contract negotiation, execution, and administration was assigned to the cognizant Ordnance District, these duties being conducted in accordance with Ordnance Procurement Instruction 1-205.7, dated 1 September 1952.[18]

(U) Though enacted in the fall of 1952, the above policy was not applied to the prosecution of the LACROSSE R&D program until January 1954—a few weeks before Cornell began final design work on the tactical LACROSSE I system. Up to this point, complete responsibility for the project, including supervision of the contractor, had rested with the OCO R&D Division. Little or no action had been taken toward the participation of industrial and field service activities in the system design effort, chiefly because of funding difficulties.

(U) The OCO R&D Division relinquished responsibility for "technical supervision" of the project to Redstone Arsenal on 11 January 1954, but chose not to exercise its authority to redelegate "technical control" functions. In addition to the routine supervisory functions, the RSA Commander was charged with maintaining close technical liaison with other Government field installations involved in LACROSSE development, these including Edgewood Arsenal, Aberdeen Proving Ground, Picatinny Arsenal, and Frankford Arsenal.[19] Responsibility for technical coordination of the fuzing system and technical supervision of design and development of a nose impact switch and warhead had been delegated to Picatinny Arsenal early in June 1952. At the same time, Frankford Arsenal had been charged with exercising technical supervision of development of the base element in the T1405 fuzing system.[20]

(U) When comparing the scope of responsibility and decision-making power retained at OCO level with that delegated to the commodity manager or technical supervisor at Redstone Arsenal, the burden carried by the

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18. (U) Ord Corps Order 43-52, "Responsibilities for Research and Development Projects," 29 Sep 52.

19. (U) Letter, ORDTU-OCO to CG RSA, 11 Jan 54, subj "Assignment of Responsibilities for Project LACROSSE ...." See Document 6.

20. (U) LACROSSE Blue Book, op. cit., p. 12.

latter might seem small and relatively insignificant. This was not the case. The Chief of the OCO R&D Division did, in fact, carry the greatest burden, in that he held the controlling power and therefore could be brought to account for both bad decisions and indecision, as well as the consequent impact on individual projects. But he could not effectively perform his duties without a current, accurate knowledge of project activities in the field. To render sound, timely decisions and/or recommendations to higher echelons, and to prevent "out-of-control"—and often embarrassing—situations from developing, the responsible OCO official had to be kept currently informed of significant actions, problems, and events affecting the speed, direction, or cost of the over-all effort. The responsibility for providing this management information rested with the RSA Commander. Thus, when considering that major decisions affecting individual programs were necessarily predicated on feeder reports, briefings, and recommendations generated by the RSA Commander, the latter's burden of responsibility naturally takes on added depth and significance.

(U) The Weak Link in Redstone's Chain of Command

(U) To fulfill its diversified missions of research, development, production, supply, and maintenance for Army missile systems, the arsenal had to have the competence among its own people to control, coordinate, direct, and technically supervise all the work for which it was responsible. With the bulk of the total effort being done by industrial contractors at distant locations, this not only required a strong, centralized management control system to coordinate the wide range of activities, but also a broad in-house scientific capability to direct and evaluate the contractor's efforts and assure quality results.

(U) By early 1953, the arsenal had accumulated a complement of technical and professional personnel and had built up a sizable in-house research capability. But the success achieved in developing an integrated organization responsive to management control requirements was quite a different story. While considerable progress had been made toward solving the coordination problems that existed early in 1951, there were still

many administrators in operating elements of both OCO and RSA "who paid only 'lip service' to the importance of coordination."[21]

(U) The weaknesses inherent in the arsenal organizational structure, and more specifically in the loosely controlled operating divisions, served as a breeding ground for many problems and tribulations throughout the 1951-58 period. Most of the problems stemmed from the fact that there was no integrated management control system and therefore no machinery for directing basic command policy or assuring cross-coordination of important mission program actions. To further complicate matters, the four separate and generally uncoordinated divisions of OCO cut across established command lines and dealt directly with their counterparts at Redstone Arsenal. Each of the RSA mission divisions operated as a decentralized functional enterprise; effective cross-coordination was the exception rather than the rule. In effect, this placed the Arsenal Commander in the unpalatable position of having to accept the burden of responsibility without an opportunity to direct or control basic policy decisions.

(U) The damaging influence of this disjointed type of operation on telescoped guided missile programs had already become painfully apparent as early as December 1952. Referring to problems in the NIKE and CORPORAL programs, in general, and to the coordination problem in particular, Colonel Durrenberger declared:

> Changes in the OCO coordination picture (retirement of General Quinton and assignment of the additional duty of guided missile coordination to Chief, R&D Division), plus the fact that we have now reached the 'eleventh hour' in the program (equipment about ready to be issued to troops), have made it imperative that our coordination operations at this arsenal be improved considerably. Failure to secure proper coordination at this arsenal is actually threatening the success of the Army's entire guided missile program. It seems unnecessary to point out what effect this may have on the country's defense.[22]

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21. (U) Office Memo, Lt Col W. J. Durrenberger, Asst Dir OML, to Brig Gen H. N. Toftoy, Dir OML, 12 Dec 52, subj "Coordination of the Guided Missile and Rocket Programs."

22. (U) Ibid.

(U) During the seven-year period ending April 1958, arsenal administrators made several attempts to correct the situation, but their efforts were largely neutralized by the pressure of dissentient division chiefs. Invariably faced with accepting watered-down versions of the desired control system, arsenal management had to apply superficial remedies unbefitting the severity of the problem. The limitations imposed on the so-called "coordination offices" set up during this period* were both frustrating and far-reaching. For present purposes, it will suffice to say that the mission divisions continued to operate much the same as they had before, while the headquarters staff office did what it could to plan and coordinate arsenal missions "after the fact" and within the limits of its authority.[23]

(U) Project Management Under Redstone

(U) The functional organization set up for the LACROSSE project could be no more effective than the command policy under which it operated. In September 1955, some five months after the follow-on R&D contract had been awarded to the Glenn L. Martin Company, the office of the Redstone Resident Ordnance Engineer (RROE) was created at the contractor's plant in Baltimore, Maryland. The chief of this office, Mr. Edward Jungerman, reported directly to the Chief, RSA Industrial Division. His duties, in general, were as follows:[24]

1. Provide engineering liaison between the mission arsenal and the contractor.

2. Provide necessary administration of Engineering Change Order (ECO) and Request for Deviation Approval (RDA) procedures.

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* Arsenal Program Coordination Ofc (under OML) - Oct52/Feb53
Mission Planning & Coord Ofc (special staff) - Feb53/Oct55
National Mission Coord Ofc) (separate staff elements) - Oct55/Feb56
Arsenal Mission Coord Ofc)
Plans Coordination Ofc (special staff) - Feb56/Apr58.

23. (U) RSA Hist Summaries: Jan-Jun 53; Jul-Dec 53; Jan-Jun 55; Jan-Jun 56; and Jan-Jun 57.

24. (U) Supplement I to LACROSSE Blue Book, op. cit., p. 19; and Interviews with Mr. George E. Woodward, Antitank & Field Artillery Weapons System Project Ofc, Army Missile Comd.

3. Approve ECO's and RDA's except as follows:

a. ECO's and RDA's affecting MC's, system functions, system design intent, safety or interchangeability.

b. ECO's affecting contract price in excess of $250,000.

c. ECO's affecting contract delivery dates.

4. Forward ECO's and RDA's beyond the RROE scope of authority to Redstone Arsenal for approval.

5. Furnish advice to the contractor as to proper procedures and channels on specific problems in dealing with Ordnance.

6. Review and approve or obtain approval on technical adequacy of engineering work in progress on pertinent contracts.

(U) Experience had shown that the transition period in a telescoped program represented an extremely crucial and exacting phase, even in those programs involving only one contractor. In the LACROSSE program, the normal transition and engineering liaison problems were magnified several fold by the distance between the two contractors* and the animosity that existed between certain elements of the two organizations. In the fall of 1956, when the phase-over of program responsibility from Cornell to Martin was just beginning, Martin decided to move LACROSSE production to new facilities which had been constructed at Orlando, Florida, at a company cost of some $40,000,000. This move, sanctioned by a joint Army-Navy agreement, increased the distance between the two contractors to more than 1200 miles and consequently amplified the liaison problem. Moreover, some of the experienced engineers who had been working on the project refused to transfer, and Martin was faced with recruiting and training an essentially new production crew. The move started with transfer of the administrative staff in November 1956, followed by remnants of the engineering staff early in 1957. While the new production facility was not fully operational until December 1957, the impact on the over-all program was negligible. The improved facilities and environment at the Orlando site by far outweighed all of the attendant disadvantages. It should also be noted

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* (U) Initially, some 345 miles from the Cornell Laboratory at Buffalo, New York, to Martin's plant at Baltimore, Maryland.

here that the LACROSSE program had been shelved in FY 1957 and reinstated with only limited funds in FY 1958.

(U) Meanwhile, Mr. Herbert R. Kelley replaced Mr. Jungerman as senior representative in charge of the Baltimore RROE Office, in October 1956, and was transferred to the new RROE Office at Orlando in January 1957. Mr. Kelley continued to report directly to the Chief, RSA Industrial Division until the middle of 1958.[25]

(U) The New Look

(U) The action necessary to correct the long-standing deficiency in RSA's management control system came late in March 1958—right at the time the LACROSSE program was in its most serious trouble and slightly over two years before Army let the axe fall.

(U) On 31 March 1958, the Secretary of the Army created a new Army Ordnance Missile Command (AOMC) at Redstone Arsenal and appointed as its head Major General John B. Medaris, who had earned a notable reputation for his command and administrative ability as Commander of the Army Ballistic Missile Agency (ABMA). Placed under General Medaris' direct control were: ABMA; the Jet Propulsion Laboratory at Pasadena, California; White Sands Missile Range (WSMR); Redstone Arsenal; and the newly activated Army Rocket & Guided Missile Agency (ARGMA).

(U) Established as a subordinate element of AOMC on 1 April 1958, ARGMA assumed responsibility for the technical missions (including the LACROSSE program) formerly assigned to Redstone Arsenal, leaving the latter with post support and housekeeping functions.

(U) The integration of primary research, development, test, and logistical support installations under single direction, together with the administrative streamlining, would provide the means to carry out more effectively the existing and future priority Army missile programs. The unity of command that Redstone Arsenal had never been able to

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25. (U) Interviews with Mr. Herbert R. Kelley, Proc & Prod Directorate, Army Missile Command.

achieve thus become a reality under the AOMC structure—at the expense of adding a new layer of authority.[26]

(U) The foremost objective of the general staff type of organization adopted by General Medaris was to insure effective staff control and coordination of the total assigned mission. During his first staff meeting on 1 April 1958, General Medaris pointed out that the function of subordinate organizations was that of "coordination for the commander of all the elements of his problems so that they are handled as a command package and not as a functional enterprise." Obviously aware that this represented a drastic departure from previous practice, he went on to say:

> . . . From the beginning of time the three major divisions of Redstone Arsenal have operated as three separate empires. General Shinkle is fully aware of the problem and is pulling it together as fast as he can, and I want nothing to come out of this headquarters that will hinder his efforts to pull it together.[27]

(U) It took considerable time, much patience, and many readjustments—but "pulled together" it was. Among the first official actions taken by the ARGMA commander was the establishment of a strong, centralized management control system to be administered by the agency Control Office. A significant part of the responsibility and authority delegated to this staff element was concerned with the activities of ARGMA liaison personnel permanently stationed at contractors' plants and Government installations.

(U) Effective with the policy directive issued in late June 1958, all agency liaison personnel were appointed by the Agency commander and assigned to the Chief, Control Office. Liaison personnel located at the respective plants and installations were placed under direct command of a Senior ARGMA Representative (SXR) designated by ARGMA orders. In carrying out his assigned responsibilities as senior spokesman and

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26. (U) For background hist of the reorganization, see AOMC and ARGMA Hist Summaries, Apr 58/Jun 58.

27. (U) Minutes of Staff Meeting Nr. 1 (General & Special Staff), AOMC Hq, 1 Apr 58.

contact between ARGMA and the contractor, each SXR operated under the direct supervision of the Chief, Control Office. Matters relating to the "formulation of new policy or resolution of policy conflict" were handled through the Control Office for staffing and coordinated agency decision. Other matters could be resolved directly with the agency mission division involved, but with a single representative in charge of all agency missions at the contractor level, effective control and coordination of significant program actions was assured.[28]

(U) As far as the LACROSSE program was concerned, the aforementioned policy was partially implemented on 3 August 1958, when Herbert R. Kelley was designated as the SXR at Martin's Orlando plant and transferred from the ARGMA Industrial Division to the Control Office. Other agency liaison personnel stationed at the plant were transferred from their respective mission divisions to the Control Office and placed under direct supervision of the designated SXR, effective 19 October 1958. The LACROSSE liaison staff assigned at that time are listed below (by name, title, and grade).[29]

Paul C. Noller, Guided Missile Engineer, GS-12
Charles H. Laney, Jr., Guided Missile Technician (Elect), GS-11
James L. McKinney, Guided Missile Technician, GS-11
Allen T. Smith, Guided Missile Technician, GS-11
Helen B. Statz, Clerk-Stenographer, GS-4

Jack D. Abercrombie, Ordnance Engineer, GS-11
Thomas M. Flanagan, Engineering Technician, GS-11
Adrian A. Wilson, Engineering Technician, GS-11
Josephine Keeton, Clerk-Stenographer, GS-4

(U) Both the LACROSSE liaison staff and operating policy remained essentially unchanged until the fall of 1960. Paul C. Noller succeeded Herbert Kelley as Acting SXR at Martin-Orlando in August 1960. A few weeks later, operational control of agency field offices was transferred

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28. (U) ARGMA Circular 7, 28 Jun 58. For full text of this directive and details on other aspects of the new control system, see ARGMA Hist Summary, 1 Apr 58/30 Jun 58, pp. 32-46 and 142-43.

29. (U) Disposition Form (DF), ARGMA Control Ofc to Chief Civilian Personnel Ofc, 30 Jul 58, subj "Transfer of Senior ARGMA Representatives." Also see DF, ARGMA Control Ofc to SXR Glenn L. Martin Co., Orlando, Fla., undated, subj "Transfer of Personnel."

from the Control Office and again relegated to mission division level. Under the revised policy, operational control of SXR offices was vested in the mission division having primary responsibility for the weapon system involved. Liaison personnel were still appointed by the Agency Commander and they were still assigned to the respective contractor plants under direct supervision of a single SXR, as before. But the formulation of new policy or resolution of policy conflict was no longer handled or coordinated at agency staff level. All policy matters were channeled to the appropriate mission division chief for staffing and coordinated agency decision; other routine matters were resolved through direct contact with subordinate elements of mission operations concerned. This new procedure was implemented on 19 September 1960, when the functions and personnel of the Orlando field office were transferred from the ARGMA Control Office to the Director, Industrial Operations.[30]

(U) The absolute centralized control thus lost under the revised policy was supplanted, in part, by a commodity management procedure which had been established and implemented earlier in the year. This procedure was designed to provide the Agency Commander with the supplementary control, coordination, and monitorship necessary to assure integrated commodity managership. The system consisted of individual weapon system teams composed of one member from each of the mission operations and one Control Office member who served as team chairman. Members of the LACROSSE Weapon System Team included George E. Woodward, Chairman; Major W. R. Morrison, R&D Division; Mr. L. N. Hightower, Industrial Division; and Chief Warrant Officer E. J. Gonsalves, Field Service Division.[31]

(U) Actually, the revised management policies effected in 1960 were too late to influence the LACROSSE program one way or the other.

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30. (U) ARGMA GO 45, 25 Aug 60; Ltr, Lt Col B. H. Schimmel, Chief ARGMA Control Ofc, to Acting Senior ARGMA Rep, The Martin Co., Orlando, Fla., 31 Aug 60, subj "Transfer of SXR Functions"; and ARGMA Circular 600-1, 19 Sep 60.

31. (U) ARGMA Circular 1-2, Agency Commodity Coordination, 12 May 60.

Cancellation of the MOD I effort the year before had caused the withdrawal of Marine Corps support, and by late 1960 the LACROSSE program had been reduced to a terminal, buy-out status. None can say for certain whether the course of the LACROSSE program would have changed if AOMC management policies had been inforced several years earlier. However, it can be said with reasonable certainty that a more dynamic management system in the 1951-57 period could not have done the program any harm, and possibly would have saved the Army much embarrassment and the taxpayers a few dollars.

III. (U) DEVELOPMENT OF THE LACROSSE I PROTOTYPE (U)

(U) Introduction (U)

(U) As mentioned earlier, preliminary LACROSSE development actually began with an intermediate program at Cornell under Army Ordnance Contract ORD-11 in July 1950. This interim phase, completed early in 1951, was limited to further investigation of systems selected in previous studies under Navy contract and to development, through the breadboard stage, of the items required for a guidance system test. Having reaffirmed the technical feasibility of the proposed STEER* guidance scheme, Cornell recommended that full effort be applied to the development of a missile system based upon the STEER and STEER-1 concepts—the latter using accurate radar tracking in lieu of optical tracking.[1]

(U) Formal development of the LACROSSE system was initiated in February 1951 under Contract DA-30-115-ORD-47.[2] The R&D program proceeded under the assigned DA priority of 1B until mid-1952. The Ordnance Technical Committee accorded it 1A priority on 31 July 1952.[3]

(U) The initial hardware phase embraced a series of pilot-monitored flight tests using breadboard components of the basic STEER guidance system. These tests, completed in November 1951, successfully demonstrated the operational feasibility of the guidance system through closed loop type airplane flights. The tactical LACROSSE I system was subsequently developed and field tested in three successive stages, as follows:

1. (U) The Group "O" program used air-launched LARK (RV-A-22) test vehicles to evaluate the terminal guidance accuracy of the system.

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* (U) Sight Tracking, Electronic Equipment Ranging.

1. (U) See above sections dealing with analyses of feasibility studies and with the interim Army program. Also see Document 3 for full text of recommended development program.

2. (U) See Footnote 26, p. 19.

3. (U) OTCM Item 34373, "Rocket Branch Projects - Assignment of Priorities," 31 Jul 52. Also see Footnote 20, p. 17.

Eight modified LARK airframes, equipped with LACROSSE command and control equipment, were air-launched from a B-26 airplane and guided to the target by ground equipment. This stage was completed on 19 January 1954.

2. (U) The Group "A" program used the LACROSSE missile and guidance station to demonstrate complete system performance and accuracy. It included 15 flight tests at WSMR and was completed in December 1955.

3. (U) The Group "B" program used the Group "A" missile with experimental prototypes of tactical guidance equipment to further evaluate system performance and accuracy. It included six flight tests and was completed in September 1956.

(U) Transfer of technical responsibility for the LACROSSE system to the Martin Company was started in 1956, concurrent with the Group B test program. After transfer of technical responsibility to Martin, Cornell's effort was reoriented toward R&D on items which would improve and extend the weapon system capabilities. In January 1958, the funding of LACROSSE effort at Cornell was changed to the extent that a second contract (DA-30-115-ORD-908) was granted, in addition to the basic contract (ORD-47). These contracts ran concurrently until December 1958, when the basic contract was terminated. Supplemental studies were continued under the second contract. Figure 6 depicts the funding of LACROSSE from FY 1950 to the termination of activities under Contract ORD-47 in December 1958.[4]

(U) Evolution of Weapon System Requirements (U)

(U) From the inception of the program to 1951, the contractor was guided by the restrictive and somewhat arbitrary weapon system specifications established by the Marine Corps in 1947.* Early in 1951, the Marine Corps Project Officer for LACROSSE, stationed at OCO, developed a paper which embodied both Marine Corps and contemplated Army requirements. This paper, entitled "Ordnance Corps Development Instructions

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* (U) For full text of original MC's, see Document 1.

4. (U) Sacher, R. E., Report BE-745-T-149, op. cit., pp. 8-11, 228.

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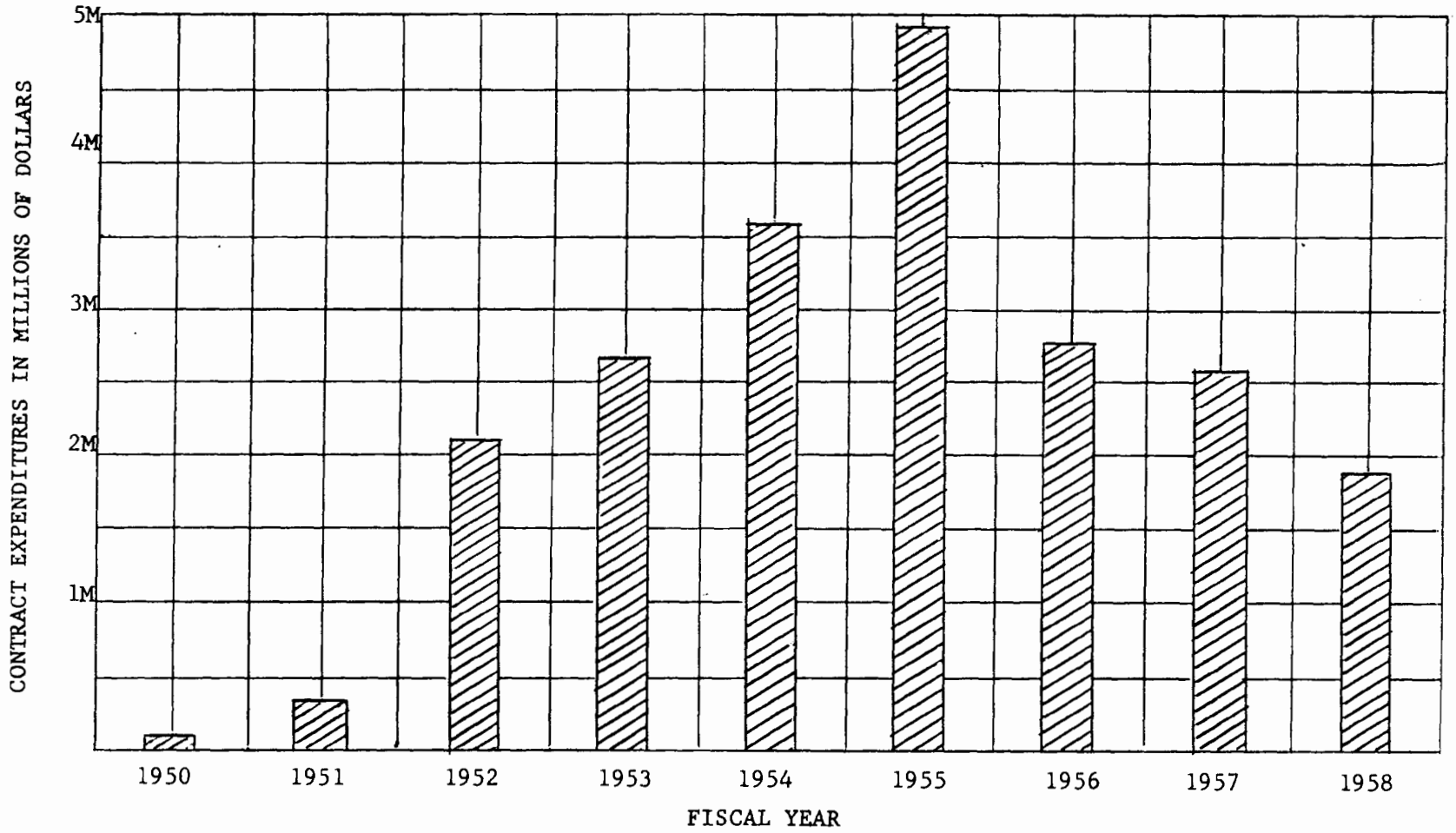

Figure 6
LACROSSE DEVELOPMENT COSTS AT CORNELL AERONAUTICAL LABORATORY
UNDER CONTRACT DA-30-115-ORD-47

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for LACROSSE Surface-to-Surface Close Support Guided Missile System, XSSM-A-12," presented broad objectives for the missile system and served as a guide to the developing agency. Significant changes from the original requirements included an increase in warhead weight to 500 lbs., and an increase in minimum range from 1,000 yards (922 meters) to 6.67 kilometers required and 3.33 kilometers desired.[5]

(U) By January 1953, LACROSSE development had progressed to a point where the major elements of the weapon system were defined and it was possible to formulate definite Ordnance Corps development instructions. The revised instructions stipulated for the first time that a solid propellant rocket motor would be used. Solid propellants were considered much easier to handle in the field and the logistics necessary to accommodate a solid propellant motor were much less complex than for liquid propellants. Another major change was an increase in maximum required missile range from 16,000 to 20,000 meters, and an increase in maximum desired range from 25,000 to 30,000 meters.[6] The observer's equipment was to consist of not more than six (6) individual items, each item weighing not more than 50 lbs.; all items to be integrally mounted on the guidance station vehicle but capable of being rapidly dismounted and carried for operation elsewhere. (Under the original specifications, observer's equipment was to weigh not more than 150 lbs.; 7 loads not more than 25 lbs. each.)[7]

(U) The Army Equipment Development Guide, 3 May 1954, stated the following requirement for a close support guided missile system:[8]

> (U) There is a requirement for a surface-to-surface guided missile system with a maximum range of the order of 30,000 yards for the specific purpose of supplementing field artillery fires for precision destruction attack with decisive power on appropriate targets. The basic design of the weapon system to fulfill the above requirement,

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5. (U) LACROSSE Blue Book, op. cit., p. 8.
6. (U) Ibid.
7. (U) Sacher, R. E., Rept BE-745-T-149, op. cit., pp. 11-12.
8. (U) LACROSSE Blue Book, op. cit., p. 9.

however, should be such that atomic and optimum fragmentation warheads may be adapted to the missile for employment in a general support role if such a concept evolves at a later date.

(U) In compliance with a directive from the Continental Army Command (CONARC), Board No. 4, Fort Bliss, Texas, prepared the MC's for a close support guided missile system in April 1955. Most of the technical guidelines furnished in the Ordnance Corps Development Instructions, as revised 19 November 1954, were included in the CONARC statement of MC's. Pending final DA approval, the MC's outlined in the CONARC document were used as a guide in development of the LACROSSE system.[9]

(U) The first formal statement of MC's for the LACROSSE missile system was approved and published in OTCM Item 36066 on 19 January 1956. The basic performance requirements set forth in the Ordnance Corps Development Instructions were retained. However, these MC's included a requirement that the basic design of the system be such that atomic and optimum fragmentation warheads could be adapted to the missile, permitting employment of the system in a general support role. This extension of use affected, primarily, the maximum guidance range. The new requirements for guidance ranges were as follows:

1. (U) Maximum Guidance Range - when using internal target survey unit data: required, 5,000 meters; desired, 8,000 meters.
2. (U) Maximum Guidance Range - when using external target data: required, 15,000 meters; desired, 20,000 meters.
3. (U) Minimum Guidance Range: required, not more than 250 meters; desired, as short as possible consistent with other considerations of the system.

(U) With the extension of guidance ranges, the required accuracy of the system was changed to specify a Circular Probable Error (CPE) of 5 meters at 5,000 meters guidance range, and a CPE of 30 to 40 meters at an extended guidance range of 20,000 meters.

(U) The maximum missile ranges remained the same as stipulated in the revised development instructions of January 1953; namely, 20,000

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9. (U) Ibid.

meters required and 30,000 meters desired. The required minimum missile range was increased from 6,670 meters (or 6.67 kilometers, as stated in 1951) to 8,000 meters.

(U) The specifications for warhead development gave first priority to a shaped charge or other penetration type capable of penetrating a minimum of six feet of reinforced concrete at 60° obliquity or 12 feet at 0° obliquity. Development of a practice warhead for training purposes was accorded second priority.[10]

(U) The statement of MC's for a Close Support Artillery Guided Missile System had been in effect less than three months when the Department of the Army reclassified the LACROSSE as a General Support Field Artillery Guided Missile System and placed a new priority on the use of warheads. The DA directive, issued on 10 March 1956, placed LACROSSE warheads in the following order of priority: atomic; controlled fragmentation; and shaped charge.[11]

(U) The revised MC's reflecting the expanded tactical mission of the LACROSSE system were finally approved and published on 13 June 1957. The General Support Field Artillery Guided Missile System was to be employed as corps artillery in general support and reinforcing roles against appropriate personnel and materiel targets, including heavy fortifications. The system was to be capable of delivering accurate close support fire and have the general support mobility to permit tactical employment similar to that of medium artillery. To insure a high degree of mobility and flexibility of operations in certain tactical situations, it was to have the capability of being transported by helicopter. Under the new operational concept, the forward observer sections would be organized and equipped to work in conjunction with division artillery in support of airborne, infantry, and armor units. All forward guidance equipment was to be man-transportable and each section capable of operating either dismounted or from a 1/4-ton truck.

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10. (U) OTCM Item 36066, "Close Support Artillery Guided Missile ... Statement of Military Characteristics," 19 Jan 56. See Document 7.

11. (U) Supplement I to LACROSSE Blue Book, op. cit., p. 3.

(S) To satisfy the operational requirements of the expanded tactical mission, it was necessary to modify certain performance characteristics of the LACROSSE weapon system. Among these changes were substantial increases in required missile range and in the extended guidance range. The maximum required missile range was increased from 20,000 to 30,000 meters, and the maximum desired range from 30,000 to 35,000 meters. The required maximum guidance range (using external data) was increased from 15,000 to 20,000 meters, and the desired range from 20,000 to 35,000 meters. System accuracy specifications called for a CPE of two (2) to five (5) meters at 5,000 to 8,000 meters guidance range, and a CPE of 30 to 40 meters at extended guidance ranges of 20,000 to 35,000 meters.[12]

(S) These changes in LACROSSE performance requirements, coupled with the production effort stretch-out and delayed release of FY 59 production funds, led to a slippage of some four months in the Ordnance Readiness Date (from December 1958 to April 1959). It should also be noted that the initial effort associated with the extension of system performance commenced in the 1956-57 period while the phased transfer of technical responsibility was in progress. This not only amplified the difficulties normally encountered during the transition period, but also contributed to delays in solving key technical problems. As will be noted in the next chapter, the LACROSSE I Service Tests began in July 1958 and were suspended four months later, along with production activity, because of serious weapon system deficiencies. The resulting delay was responsible for another program slippage, this time to July 1959. This Ordnance Readiness Date was actually achieved after a total slippage of twelve months. Yet, the LACROSSE system issued to Army units fell short of required performance capabilities in a number of areas. The MC's established for a general support field artillery weapon system were never completely fulfilled.[13]

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12. (U) OTCM Item 36527, General Support Field Artillery Guided Missile System - LACROSSE - Revision and Restatement of MC's, 13 Jun 57. See Document 8.

13. (U) Fact Sheet, "LACROSSE Ordnance Readiness Dates," prepared by ARGMA Control Ofc. Also see ARGMA Hist Summaries: Jan-Jun 60, pp. 98-102; and Jul-Dec 60, pp. 120-24.

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(U) Demonstration of Guidance System Feasibility (U)

(U) During the 1951-53 period, the effort at Cornell was principally concerned with the development and field test of LACROSSE guidance components. From the very outset of the program in 1947, Cornell engineers had recognized that the achievement of the required guidance accuracy would be their most difficult problem. After considering a number of possible guidance schemes they concluded that the STEER system could be developed to meet or exceed LACROSSE specifications. While these early investigations were not sufficiently thorough to positively preclude that a better system might be conceived, the current state of the guided missile art indicated that development of a more effective system within the same time and cost would be highly improbable. Cornell thus recommended in March 1950, that development of the STEER guidance system be commenced immediately, rather than search further for "an ideal system."[14]

(U) The transition of LACROSSE from a feasibility study to a hardware program occurred with the initiation of Project STEER in July 1950. During this interim program, completed in February 1951, Cornell conducted further detailed studies of the STEER guidance scheme and fabricated breadboard models of key components, including the command computer, optical tracker, and radio link.[15] Having thus reaffirmed that the proposed terminal guidance scheme was technically feasible, project engineers turned to the more exacting task of demonstrating the operational feasibility of the system in actual field tests.

(U) Pilot-Monitored Airplane Tests (U)

(U) The prime objectives of this early hardware test phase were to establish the operational feasibility of the basic STEER control and guidance scheme, and to evaluate performance of the interim system components. Cornell chose to do this by guiding an instrumented

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14. (U) See sections dealing with studies conducted under Navy contracts, Chap I. The operational concept of the STEER system is described and illustrated on pp. 11-13.

15. (U) See section dealing with the interim Army program, Chap I, p. 18. Also see Document 3.

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[redacted]

Beechcraft AT-7 airplane, which simulated the missile, along a predetermined flight path. Data on the aircraft's position in space were obtained from an optical tracker and electronic Distance Measuring Equipment (DME), and fed to a guidance computer which determined position error with respect to the "control line."* The error signal, transmitted to the airplane through a radio command link, was displayed to the pilot by cross-pointers on the instrument panel. By maneuvering so as to keep the cross-pointers at zero, the pilot attempted to reduce the off-beam errors to zero, thus replacing the airborne servos.

(U) Using the stringent LACROSSE system MC's as a guide, project engineers wrote tentative specifications for the various components in the fields of electronic DME, the optical and radar trackers, and the RF (Radio Frequency) command link. Since the ultimate goal of LACROSSE was a military missile system, they had not only the objectives of STEER in mind, but in addition the more acute problem of component suitability in terms of size, weight, and reliability for the interim and prototype missile systems. Realizing that the state of the art in these fields did not fully meet the LACROSSE specifications, they decided in the case of the STEER program to accept on-the-shelf components that would require a minimum of modification by the manufacturer for qualification.

(U) As an expedient necessary for an early demonstration, a Government-furnished MK-51 Gun Director was modified at Cornell to serve as the optical angular tracker. Other items of Government-furnished equipment (GFE) included a K-60 truck to house the ground station equipment, an AT-7 aircraft, and an M-10 ammunition trailer. Air Associates supplied an appropriately modified RF command link. The range or distance measurement equipment (DME) used was the Hastings Company's (HICO) Raydist system,** which had some limited field survey usage.

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* (U) In STEER Guidance, the "control line" is a fictitious line extending from the target to the region where terminal guidance (or forward observer) takes over control of the missile, the latter being launched from a rearward position. The forward observer is supplied with tracking, ranging, computing, and radio command link equipment.

** (U) Also known by the code name HICO-DME. See identifying note on p. 9.

(U) Preliminary evaluation tests of the HICO-DME showed that the equipment did not measure range with the consistency and accuracy required, and that the calibration did not hold from day to day. Under optimum conditions of propagation and equipment adjustments, a 25-foot accuracy was obtained on the fine (500-foot) channel. Inability of the equipment to hold calibration forced the adoption of an in-flight calibration technique, and the constant range error of about 500 feet was accepted rather than incur the costs in time and equipment necessary to improve performance.

(U) During the period 9 August to 19 November 1951, 11 pilot-monitored flights were made, most of them including about seven test runs. The duration of each flight was about two hours. The test locale for the second and eleventh flights was near the Buffalo Airport; all other flights were made at a Cornell-owned ten-acre site on the south shore of Lake Ontario, near Wilson, New York. The Wright Air Development Center provided theodolite services, including the instruments and a technical crew for operating them. The hypothetical target was located 2,500 feet off-shore at an altitude of 2,000 feet. Equipment located on the ground consisted of the HICO-DME, the MK-51 optical angular tracker (specially modified by Cornell), the interim computer, the radio command link, and auxiliary communication equipment to coordinate the tests. Carried in the Beechcraft AT-7 were the command link receiver, electronic DME transponder, the pilot's cross-pointers, and auxiliary communication equipment.

(U) The general opinion of those participating in the tests was that the HICO-DME represented the weakest link in the STEER guidance system. An analysis of the test data showed that this equipment was the largest source of error and that the miss distances recorded would have been much less if the equipment had provided correct range. It was concluded that STEER guidance was a "practical system" and, with improved components, the over-all accuracy would meet reasonable performance specifications.[16] A table showing the general results of

16. (U) Cook, S. P., "Pilot Monitored Airplane Flight Tests of the LACROSSE STEER Guidance System," CAL Rept Nr. BE-745-T-105, Jan 53, RSIC. Also see Sacher Rept BE-745-T-149, op. cit., pp. 89-95.

each flight is presented in Document 9.

(U) Group "O" Program (U)

(U) The design phase of the Group O non-tactical prototype guidance system actually began in late 1951 and continued until March 1953. Field tests began in April 1953 and continued through late January 1954. The level of effort for FY 1952-53 was established in January 1952. In a memorandum to the R&D Board, the Assistant Secretary of Defense recommended that the LACROSSE R&D program be funded for $3.7 million in FY 1952 and $3.2 million in FY 1953. Actual programs released for these two years were $3.9 million and $4.0 million, respectively. But with the austere funding of $3.1 million for FY 1954 effort, FY 1953 funds had to be stretched out and the level of effort reduced accordingly.[17]

(U) Possibly contributing to the reduced funding decision were comments and recommendations made during a conference on surface-to-surface missiles (SSM) held at Fort Monroe, Virginia, late in April 1953. The purpose of this conference was to review the current Army SSM program, to develop a priority list of SSM projects,* and to make recommendations as to the desirability of these projects for Army use. Significant comments and recommendations concerning the LACROSSE program are quoted below (underline supplied).

> (U) . . . Technical problems include ranging and acquisition of missile. The cost to date is 8.8 million dollars with an estimated total cost of 20-27 million dollars. Handling problems include heavy forward observer equipment. Maintenance is complicated. Limited employment foreseen.
>
> (U) . . . Fourth priority - This missile will partially fulfill a requirement . . . for a highly accurate close-support missile. This project should continue on low priority until feasibility of guidance system and components are

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* (U) Including the CORPORAL, HERMES A-2, HERMES A-3, LACROSSE, REDSTONE, and HERMES C-1—listed in the order of established priority.

17. (U) LACROSSE Blue Book, op. cit., p. 7; and Letter, ARGMA Dep Comdr to OCO, 15 Jul 60, subj "House Committee on Appropriations - LACROSSE," w/10 Incls (including Presentation on LACROSSE Development and funding tables). Compl file of latter document in AT & Fld Arty Weapon System Proj Ofc, Army Missile Command.

demonstrated. The LACROSSE project should be terminated as a weapons project. If the guidance system is successful, project should then be reoriented to meet new requirement for a light weight inexpensive missile capable of high accuracy with great destruction power utilizing forward observer control.[18]

(U) During the design phase of the Group 0 program, R&D effort was focused on the selection of existing hardware that could be modified for use in the program, the investigation of problem areas in existing equipment, and the development of a field test program. Two basic systems using STEER guidance were developed: an All Weather (AW) system and a Fair Weather (FW) system. The latter system used some optical components, while the AW system used only electronic components except for observer-to-target ranging. Once the AW system was set up its operation was completely automatic, in that the electronic DME and angular tracker operated without manual assistance other than monitoring. The FW system, on the other hand, required a human operator to operate the optical angular tracker. Each set of forward guidance station equipment included a tracker, a ranger (DME), and associated computers. The command link between the guidance station and missile was designed to operate with either system.

(U) AW Forward Guidance Station (U)

(U) Radar Tracking System. The AN/APG-26 radar, built by Dalmo Victor under subcontract to Westinghouse, was selected as the interim AW radar tracker on the basis of lightweight and ease of modification. This radar was an X-band unit weighing 155 lbs. and using a 10-inch rotating dish as a radiator. Its tracking accuracy was 4.4 mils in azimuth and elevation. Modifications consisted of converting the radar from an active tracker to a passive tracker, and cutting off half of one gimbal ring and substituting an 18-inch dish for the 10-inch dish, the latter change increasing the tracking accuracy to 2.0 mils. The

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18. (U) Ltr, Chief of Army Field Forces to OCO-ORDTU, et al., 28 May 53, subj "Letter of Transmittal No 21-5-9," w/Incl: Memo for Record, subj "Minutes of Conference on Surface-to-Surface Guided Missiles, Fort Monroe, Virginia, 22-23 April 1953."

air-borne beacon selected for use with the AN/APG-26 radar was a modified AN/DPN-12 free-running X-band pulse modulated beacon, designed by the Pacific Division of Bendix Aviation Corporation.

(U) Radio Ranging Equipment. At the conclusion of the subcontract with HICO, the ranging equipment still was not suitable for immediate application to LACROSSE and several major problems were yet unsolved. Among these were miniaturization of ground and air-borne equipment, development of an output range transducer, and the determination of accuracy performance of equipment. Consequently, Cornell placed a subcontract with HICO to conduct field tests of "range only" equipment and perform necessary modification to obtain satisfactory operation in range measurement, provide technical liaison during Cornell tests, and design and construct a suitable range output transducer.

(U) In view of the importance of electronic distance measuring equipment, Cornell conducted a survey of DME manufacturers and obtained a comparative evaluation of the various devices available. It was found that Convair had under development suitable DME operating at 72 and 144 megacycles. Cornell gave Convair a three-month contract for delivery of DME similar to that already under development for the AZUSA system. The ground station for this equipment was in a standard relay rack and weighed about 600 lbs. In this form it was not considered suitable for ultimate LACROSSE use; however, it did represent equipment that could be made available in a very short time. The only change required was a shift of operating frequencies to 36.5 and 73 megacycles to make the ground equipment compatible with antennas already built into the test vehicle airframe. Because Convair was not interested in further LACROSSE work—namely, the redesign of equipment for LACROSSE application—Cornell gave the Cubic Corporation a subcontract for further DME development.

(U) The Group O DME was similar in design to the original Convair equipment. Its operating frequencies were changed to 44.8 and 89.6 megacycles to be compatible with the radio frequencies allocated the LACROSSE project at White Sands Missile Range. To meet the time

schedule for the Group 0 firing program, Cornell had to accept the Cubic Corporation equipment before all specifications had been met. The "debugging" and final engineering of this set of equipment was done by Cornell engineers. Five transponders for use in the control test vehicles were received as part of the Cubic contract. Cornell selected Sylvania Electric Products, Inc., as the production subcontractor for the remainder of the transponders required for the Group 0 program.

(U) AW Computer. The AW computer for use with the AN/APG-26 radar tracker and DME was developed by Professor W. E. Meserve, of Cornell University.

(U) Command Link. The Collins Radio Company developed command link equipment for missile control under subcontract to Cornell. The Collins standard AN/ARW-55 transmitter and AN/ARW-59 air-borne receiver were used with new modulator and demodulator units to provide two proportional channels and six "on-off" channels of information. This equipment proved to be very satisfactory. It was used not only in the Group 0 program, but also without change in the Group A program which followed. In redesigning the Forward Guidance Station (FGS) equipment for prototype use, the Federal Telecommunications Laboratory (FTL) repackaged the original Collins design, adding the required circuit for continuous wave (CW) ranging.

(U) FW Forward Guidance Station (U)

(U) Optical Tracker and Ranger. An optical system was originally selected for angular tracking of the missile for a FW system because the errors inherent in such a system were generally less than errors resulting from the then current radar angular tracking systems. Optical tracking also offered a virtually jam-proof system, while radar was susceptible to jamming by the enemy. In the course of investigating optical trackers and distance measuring equipment, Cornell found that the Farrand Optical Company, Inc. (FOCI) had developed, under a Navy contract, a pulsed light range finder which operated by measuring the transit time of a light pulse from observer to target and return. It appeared possible to use the distance measuring equipment to measure

target range initially, and then have it continue with the missile tracking and ranging assignment. Consequently, Cornell gave FOCI a subcontract for a pulsed light range tracker and two computers—a guidance computer for missile control and a rate prediction computer for tracker elevation and azimuth drive. Specific functions of this equipment were to provide for semi-automatic tracking of the missile, whenever weather permitted; to measure continually and automatically (by pulsed light technique) the range to the missile; and to compute signals which would direct the missile along predetermined guide beams.

(U) Although the LACROSSE performance specifications required that the system be capable of all weather operation, the fair weather guidance system was developed on the basis that it would be ready for field test operations in advance of the all weather system. The operational limitations of the FW guidance system, coupled with the development status of the optical tracker and the FY 1953 funding restrictions, led to a decision in August 1953 to drop the FW approach in favor of the all weather guidance system. At this time, three flight tests had been made using the FW guidance equipment.

(U) Group 0 Control Test Vehicle

(U) Since it had been established in earlier studies that the prototype LACROSSE missile would be a cruciform, winged type similar to the LARK, it was decided to procure LARK airframes from the Fairchild Engine & Airplane Company* for the Group Zero test program. These airframes were readily available and could be modified to simulate the LACROSSE missile. The major work required was installation of LACROSSE guidance and telemetering components. Aerodynamic control in pitch and yaw was by flaps on the vertical and horizontal wings, respectively; roll control was by flaps on all four ruddervators. A cut-a-way drawing of the LACROSSE Group Zero Vehicle is shown in Figure 7.

(U) The Army requested that the unpowered RV-A-22 test vehicle be made ready for air drop tests with a minimum of design effort.

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* (U) See note relating to the LARK missile on p. 8.

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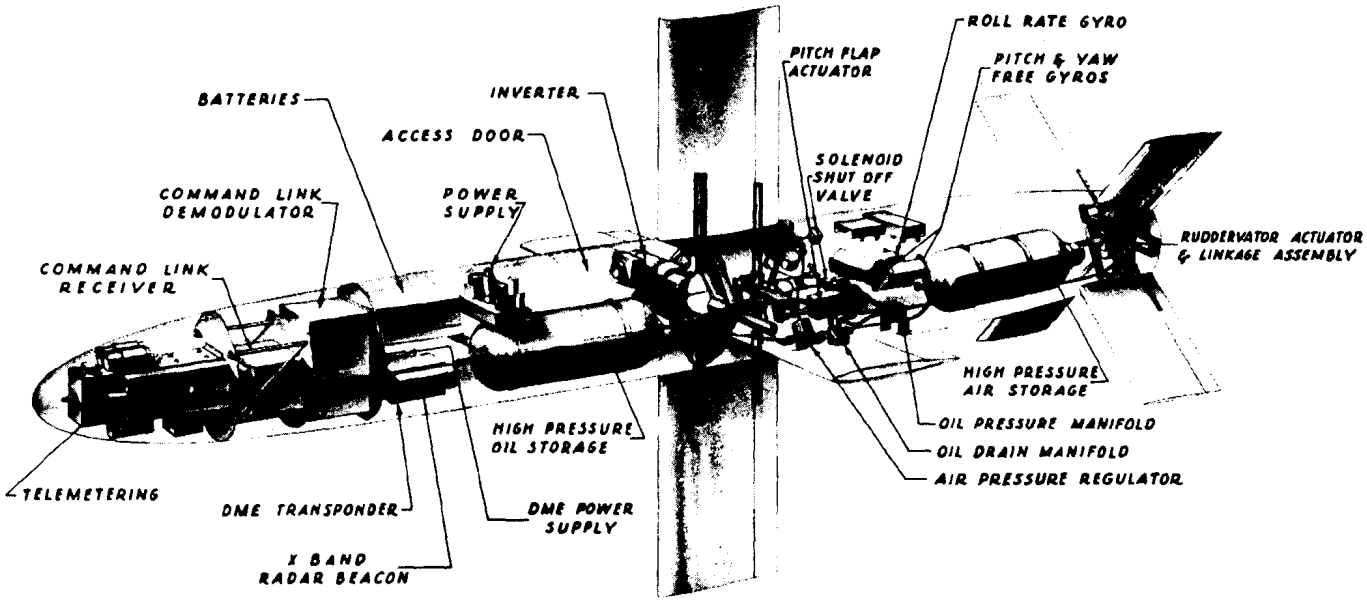

LACROSSE GROUP O VEHICLE

GENERAL ARRANGEMENT

TABLE OF CHARACTERISTICS	
CENTER OF GRAVITY POSITION	STA 87.34
WEIGHT	800 LBS
DIAMETER	17 INCHES
OVERALL LENGTH	102.15 INCHES
WING SPAN	74.2 INCHES
TAIL SPAN	48.0 INCHES

CORNELL AERONAUTICAL LABORATORY, INC.
BUFFALO NEW YORK

Figure 7

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Environmental conditions were relaxed, since very low levels of vibration, shock, and accelerations would be seen by the missile except for the short time at pitch down. This was important since it permitted the use of off-the-shelf items for the power source and gyros; and the remaining flight equipments did not have to be developed to a high state. The object was to get a controllable missile having the necessary performance with a minimum of effort and time. For later missiles, however, it was recognized that high performance and size reduction, rather than moderate performance coupled with best availability, would be the objective.[19]

Group Zero Test Program (U)

(U) The basic objectives of the Group Zero test program were to demonstrate conclusively the feasibility of the proposed terminal guidance system and to study the operation of the various guidance system components from the viewpoint of their ability to meet the required accuracy and performance specifications.

(U) The LACROSSE terminal guidance phase begins at the point where control of the missile is acquired by the guidance equipment at the forward observer station. To separate the study of this phase from dependence upon the launch and midcourse phases, the Group 0 plan was to ferry an unpowered RV-A-22 test vehicle into the terminal region using a modified B26 bomber. When, after release, the test vehicle had safely cleared the aircraft, a dive command was given, and the resulting maneuver brought the vehicle into the terminal path. Guidance along this path to the target was thereafter maintained by control from the forward guidance station.

(U) The White Sands Missile Range was selected as the base for Group 0 tests partially because of the availability of hangar and

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19. (U) The full story of LACROSSE Group 0 design effort is recorded in the following CAL Progress Repts, prepared by A. Ahlin, Asst Guided Missile Coordinator: Rept Nr. BE-745-T-5, Jan-Mar52; BE-745-T-6, Apr-Jun52; BE-745-T-7, Jul-Sep52; BE-745-T-8, Oct-Dec52; and BE-745-T-9, Jan-Mar53, RSIC. Also see Sacher Rept BE-745-T-149, op. cit., pp. 63-86.

maintenance facilities for the B26 aircraft at nearby Holloman Air Force Base. Cornell made arrangements through OCO for an assembly building and range facilities at White Sands and for hangar and maintenance facilities at Holloman. Components of the forward guidance station were set up on a concrete pad located about 2,600 feet south and 1,500 feet east of the target pole. The position in space of the test vehicle was tracked by available theodolite stations in the range area.

(U) Between 24 April 1953 and 21 January 1954, eight RV-A-22 LACROSSE test vehicles were air-launched in the Group Zero program, three of them using FW guidance components and the other five using the AW system. Original test plans called for a total of 10 flights; however, Redstone Arsenal, OCO, and Cornell jointly agreed that the results of the first eight flight tests had satisfied the program objectives by demonstrating the accuracy obtainable with the terminal guidance system. Flight testing of the last two rounds was therefore postponed indefinitely.[20]

(U) FW Guidance Tests. Of the three flight tests using FW guidance components, two (S/N-1, 24 Apr 53; S/N-4, 10 Aug 53) were considered essentially successful in over-all operation, though impact errors were excessive.

(U) In the first test flight, the FW guidance components performed very well from the standpoint of ranging, computing, and transmission of command signals to the vehicle. Response of vehicle controls to command signals was equally good. However, the vehicle velocity at release was lower than preflight calculations had assumed, and the terminal guidance control line erected to an angle lower than originally intended. Aerodynamic lift was insufficient for the vehicle to acquire the control line, with a resulting impact point 2,052 feet short and 372 feet south of the target.*

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* (U) CAL engrs made these changes beginning with S/N-4: Vehicle center of gravity moved back to 25% of mean aerodynamic chord to increase maximum lift; vehicles released earlier with respect to control line position to minimize overshooting the beam; an accurate calibration of control line position made before each launching.

20. (U) Sacher Rept BE-745-T-149, op. cit., pp. 99-110.

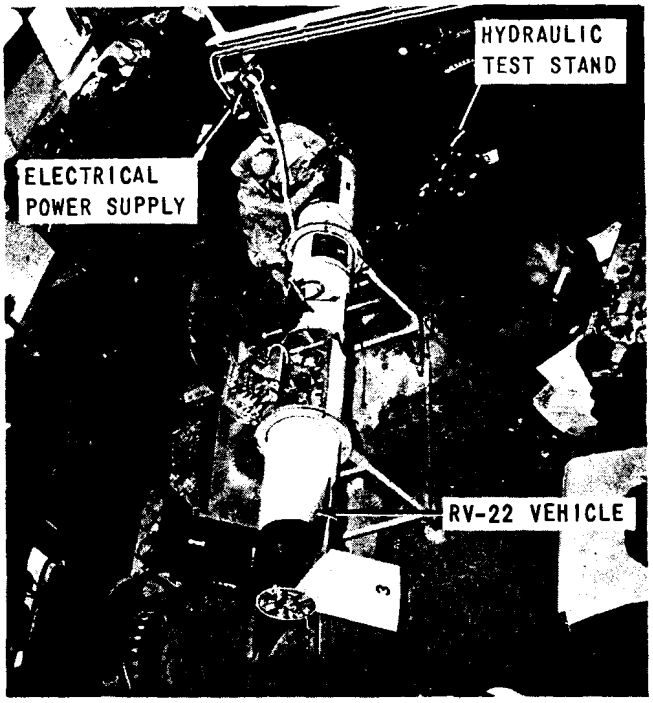


Figure 8. Preliminary Check at Bldg N-64, White Sands Missile Range.

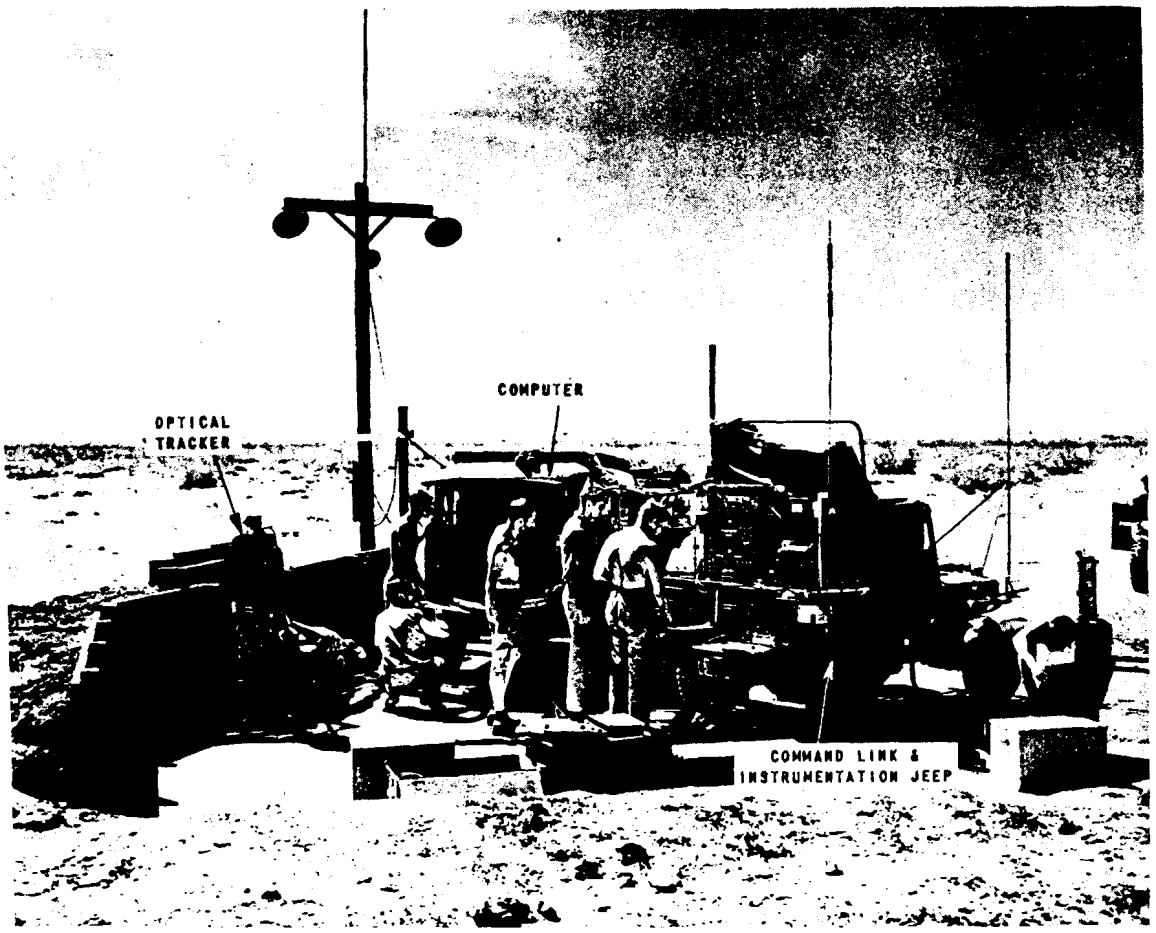
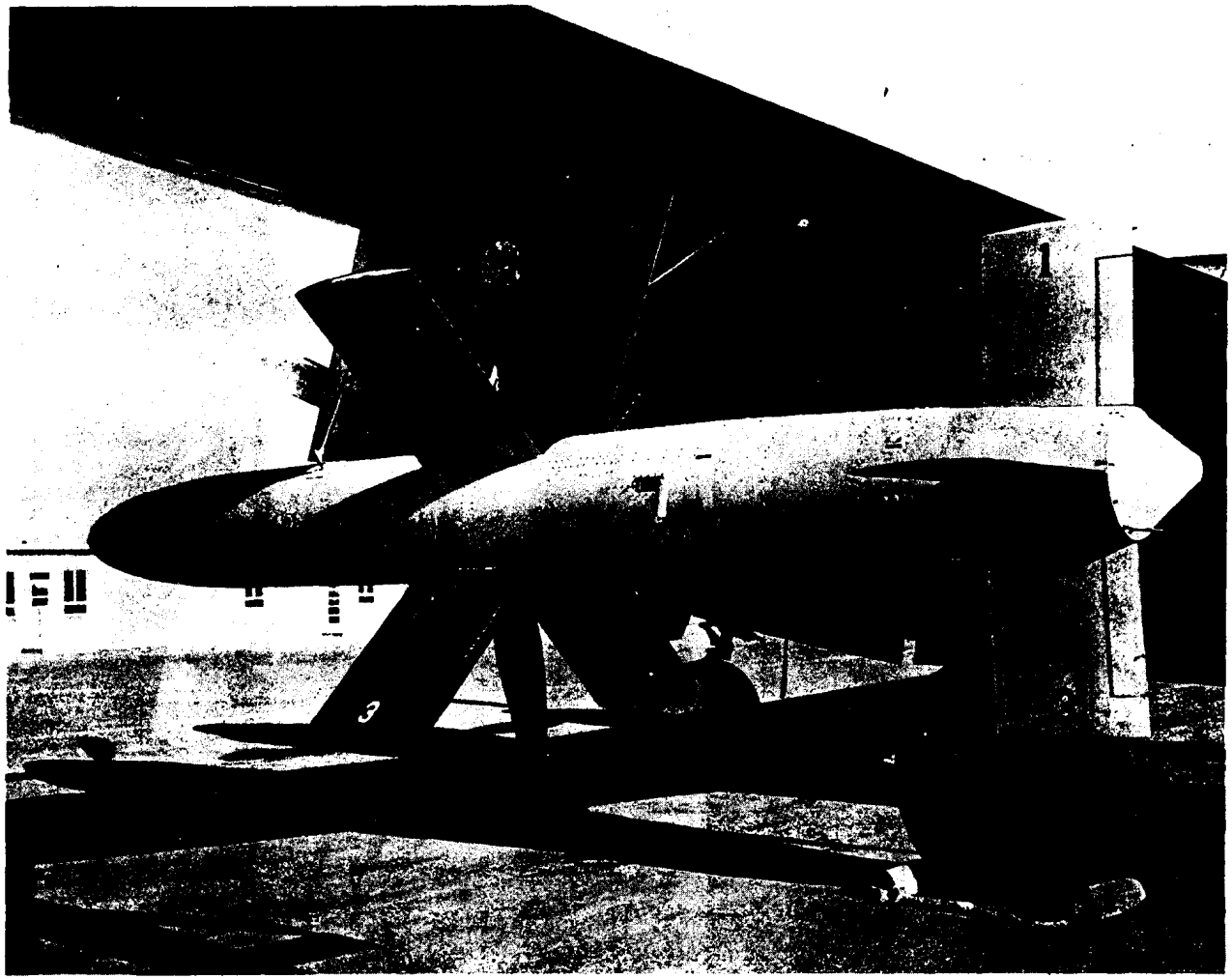


Figure 9. Forward Guidance Station.



LACROSSE S/N2 ATTACHED TO B-26 AIRCRAFT (Left-rear view)

Figure 10

(C) During the controlled portion of flight, S/N-4 followed a course closely approaching the ultimate objective of five meters CPE, but a malfunction in the roll servo system at 16.7 seconds after launch caused the vehicle to go out of control and it impacted about 1,200 feet short and 300 feet to the left of the target.

(C) The other FW guidance test (S/N-3 on 17 Jun 53) was marred by a wiring discrepancy in the servo valve control coil. The resulting divergent control system caused the vehicle to turn sharply and dive, impacting far short and to the left of the target.[21]

(C) AW Guidance Tests. The five flight tests using the all weather guidance components culminated in a convincing demonstration that the LACROSSE terminal guidance system would meet performance requirements of the tactical weapon. Vehicle S/N-6, air-launched on 19 October 1953, was the one and only flight in which the terminal guidance system failed to achieve closed loop control, the AW tracker losing the missile about one-half second after release. In two of the tests (S/N-2 on 10 Jun 53 and S/N-5 on 21 Sep 53), the control system was able to overcome certain operational difficulties and return the missile to the near vicinity of the control line, with resulting miss distances of 9 yards and 47.8 yards, respectively. But the real proof of control system capability came with the flight test of S/N-8 and S/N-7, in January 1954. Although a four-second launch delay caused S/N-8 to overshoot the control line by about 600 feet, the control system recovered completely with only five seconds of flight time remaining and achieved a radial miss distance of 6.5 yards. The last flight was a complete success, with a radial miss distance of 6.8 yards.[22]

(C) Summary and Evaluation (U)

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21. (U) Orlando, P. J., "Flight Test of Air-Launched LACROSSE RV-A-22, Serial No. 1," Mar 54, CAL Rept BE-745-T-109; and Smith, Robert, Flight Tests of RV-A-22 Missiles S/N-3 thru 8, 24 Aug 55, CAL Rept BE-745-T-122, RSIC.

22. (U) Smith Rept BE-745-T-122, op. cit.; and Orlando, P. J., Flight Test of RV-A-22 S/N-2, Jun 54, CAL Rept BE-745-T-110, RSIC. Also see Document 10.

(U) From the very outset of this program, Cornell engineers realized that perfect performance could not be expected from the Group 0 system. They believed, however, that the experience necessary to specify what was actually required for a tactical weapon system could be gained only by working with the equipment and by means of actual flight tests such as the Group 0 series. From this viewpoint, the LACROSSE Group 0 program was very successful and certainly worthwhile, for it not only proved that ground guidance of a missile with a high degree of accuracy was technically feasible, but also provided the experience and technical data necessary for selection of a practical missile system to fulfill LACROSSE requirements. Significant conclusions and recommendations for system improvement were as follows:

1. (U) Radar Tracking. Test data showed that sufficient tracking accuracy at X-band could only be achieved at the expense of a large parabolic antenna. Since it was essential that the size and weight of the tracker be held to a minimum, the use of K_a band was recommended.

2. (U) CW Ranging. Though not proved by actual field test, analysis showed that a higher degree of ranging accuracy could be expected by changing the DME carrier from a 44.6 - 89.6 mc frequency doubling system to a 420 - 450 mc off-set system. At higher frequencies and with more directional antennas, the multipath propagation possibly would be reduced. In addition, this frequency was more acceptable to the military.

3. (U) Guidance Computers. While the use of an analogue computer without resolver boosters was attractive in terms of increased reliability and lower power requirements, temperature and loading effects resulted in zero drifts which made this practice unsuitable for LACROSSE application.[23]

(U) Design of the LACROSSE Prototype System XSSM-A-12 (U)

(U) This phase of the LACROSSE R&D program embraced the design, development, and demonstration of the pre-production LACROSSE I prototype

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23. (U) Sacher Rept BE-745-T-149, op. cit., pp. 114-15.

system, including target location, launching, missile control to the point of acquisition by the forward observer (midcourse guidance), and terminal control onto a ground target. The first prototype model of the tactical system* evolved from two specific design groups. The Group A experimental system, designed and built by Cornell, represented the first complete set of LACROSSE equipment. It had the characteristics of a performance demonstration model and was not properly packaged for tactical use, but all elements of the tactical system were accounted for functionally. The Group B program represented the interim step from Group A to tactical LACROSSE I development, in which packaging requirements, ruggedness, ease of maintenance, and lightweight were given primary emphasis. The objective of this interim program was to establish the accuracy of the second generation guidance equipment (pre-production tactical model) in guiding the missile to a pre-selected target. Basically, the Group B missiles were Group A test vehicles with LACROSSE I terminal guidance components incorporated.

(U) Program Plans and Schedules (U)

(U) In planning for full-scale development effort, Cornell recognized that a considerable quantity of research equipment would have to be built and tested. In mid-April 1953, when Group 0 tests were just beginning at White Sands, Cornell submitted to OCO a proposed R&D flight test program, together with a plan for phasing in the co-contractor. The R&D test program proposed at that time consisted of 25 Group A firings (as follow-on research vehicles to Group 0) and about 15 LACROSSE I tactical prototype firings, all to be completed by the middle of CY 1956. To carry out this program, Cornell requested $5.0 million for FY 1955 and $10.0 million for FY 1956. The proposed co-contractor plan called for selection of the contractor by January 1954 and transfer of technical responsibility for the project by January 1956.[24]

(U) Following a DA Staff review of the LACROSSE Project at Cornell

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* (U) Designated as the LACROSSE XSSM-A-12 (Experimental Surface-to-Surface Missile, Army--).

24. (U) LACROSSE Blue Book, op. cit., pp. 12-13.

Laboratory, the Assistant Chief of Staff for Logistics (ACS/G-4) recommended in December 1953 that the experimental guidance system be conclusively demonstrated before obligating the $5 million requested by Cornell for FY 1955, and that the $10 million requested for FY 1956 not be obligated until Group A flight tests provided conclusive evidence that the LACROSSE I would fulfill accuracy objectives. The condition specified for release of the FY 1955 funds presented no immediate problem, for the terminal guidance accuracy of the experimental (Group 0) system was successfully demonstrated in the last two firings during January 1954, as noted above. A few weeks later Cornell commenced design work on the tactical LACROSSE I system and prepared to begin the series of Group A firings at White Sands early in August 1954. Funds actually obligated for the FY 1955 R&D effort amounted to $5.937 million. Because of major program changes effected during the spring of 1955, the R&D funds allocated for the FY 1956 program were cut from the requested $10 million to $4.3 million, with an additional $2.210 million in PEMA/S* funds for initial production engineering effort.[25]

(U) During the early part of FY 1955, a minor slippage occurred in the original schedule for delivery and flight testing of the 40 R&D missiles (25 Group A and 15 LACROSSE I), because of problems encountered in preliminary checkout of Group A test equipment and the delay in selection of the co-contractor. The first Group A R&D test firing took place at White Sands on 17 August 1954. Some three months later, the RSA-CAL survey of prospective contractor companies ended with a recommendation that the Glenn L. Martin Company be chosen as the new R&D co-contractor. By the time contract negotiations were completed with Martin in the spring of 1955, Cornell had essentially completed the design of the tactical LACROSSE I prototype and had test-fired seven of

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* (U) Procurement of Equipment and Missiles, Army/Support.

25. (U) Ibid., p. 11; Sacher Rept BE-745-T-149, op. cit., p. 209; and Incl to ARCMA Ltr, 15 Jul 60 (see footnote 17 above).

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the Group A research vehicles.[26]

(U) Meanwhile, Redstone Arsenal learned that the over-all FY 1955 budget, prepared as of 11 October 1954, had been reduced and that LACROSSE R&D funds would have to be conserved. As a result, Redstone submitted a new program schedule whereby R&D (Cornell) would only build the research vehicles and allied equipment and the new co-contractor would build the first tactical prototypes, which would then be allocated to R&D for flight testing and evaluation. This approach eliminated the 15 LACROSSE I missiles which Cornell had originally planned to build, and the number of Group A research vehicles to be fabricated by Cornell was later reduced from 25 to 18. (One of the latter vehicles was held for laboratory use and two were reassigned to the Group B program.)

(U) The first official LACROSSE Weapon System Plan (Figure 11) was published by Redstone Arsenal on 25 March 1955.* It depicted project scheduling through 1958, including 50 LACROSSE I missiles and 4 sets of ground equipment to be built by the Martin Company and an Ordnance Readiness Date of July 1958. By the end of FY 1955, three contracts totaling $13,692,643 (including a fixed fee of $951,850) had been awarded the Martin Company, as follows:[27]

1. (U) Contract DA-36-034-ORD-1892, 1 Apr 55, $699,982, for research, development, design, fabrication, and evaluation of LACROSSE Guided Missile System; delivery period, 1 Apr 55 to 31 Dec 55.

2. (U) Contract DA-36-034-ORD-2000, 31 May 55, $4,934,074, for Phase II Product Engineering Study on LACROSSE I Missile; delivery period, May 55 to May 57.

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* (U) Subsequent revisions in this weapon system plan were primarily concerned with the industrial program and will be discussed in the chapter dealing with that subject.

26. (U) LACROSSE Blue Book, op. cit., pp. 13-14 & 35; and Sacher Rept BE-745-T-149, op. cit., p. 209. Also see: Lein, H. S., "Quarterly Progress Report - Project LACROSSE, July-September 1954," 15 Oct 54, pp. 20 & 22, RSIC. The latter report hereinafter cited as: Lein Rept BE-745-T-15.

27. (U) Incl to ARGMA Ltr, 15 Jul 60, op. cit.; Sacher Rept BE-745-T-149, op. cit., p. 193; and LACROSSE Blue Book, op. cit., pp. 13-14 & 82-83.

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3. (U) Contract DA-36-034-ORD-2013, 1 Jun 55, $8,058,587, for delivery of 50 LACROSSE I Missiles and associated equipment; delivery period 1 Jun 55 to 30 Nov 57.

(U) The R&D flight tests of Martin-built LACROSSE I prototypes were originally scheduled to begin concurrently with termination of Group A tests. However, because of the necessary production lead time, the first LACROSSE I missile could not be delivered until June 1956. To bridge the gap between availability of the LACROSSE I guidance system (January 1956) and the initial LACROSSE I production prototype (June 1956), the Group A missile test program was terminated with the 15th firing in December 1955 and an interim Group B test program was established. In addition to providing the transition from the Cornell field test program to Martin's test program, the Group B test series would establish the accuracy of the pre-production LACROSSE I tactical model ground equipment in guiding the missile to preselected targets.

(U) The Cornell-Martin Group B program included a total of six flight tests at White Sands, using Group A missiles with a LACROSSE I guidance package. Two of the six missiles were reassigned from the Group A test program and the other four were fabricated by Martin from Cornell specifications and drawings. This interim Group B test program began on 29 March 1956 and continued through 2 September 1956.[28]

(U) Weapon System Employment Concept (U)

(U) Since the immediate objective of the LACROSSE Group A program was to develop and test a complete system, the guidance equipment had the characteristics of a performance demonstration model and was not packaged for tactical use. However, the missile and launcher requirements were sufficiently defined to permit the development of a pre-production tactical missile mobile launcher and missile shipping container early in the program. Early analysis of the missile loading

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28. (U) Sacher Rept BE-745-T-149, op. cit., pp. 205-06 & 219; and Szabo, W. J., "Quarterly Progress Report - Project LACROSSE, January - March 1956," 15 Apr 56, pp. 9 & 53, RSIC. The latter document hereinafter cited as: Szabo Rept BE-745-R-21.

LACRO WEAPO

ARGMA

TE 25 March 1955

	960		1961				1962			
	3	4	1	2	3	4	1	2	3	4
DESIGN, DEVELOP & TEST										
ENGINEER - SERVICE TEST										
PRODUCTION PREP & LEAD TIME										
PROTOTYPE PRODUCTION										
DOCUMENTATION										
TRAINING										

ORD

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and launching problem showed that a missile battery consisting of four active launchers and one spare could maintain a sustained rate of fire of 12 missiles per hour.

(U) The Forward Guidance and Observation Unit was packaged for Group B (Group A type missiles with LACROSSE I guidance equipment) such that nine man-packs were required when operated away from the Forward Guidance Station (FGS) jeep. One officer and twelve enlisted men comprised the total complement of the Forward Unit. Mobile equipment included three jeeps: one FGS, one radio jeep, and one cargo jeep with trailer. Four men were required to set up the operating condition once the equipment was in position, but only one man (the Power Supplies Operator) had to remain with the equipment once it was readied for missile firing. The tactics and technique of employment of the Forward Guidance System were developed for three modes of target engagement: direct observed fire; indirect observed fire; and indirect unobserved fire. These applied to both the on-vehicle and off-vehicle modes of equipment operation.

(U) Forward area test equipment for use with the FGS was "built-in" where feasible and not separately housed, the single exception to this principle being the beacon simulator. The Martin Company later developed a Missile Automatic Checker capable of automatically checking the operational readiness of the LACROSSE missile while on the launcher on a simple go-no-go basis.[29]

(U) The Missile (U)

(U) Early missile design studies were centered around the development of a subsonic configuration requiring the use of a liquid rocket sustainer motor. However, it was soon apparent that the use of liquid rocket propellants would involve a number of objectionable handling and storage problems for which there appeared to be no satisfactory solution. Realizing that the tactical operation of LACROSSE could be considerably simplified if liquid propellants were not used, Cornell initiated flight

29. (U) Sacher Rept BE-745-T-149, op. cit., pp. 116-17.

path and design studies toward development of a missile configuration suitable for use of solid fuel propellants.[30]

(U) By the end of 1953, after two series of wind tunnel tests, it was firmly established that the Group A missile would be a 500-pound warhead carrier with a maximum tactical range of about 30,000 meters. As finally developed and used in Group A flight tests, the XSSM-A-12 missile was of cruciform, swept wing configuration with interdigitated wings and tails. The wings were fixed with respect to the missile body, and the tails were all movable to guide the missile in pitch, yaw, and roll. Attached to the missile body were four shoes which engaged the launcher rails. Propulsion was provided by a single, solid propellant rocket motor located in the rear of the missile body. A total impulse of about 100,000 pound-seconds was delivered by the rocket motor over a period of 2.8 seconds. Figures 12 and 13 show the construction details of the major subassemblies making up the missile airframe. Major nominal characteristics of the XSSM-A-12 missile are shown below.[31]

(U)

Total Weight.....	2350 lbs.
Booster Fuel Weight..... (T52 integral booster)	500 lbs.
Warhead Weight.....	500 lbs.
Body Length.....	19 ft.
Body Diameter.....	20.5 in.
Wing Span.....	9 ft.
Tail Span.....	55 in.
Booster Thrust..... for a nominal 2.8 sec.	38,000 lb.
Maximum Speed.....	1400 ft. per sec.
Maximum Control Speed.....	850 ft. per sec.
Minimim Control Speed.....	400 ft. per sec.
Minimum Radius of Turn.....	3500 ft.

(U) Warhead Development (U)

(U) In developing the LACROSSE warhead, the Ordnance Corps used a

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30. (U) Ibid., p. 117.

31. (U) Ibid., pp. 124, 138; and Sacher, R., "Summary Analysis of Flight Tests of LACROSSE XSSM-A-12 Group A Missiles," 15 Oct 57, CAL Rept Nr. BE-745-T-137, pp. 10-12, RSIC. The latter document hereinafter cited as Sacher Rept BE-745-T-137.

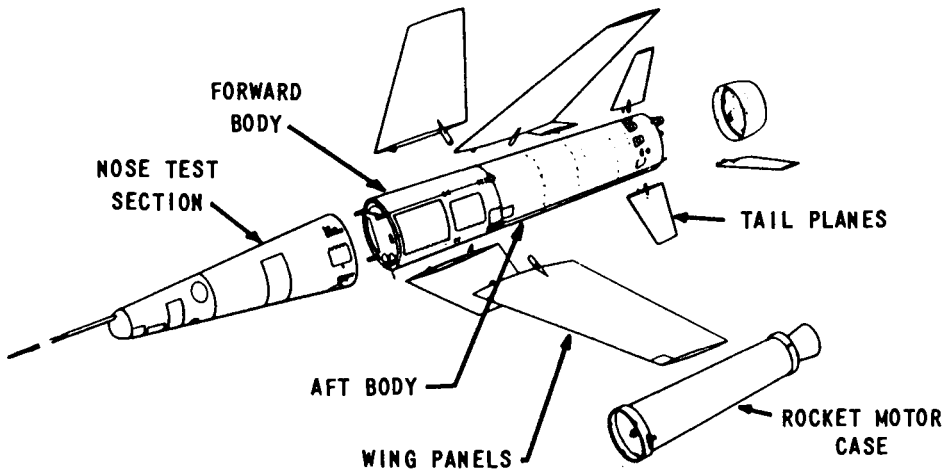

FIGURE 12 MISSILE EXPLODED VIEW

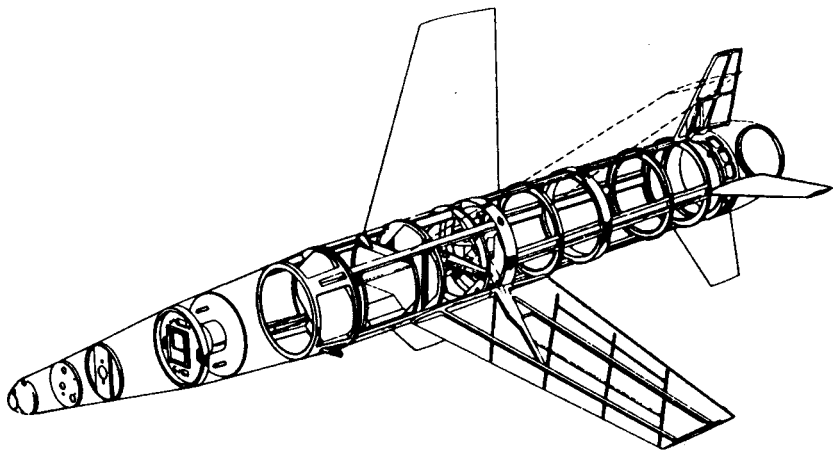

FIGURE 13 AIRFRAME STRUCTURE

relatively new approach. Normally, the warhead package for a missile is designed by Ordnance to fit into a nose section designed by the prime R&D contractor. This was not feasible in the case of LACROSSE, because the warhead made up the complete nose section as an integral part of the missile. Cornell therefore designed and fabricated the metal parts of the warhead, including the shaped charge liner, and Picatinny Arsenal furnished the explosives and tested the completed warheads.

(U) Since the LACROSSE was originally conceived as a weapon to reduce strong points of resistance, the warhead receiving the highest priority was a high explosive type incorporating a shaped charge at the forward end. A cross section of the Type I (500-lb. pure shaped charge) warhead design finally adopted in shown in Figure 14. Cornell fabricated the first lot of eight nose warhead metal parts and shipped them to Picatinny Arsenal for loading and subsequent testing at Aberdeen Proving Ground (APG).

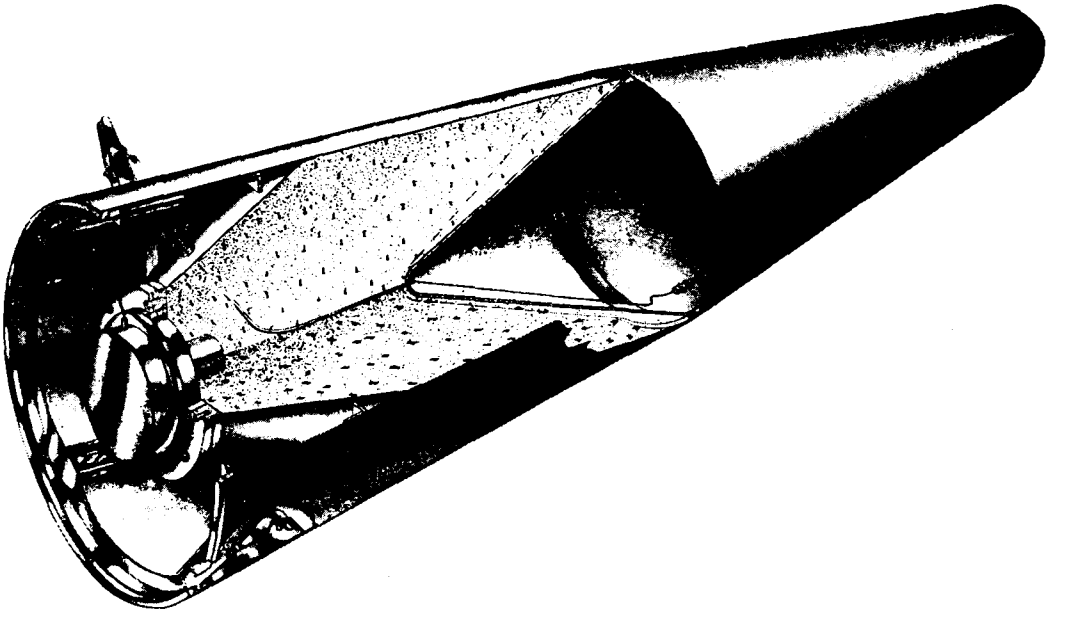

FIGURE 14 LACROSSE I T-34 WARHEAD (CROSS SECTION)

(U) Early in 1953, two of the loaded warheads were fired at APG to demonstrate penetration capabilities. The target was a concrete pillbox type structure. One of the warheads penetrated seven feet of wall, plus 13 feet of air, plus one-half inch of steel; the other, fired at 55° from the normal, penetrated over 12 feet of concrete with some unexpended momentum remaining in the slug. Accompanying these penetrations were large amounts of thick dust raised in the pillbox, about a cubic yard of rubble and bits of concrete thrown about from the spalling of the wall.[32] In a later test at Aberdeen, the warhead was tested for penetration into a simulated mass of concrete, the target consisting of five 7' by 7' by 4' reinforced concrete blocks. Penetration of nearly 13 feet (three 4-foot thicknesses and 11½ inches of the fourth) occurred, and the entire group of blocks was pushed forward about six or eight inches.[33]

(U) These and other similar tests showed that the destructive power of the shaped charge warhead would meet LACROSSE requirements. But before adopting the warhead, its useability in the field had to be verified. In the late summer of 1953, two loaded warheads of the configuration being considered were safety tested. When dropped from various heights up to 40 feet onto an angle iron, the warhead shells ruptured but no low or high order explosion occurred. Bullet impact tests, conducted with 30 caliber bullets, apparently caused no high order explosion. Several single shot bullets and a tracer caused slight burning and shell rupture. A burst of machine gun fire did cause an explosion which destroyed the warhead. Tests with 50 caliber bullets caused a partial explosion. From these tests it was concluded that the Type I warhead design shown above was acceptable for field use.

(U) Other types of conventional warheads, such as the Type 2 (shaped-charge-fragmentation combination) and the Type 3 (shaped-charge-incendiary combination) were not developed since it was impossible to establish firm requirements until the capabilities of such combinations

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32. (U) Sacher Rept BE-745-T-149, op. cit., pp. 125, 155-56.

33. (U) Lein, H. S., "Quarterly Progress Report - Project LACROSSE, October-December 1953," 15 Jan 54, CAL Rept BE-745-T-12, p. 60, RSIC.

were more firmly realized by experimentation. The Army Chemical Center started development of a shaped charge warhead backed by incendiary material, but sufficient funds were not available to complete the project.

(U) A change in the LACROSSE MC's to include the concept of a general support weapon led to the requirement for an atomic warhead. The initial feasibility study was made jointly by Picatinny Arsenal, representing the Department of the Army, and the Sandia Corporation, representing the Atomic Energy Commission in coordination with Field Command, Armed Forces Special Weapons Project. Data gleaned from this study indicated that it would be feasible to use the LACROSSE missile for delivery of three different warheads of varying yields. Development of the warheads was done by the Sandia Corporation and General Electric. Cornell effort was directed toward the development of a method for reduction of burst point dispersion by use of a "volume-in-space" concept for "on target command" to arm.[34]

(U) Fuzing System (U)

(U) The T1405 fuzing system developed for the LACROSSE was a combination of an electric point initiating, base detonation fuze and a mechanical inertial base detonating fuze, with the necessary electrical energy being furnished from the missile power supply. Both the mechanical and electrical portions of the fuze are detonator safe and remain so until armed through a radio command system. Arming time is under 0.5 seconds, and arming by radio command is not possible until after five seconds of flight. An acceleration actuated switch is used in series with the command switch, thus preventing accidental arming of the warhead fuze by spurious signals when the missile is on the launcher or during early part of the flight.

(U) Included in the fuze program was the design and development of a nose impact switch and warhead wiring system. The latter system consists of an electrical lead from the radio command arming relay to the fuze base element, a "hot" lead from the missile power supply to the

34. (U) Sacher Rept BE-745-T-149, op. cit., pp. 125, 156.

fuze base element to energize the electrical detonator, and an electrical circuit from the nose impact switch to the fuze base element. Picatinny Arsenal developed the nose switch and wiring harness. Frankford Arsenal had development responsibility for the base element.[35]

(U) Rocket Motor Development (U)

(U) The T-52 rocket motor used with the XSSM-A-12 missile was designed and developed by Picatinny Arsenal. Aside from an apparent grain weakness at certain temperature extremes, this rocket performed satisfactorily in the field experimental program. However, it was apparent that the T-52 motor would not meet performance requirements of the ultimate LACROSSE I system. Cornell engineers voiced this opinion during a conference at Picatinny Arsenal on 21 September 1954, shortly after the first Group A missile firing.

(U) To provide a rocket motor which would meet LACROSSE I requirements, Redstone Arsenal entered into a contract with the Thiokol Chemical Corporation on 26 May 1955 for initial development of the XM-10 motor. This initial effort, costing $96,296, was completed early in 1956 and 12 of the XM-10 motors were statically fired in March. The results of these static tests showed that the motor performance fell short of established requirements in total impulse, allowable thrust variation (from average), and ignition interval. A resonance condition also occurred which was not eliminated.

(U) Pursuant to decisions made during a rocket motor coordination conference at Redstone Arsenal on 12 March 1956, work on the XM-10 motor at Thiokol was reoriented toward development of a suitable tactical motor to insure proper operational characteristics at low temperature, and a product engineering effort on the T-52 E1 rocket motor was initiated at Picatinny Arsenal as a backup program. The T-52 E1 motor was to be used as an interim motor until a new one could be completely proved.[36]

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35. (U) Ibid., p. 157.

36. (U) LACROSSE Blue Book, op. cit., pp. 14, 82, and Supplement 1 thereto, p. 7. Also see Szabo Rept BE-745-T-21, op. cit., pp. 57-58.

(U) Forward Guidance Station (U)

(U) Angle Tracker. Procurement of a suitable angle tracker started in late 1950 with the writing of preliminary specifications for a CW radar operating in the K-band, having an 18-inch dish antenna, and weighing about 100 pounds. In reviewing these specifications with leading radar manufacturers, Cornell found that most companies were reluctant to attempt building such a tracker on the time schedule proposed. One of the companies contacted, the Federal Telecommunications Laboratories (FTL), was already working on a K-band radar and had knowledge of a British 0.86 cm magnetron with a reputed output of 9-10 watts. Cornell thus awarded FTL a subcontract for development of the prototype angle tracker. Development of the 5789 magnetron operating at 0.86 cm by Sylvania Electric Products assured a multiple source for the beacon magnetron. Although early work was done on both the pulse and CW systems, the pulse system was finally selected.

(U) The beacon and tracker units were designed as an angle tracking system capable of measuring both elevation and angles to an accuracy of ±1mil at low tracking rates and of operating at ranges from 250 meters up to 25,000 meters. The LACROSSE tracker was of the conical scan type, which senses and tracks the angle of arrival of missile-beacon transmitter pulses. Acquisition is accomplished within five seconds after the missile appears within the 20° cone scanned by the acquisition horn antenna, and tracking thereafter is continued within the specified accuracy to within 1° of the horizon. The tracker was equipped with a monocular to aid in sighting the target and aiming the antenna within an accuracy of ± 0.3 mil. Also, a mechanism was included to allow leveling the tracker to within 0.5 mil whether the operating site was on level ground or on a 20° slope. The beacon and tracker units were capable of satisfactory operation under the various environmental conditions specified for the airborne and ground-based LACROSSE equipments.

(U) In general, the above specifications for the Group A tracker were similar to those for the Group B program. Differing primarily were

the known and controlled test conditions at White Sands (such as simple trajectory, reduced temperature, humidity and altitude problems, size and weight tolerances), which allowed compromises in the design and operation of the Group A equipment. The tactical requirements and features, as applied to the Group B equipment, account for the significant design differences. The major changes were mechanical, electrical modifications being incorporated where substantial improvements in accuracy, ruggedness, and reliability could be assured.[37] A brief account of design changes made in the Group B tracker is presented below.

1. (U) The narrow beam, parabolic antenna employed a front-type feed mechanism. This assembly was smaller and more rigid, and permitted the use of a higher scan frequency; namely, 60 cycles per second (cps) instead of 35 cps.

2. (U) The higher scan frequency not only led to the simplification of filters, detectors, etc., but also generally improved the servo system operation.

3. (U) The squint angle of the "dish" antenna was changed to increase the depth of scan or error signal modulation about 3 decibels (db) at a 1 mil off-beam pointing angle.

4. (U) A British Type VX-5023 klystron was used in place of the QK-406 because of its frequency stability and low current demand. The lower current demand allowed a reduction in size and weight in the klystron power supply. A new thermostatically controlled unit was installed to cool or warm the klystron, as required.

5. (U) The power supply section of the tracker met the klystron power requirements only. All other power was supplied directly to the tracker from the electronic power supply.[38]

(U) The Group A and Group B prototype trackers are shown in Figure 15.

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37. (U) Ibid., pp. 158-60.

38. (U) Ibid., pp. 166-67.

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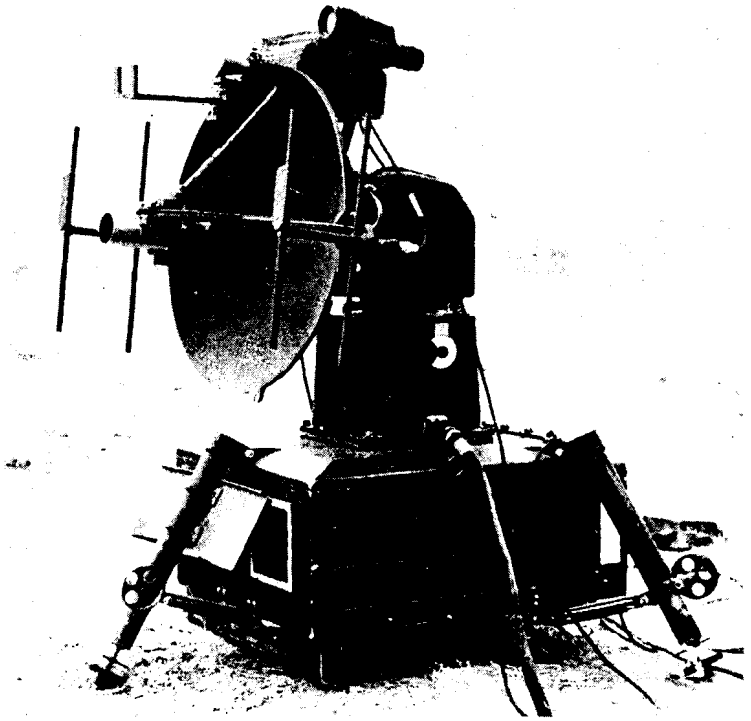

GROUP B TRACKER

GROUP A TRACKER

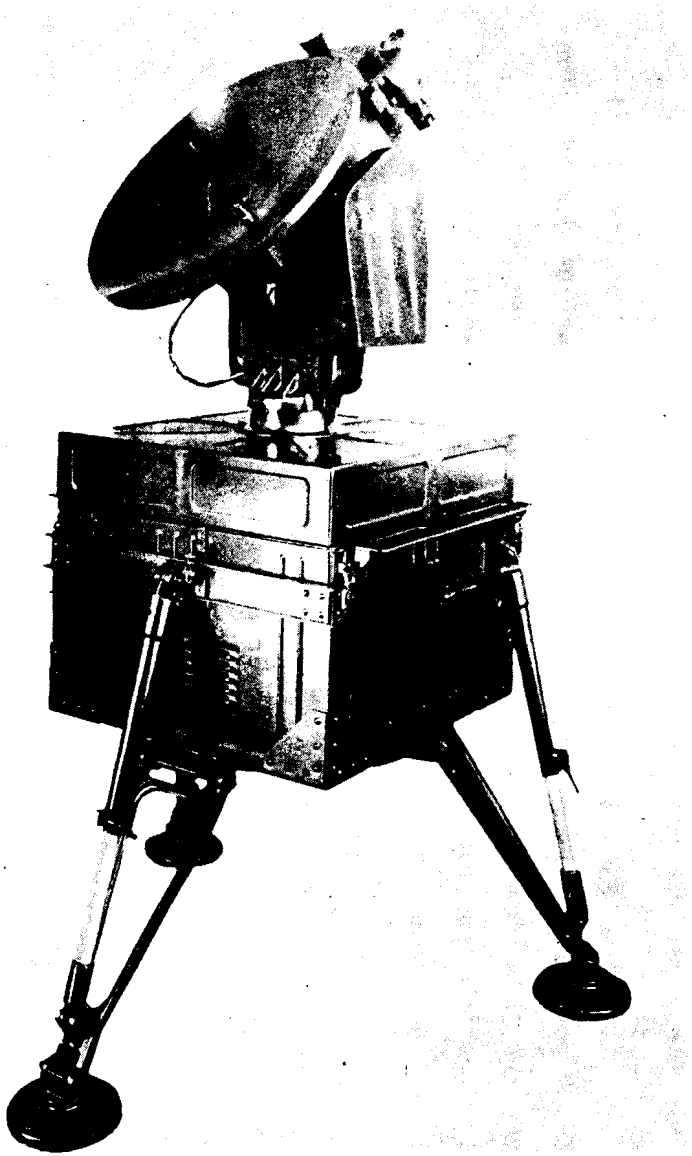

FIGURE 15 GROUP A AND GROUP B ANGULAR TRACKERS

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(U) Electronic Distance Measuring Equipment (DME). As a part of the original subcontract for the 44.8 and 89.6 megacycle (mc) DME used during the Group 0 program, the Cubic Corporation also developed the 420-450 mc DME for the Group A program. In going to the 420-450 mc equipment, it was felt that this frequency would be more acceptable to the military and that at these higher frequencies multipath problems would be minimized and higher accuracy achieved.

(U) When the subcontract with the Cubic Corporation was terminated in December 1952, only two transponders had been delivered to Cornell. The transponders used during the early portion of the Group A program were built by Cornell; other Group A transponders were built by FTL. These units followed the basic Cubic Corporation design with some minor changes. The Group B DME was built by FTL as part of the integrated FGS.

(U) The electronic DME measures the range of the missile from the FGS for computation of guidance orders. The DME ranging operates by the FGS transmitting a modulated continuous wave signal which is then re-transmitted by a transponder to the ground station. The modulated envelope of the received signal from the missile is then compared in phase to the so-called reference modulation of the ground transmitted signal. The phase delay during the transit time to and from the missile is a measure of range to the missile from the ground station. The LACROSSE DME consists of ground transmitter-receiver equipment and a missile-borne transponder. The ground equipment consists of radio frequency unit and a range servo (indicator). The transponder is essentially a receiver and off-set frequency transmitter.

(U) Although the Group A DME specifications were similar to those for the Group B, the Group A DME was representative of laboratory equipment instead of field gear. The Group A DME ground station unit (including direct current power supply) weighed about 400 pounds and occupied about eight cubic feet. In contrast, the Group B DME packages weighed 100 pounds total, occupied a total volume of less than two cubic feet, and performed the command link ground function as well. Aside from complete repackaging and miniaturization of the ground station unit,

the DME and the command [redacted]ned to the extent that a common RF carrier was modulated by both command and DME intelligence.[39]

(U) Command Link. As noted earlier in this chapter, the command link equipment for Group A was supplied by the Collins Radio Corporation and represented "ruggedized" versions of the Group 0 equipment. The Group B command link used the DME RF system instead of a separate transmitter and receiver as in Group A, and was therefore built by FTL as part of the electronic distance measuring equipment. This feature had a distinct advantage in terms of reduced size, weight, and complexity. Two intermediate instruments, the modulator and demodulator, are required to transform DC control signals from the computer to subcarrier amplitudes, and to transform the subcarrier amplitudes to DC control signals in the missile.

(U) Command Guidance Computer. The computer used in the Group A program was very similar to that used in the Group 0 program and was built by the Farrand Optical Company. The transfer chassis, providing the necessary signal shaping networks for control of the missile, was built by Cornell. The prototype (Group B) computer was designed in the Cornell Laboratory.

(U) Electronic Power Supply. In the Group A program, the electronic power supplies for the several FGS components were a part of the individual units and as such were supplied with the unit. In the Group B program, the FGS was designed as an integral unit and a common power supply was used to supply all DC power for the FGS except the high voltage required by the tracker klystron. This unit was built by FTL.

(U) The input to the electronic power supply is obtained from the primary power supply which has a 400 cps, 3-phase, 120-volt line-to-neutral system and a total rated output of 3 kw. Five different DC voltage levels are developed from the rectified AC input; namely +300, +250, +28, and -150 volts. The unrectified AC is distributed at 120

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39. (U) Ibid., pp. 167, 169. Also see Sacher Rept BE-745-T-137, op. cit., p. 13.

volt and 6.3 volt levels.

(U) While the electronic power supply was designed to meet all of the environmental conditions imposed by the LACROSSE specifications, the size, weight, and heat dissipation problems are particularly difficult with this unit. In the first place, power supply components are always large and heavy. Also, the entire power requirements for the FGS are being distributed through the electronic power supply, yet the standard case size of 7" x 12" x 19" is used for the power supply as well as for several of the other components.[40]

(U) Target Locator (U)

(U) Group A. As originally conceived, the LACROSSE system was to use an optical tracker-ranger to determine missile position, the tracker-ranger having the dual function of target location and missile guidance. As noted earlier, the fair-weather optical tracker system was dropped in favor of the all-weather tracker in August 1953. This resulted in a requirement for a pulsed light target locator independent of the guidance equipment. Hence, the Farrand Optical Company was instructed to stop work on the second generation tracker-ranger and concentrate on a self-contained target locator. The 18-inch experimental system developed under the Extended Range Feasibility Study was the basis for the early work in this program. At the close of the contract, the Farrand instrument was able to range out to about 3100 meters with prescribed accuracy.

(U) Group B. Upon completion of the Farrand contract, it was apparent that considerable improvement could be made in the electronics of the target locator unit. Of prime concern was the marginal performance of the power supply. Cornell decided to design and build the Group B Target Locator in its own laboratory.

(U) The optics and lamp used for the Group B unit was identical to that developed for the Group A target locator. Two separate power supplies were developed, one of them an inverter set and the other a

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40. (U) Ibid., pp. 174-75, 179.

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transistor set. Early inverter sets proved to be unreliable because of dynamic unbalance in the inverter armatures; however, with improved manufacturing techniques, later units were much more reliable and operated for periods in excess of 500 hours with no maintenance. Although the transistor supplies were found quite satisfactory in operating characteristics, conversion efficiency, and circuit impedance considerations, the transistor and transformer reliability when used in these circuits was significantly poorer than that of the inverter supply. For this reason, the transistor supply saw little service in the Group B unit.[41]

(U) Launcher Development (U)

(U) Cornell decided in early 1952 to design a mobile launcher which would impart an initial spin to the missile during free flight prior to guidance, thereby reducing the dispersion effects of thrust and aerodynamic misalignments. Investigation revealed that a $6\frac{1}{2}^{\circ}$ helix would rotate the missile through a total angle of 42° at an approximate rate of 480° per second at the time the missile left a six-foot length launcher rail. Original plans had called for a zero length launcher using a 105-mm howitzer carriage, mounted on an M44 truck chassis; however, early laboratory studies indicated that the zero length launcher would not be suitable because of high missile instablility at launch.

(U) The decision to use a helical rail type launcher posed major problems in both design and production. The use of rails, plus the need for spinning the missile during launch, ruled out the use of the howitzer carriage because of excessive elevating loads arising from the weight of the missile in motion. Anticipated missile reactions were of such magnitude as to require an exceptionally rugged launcher structure. When the launcher was elevated a rotating force in azimuth would be introduced and the helical rails would impart a rolling moment to the launcher. Forming of the rails into a helix accurate enough to keep friction forces to a minimum also presented a fabrication problem.

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41. (U) Ibid., pp. 181-82.

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(C) The LACROSSE mobile launcher subsequently developed was mounted on the chassis of a standard 2½-ton Army truck (Figure 16). The launcher rails can be elevated up to 790 mils and trained in azimuth to ± 213 mils by means of hydraulic actuators. Aiming of the launcher mechanism is achieved by using a standard howitzer sight. The 6½-foot guide rails have a 6° helical twist which imparts a spin to the missile, causing it to leave the launcher with a rolling velocity of about 480 degrees per second. A typical missile handling operation is depicted in Figure 17.[42]

(U) Support Equipment - Ground Control Station

(U) Group A. The forward guidance equipment, together with instruments and communications equipment, was installed in a 3/4-ton maintenance type vehicle. An M56, 3/4-ton, 4 x 4 truck chassis was furnished by the Government and the special body was built to Cornell specifications by a local subcontractor. Figure 18 shows the forward guidance side of the vehicle; the angle tracker and other auxiliary equipment were carried in the well of the vehicle.

(U) Group B. To achieve complete mobility of the Group B FGS, all the equipment necessary for successful operation of the station was mounted on a standard M38A1, 1/4-ton truck (jeep). Two main units were installed on the jeep: a shock mounted tray carrying the DME, computer, secondary power supply, target survey unit, and battery eliminators; and a tracker antenna and receiver mounted next to the driver in place of the passenger seat. The guidance station equipment was designed so that it could be removed from the jeep, hand-carried to a forward position, and set up for operation using a portable wire harness. Because of the bulk and weight of the tracker antenna-receiver assembly, the unit had to be man-packed in two separate loads. Figure 19 shows the Group B prototype ground station in the operation mode.[43]

(C) Group A and B Flight Test Programs (U)

(C) Group A Program (U)

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42. (U) Ibid., pp. 45, 182.

43. (U) Ibid., pp. 187-90.

FIGURE 16 LACROSSE MOBILE LAUNCHER (GROUP A)

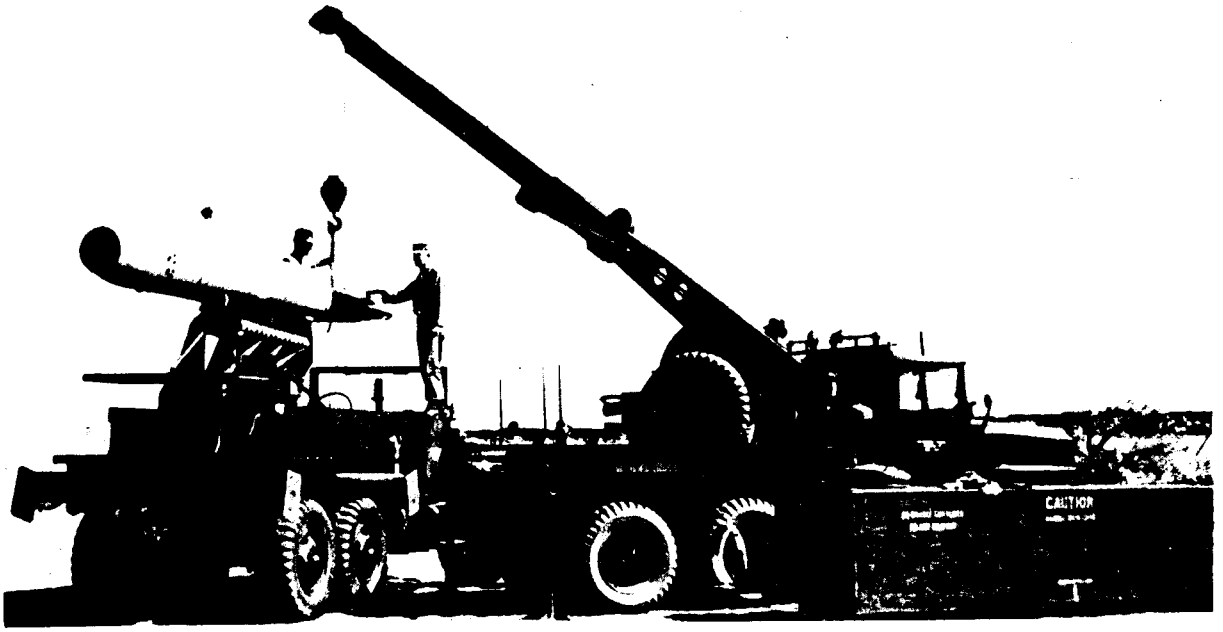

FIGURE 17 MISSILE HANDLING

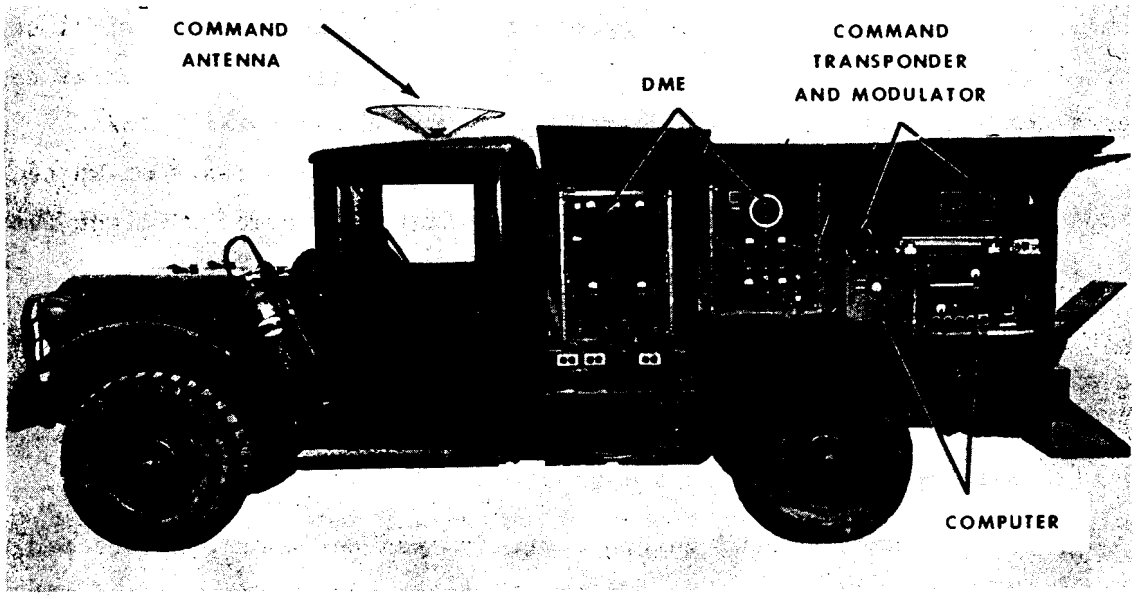

Figure 18. Forward Guidance Station - Group A

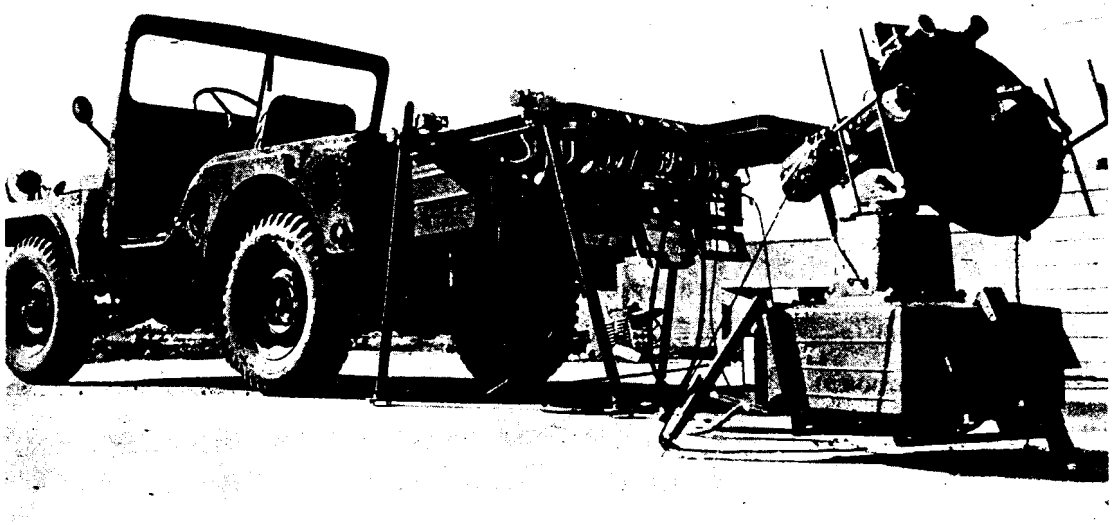

Figure 19. Forward Guidance Station - Group B

(U) Initial field testing of the LACROSSE Group A forward guidance station equipment began at Buffalo, New York, in September 1953 and continued until May 1954. This phase of the program consisted of closed-loop type airplane flights very similar to the pilot-monitored guidance tests conducted in late 1951, preceding the Group 0 program. The suitability of guidance equipment for use in full-scale tests at White Sands Missile Range was successfully demonstrated in some 30 flight tests using an AT-7 airplane to simulate the missile.[44]

(U) Meanwhile, Cornell completed preparations for full-scale testing of the LACROSSE missile system at White Sands Missile Range. The full field crew moved to the test site in June 1954 and the first Group A missile was launched two months later.

(U) The Group A ground guidance station was set on a concrete pad, with a 120-volt, 400-cycle, gas-driven portable power unit located about 25 feet away. The LACROSSE launcher was set up on the east pad near the Navy Blockhouse at White Sands. For S/N-1 and 2, the launcher was mounted on pedestals which were instrumented with strain gages to measure loads and deflections. These two tests indicated satisfactory launcher performance and subsequent missiles were launched with the truck wheels resting on the ground as would be the case during combat operations.[45]

(U) The immediate objective of the Group A program was to evaluate the combined performance of the complete LACROSSE system, including the XSSM-A-12 missile, the helical rail launcher, missile guidance during midcourse flight, and terminal guidance accuracy. A block diagram of LACROSSE terminal guidance is shown in Figure 20. Between 17 August 1954 and 13 December 1955, fifteen (15) missiles* were flight tested in this program, all of them using the T-52 rocket motor. The launcher-to-FGS range was 13,000 meters for all missiles except S/N-16 which had a

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* S/N's 1, 2, and 4 thru 16—S/N-3 was reserved for laboratory test.

44. (U) Ibid., pp. 190-92.

45. (U) Ibid., pp. 193-96.

LACROSSE TERMINAL GUIDANCE

BLOCK DIAGRAM

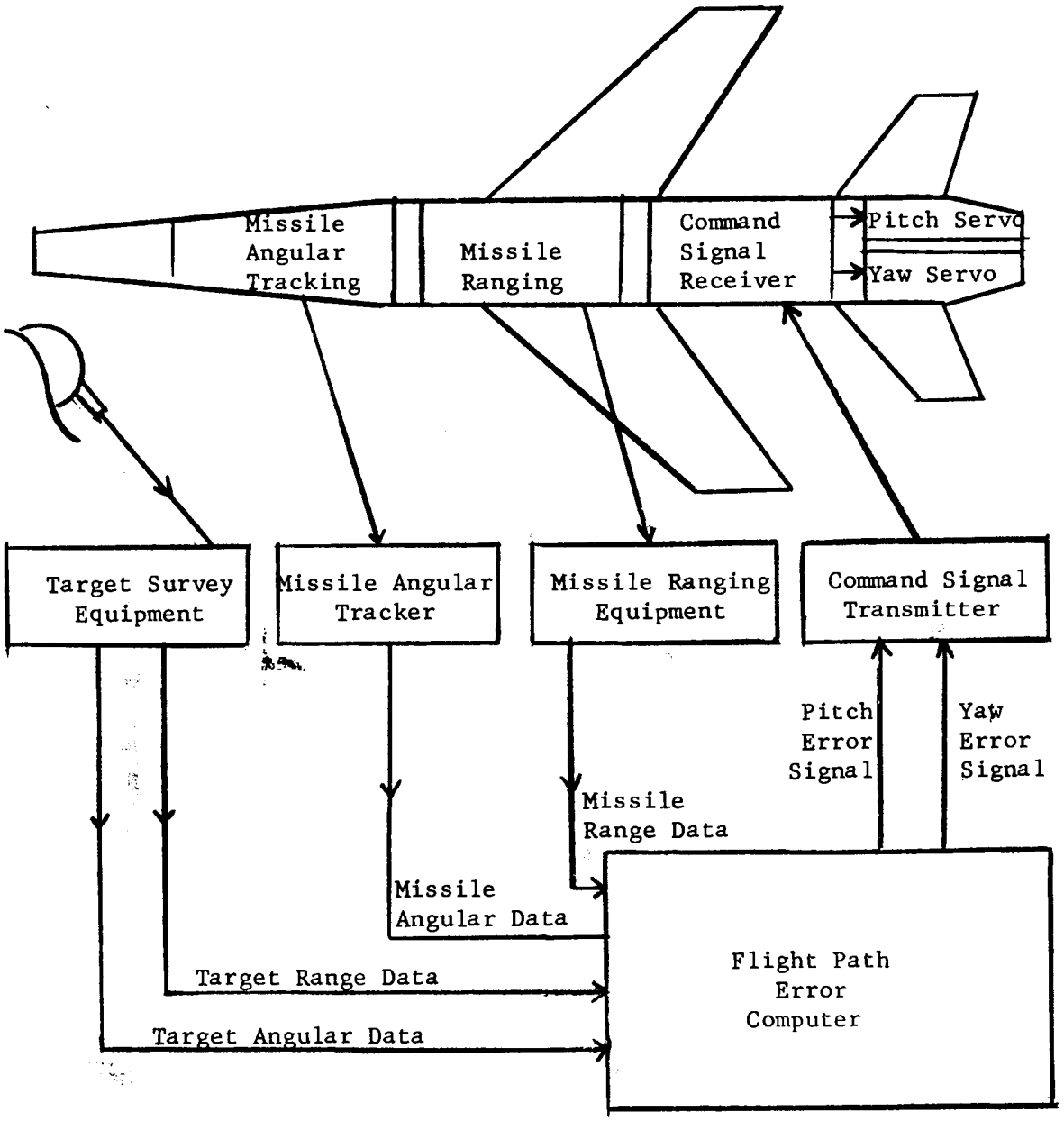

Figure 20

short range of 9,000 meters. The FGS-to-target range was 935 meters for S/N-1 and 2, and from 1,580 to 2,770 meters for all other rounds. Significant results of these tests are briefly described below.

(U) System Accuracy. An excellent demonstration of system accuracy was achieved in five of the tests, with actual miss distances of 2.0, 3.2, 4.3, 4.9, and 5.5 meters, respectively. The desired impact accuracy was not achieved in other flights because of various component malfunctions.[46]

(U) Warhead Performance. Of the 15 missiles fired during the Group A program, nine carried fuze elements and three of these (S/N-11, 14, 15) carried live warheads. The warhead arming sequence failed in only one (S/N-16) of the nine flights, faulty missile wiring preventing completion of the launch arming sequence in this case. In the first live-warhead test (S/N-11 on 19 Aug 55), ground guidance was lost during the last 16 seconds of flight and the failsafe features of the arming circuit prevented warhead detonation, as desired. The second missile carrying a live warhead (S/N-14, 10 Nov 55) completely destroyed its target, a log-earth bunker. S/N-15, fired on 29 November 1955, failed to achieve the desired impact accuracy, but warhead arming, detonation, and blast effects were satisfactory.[47]

(U) System Reliability. Malfunctions in the LACROSSE system were attributed to both failure resulting from the inadequacy of equipment used and gross failure of specific components. As the program progressed, the necessary repairs or modifications were made and the reliability index showed a generally upward trend. As previously noted, the equipment used in this program was of a research and development nature and was not designed or packaged for tactical use. The success of the program was, in large measure, credited to the efforts of skilled engineers who operated the equipment. In future equipment, the requirements for operator skills would have to be reduced and substantial

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46. (U) Sacher Rept BE-745-T-137, op. cit., pp. 2, 4, 26, & 101.

47. (U) Ibid., pp. 26, 34-37, 99, & 125.

improvements would have to be made in electronic design for a simpler, more reliable system.[48]

(U) Group B Program (U)

(U) The objective of the Group B program was to establish the accuracy of the pre-production tactical model ground station in guiding the missile to preselected targets. As the program progressed, the objectives were extended to investigate the minimum and maximum range capabilities of the system. A general description of both Group A and B equipments is presented above and will not be repeated here. Some of the equipment changes were aimed at making the system simpler and more reliable; others were concerned with extending the maximum guidance range to meet revised performance requirements (see Figure 21).

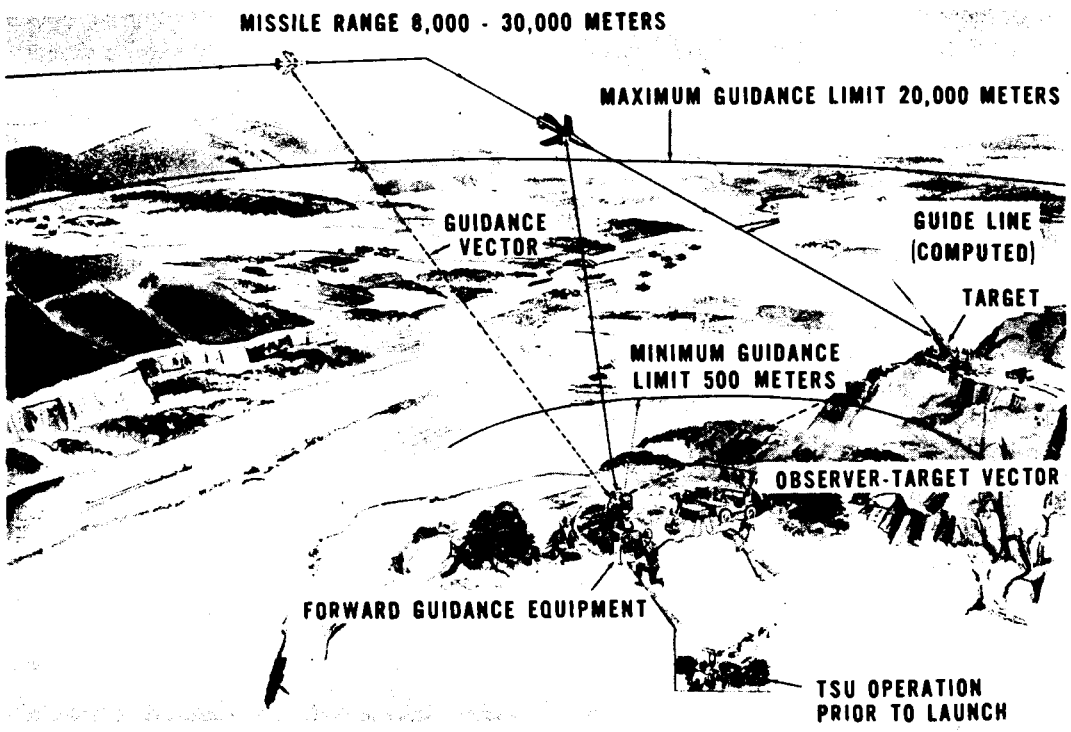

FIGURE 21 LIMITS OF OPERATION (MODIFIED)

(U) The redesign of equipment for tactical use involved three major changes in the over-all electronic system:

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48. (U) Ibid., pp. 127-31. For further details relating to the Group A flight test results, see Document 11.

1. (U) The total time required from launch to the initiation of terminal guidance was reduced to a minimum, since with late acquisition (X + 20 seconds) the missile down range distance at pitch down would be about 5,000 meters and minimum range shoots would not be possible. This was done by initiating roll stabilization and internal guidance six seconds earlier than in the Group A program.

2. (U) The method of pitch midcourse guidance was changed from a fixed beam generated by the ground-based guidance computer to an altimeter system within the missile. This resulted in a less complex system.

3. (U) The computer was modified to extend the maximum guidance range of the FGS from 10,000 meters to 20,000 meters to accommodate special warheads. This was done by reducing the computing scale factor by .4 and resulted in a like reduction in the gain of the system when operated in this mode.[49]

(U) Accuracy limits of the Group B system fell in two categories, depending upon the range of the target from the forward guidance equipment and the target surveying conditions. For targets within 5,000 meters of the FGS and which could be seen by the Target Survey Unit (TSU), the accuracy limits were: 5 meters CPE at 1,000 meters guidance range; and 10 meters CPE at 5,000 meters guidance range. For targets within 20,000 meters of the FGS and which could not be seen by the TSU, the accuracy limits were 5 to 30 meters CPE, depending largely upon the error in the coordinate system location of targets with respect to the guidance equipment.[50]

(U) The Group B flight test program began at White Sands on 29 March 1956 and ended with the sixth firing on 21 September 1956. An account of these tests is given below with primary emphasis on

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49. (U) Sacher, R., "Summary Analysis of Flight Tests of LACROSSE ... Group B Missiles," 28 Apr 59, CAL Rept BE-745-T-144, pp. 3-4, RSIC.

50. (U) Ibid., pp. 5-6.

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performance of the tactical ~~guidance equipment~~ and technical deficiencies yet to be corrected. A summary of each firing, together with major changes made in the equipment, is presented in Appendix Document 12.

~~(C)~~ All six of the Group B missiles* were launched from the LACROSSE mobile launcher, elevated to 790 mils. Propulsion was provided by T-52 rocket motors, all temperature conditioned prior to firing. The average missile height attained during the ballistic phase was 5,496 feet, the spread ranging from 5,145 feet for missile S/N-18 to 5,980 feet for S/N-22. Yaw dispersions at the time of initiation of internal guidance varied from 1,552 feet east to 600 west of the guide beam.[51]

~~(C)~~ Internal guidance performance of all six missiles was very satisfactory. Data gleaned from the tests showed that roll stabilization could be initiated as early as X +12 seconds without degrading the system, and that the time required for roll stabilization could be reduced to two seconds. While the yaw gyro control unit was apparently satisfactory in returning the missile to its launch heading, the short samples of yaw gyro guidance precluded any conclusions regarding the performance of this unit during a long period of missile flight.[52]

~~(C)~~ Terminal guidance performance of the Group B system was also considered very satisfactory. The effective use of the LACROSSE system at extended guidance range was successfully demonstrated; however, the over-all impact accuracy was not as good as expected. The required CPE varied from 4 meters to 16.2 meters. Of the six missiles fired, only two (S/N-18 and 20) impacted within the required CPE. A third missile (S/N-19) impacted slightly beyond the established tolerance largely because of an error in zeroing the missile DME transponder, which produced a discrepancy between indicated range and actual range.

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* (U) Serial numbers assigned in consecutive sequence beginning with S/N-17, the last Group A missile being S/N-16.

51. (U) Ibid., p. 51. A complete analysis of the effects of missile dispersion on system performance can be found in "System Dispersion Affecting Operation Performance of LACROSSE," by R. Mirsky, LCM-0210, 16 Aug 56.

52. (U) Ibid., pp. 61-62.

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(c) Missile S/N-21 had a relatively large impact error because of low command link gain and excessive climb angle at pitch down, resulting in a large oscillation about the terminal beam. Had this missile been fired at a normal launch-to-target range,* the impact error would have been greatly reduced.

(c) The excessive impact errors recorded for missiles S/N-17 and 22 were the result of guidance in the pitch plane only. In both cases, yaw command signals were generated in the computer but failed to reach the missile control surfaces. The failure of S/N-22 was attributed to a relay malfunction in the computer which prevented yaw signals from being transmitted to the missile. In the case of S/N-17—fired on 21 September 1956 in a LACROSSE demonstration for the Industrial College of the Armed Forces at APG—a malfunction of the missile transponder resulted in no yaw guidance. The exact nature of this failure could not be determined because the missile was never recovered.

(c) The following table shows the required CPE and the actual miss distance recorded for each of the six Group B flight tests:[53]

Missile S/N	Date Fired	FGS-to-Tgt Range (Meters)	Required CPE (Meters)	Actual Miss Distance (Meters)
19	3/29/56	927	4.0	5.6
18	4/5/56	927	4.0	2.6
20	5/24/56	6,662	9.8	9.3
21	6/29/56	3,691	6.8	37.7
22	7/8/56	13,229	16.2	2253.0
17	9/21/56	588	4.0	1670.0

(c) As a whole, the operation of the command guidance equipment was very satisfactory, though several problem areas still existed. The angle tracker-beacon performance was very good. All missiles were acquired within one cycle of frequency search. Although not proved by

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* (c) In this case the launcher-target range of 7,825 meters was slightly below the minimum requirement of 8,000 meters, with a medium FGS-to-target range of 3,691 meters. To achieve this range, the terminal dive angle was necessarily 45°. Ibid., p. 35.

53. (U) Ibid., pp. 29, 35, 76-77, 103.

the program itself, aircraft experiments with a drone type aircraft indicated that acquisitions at ranges up to 22,000 meters were possible. The accuracy of the angle tracker in terms of pointing error was well within specifications. No low angle problems were encountered during the extended guidance range flight.

(U) Performance of the DME I indicator was excellent; however, some marginal performance was noted in the DME/Command Link. Acquisition of the missile by the DME was successful in each of the missile flights. Time required for the DME to slew to the proper operating range was much less than that required for a complete acquisition by the angle tracker. The ranging accuracy of the DME was estimated to be about 2.5 meters. At times, the gain of the command link was marginal.

(U) While performance of the guidance computer as a whole was very satisfactory, the circuits controlling the insertion of integral control needed improvement. The relay failure noted in the flight of S/N-22 was a case in point. The ability of the guidance computer to operate at a scale factor of .8 millivolt/meter was successfully demonstrated.

(U) Again, the success of the program was partially attributed to the highly skilled engineers and technicians who operated the ground guidance equipment. Further effort would be required, not only to reduce the need for skilled operators, but also to eliminate existing technical deficiencies and achieve a greater equipment reliability.[54]

(U) Program Summary and Conclusions (U)

(U) Despite the marginal performance of some prototype components, the basic objectives of the Group A and B test programs were successfully achieved. An analysis of the over-all flight test results clearly indicated that the LACROSSE Weapon System was capable of delivering a warhead on a preselected target with the specified accuracy, and that the various components, individually and working together, were capable of behaving as intended. The program was therefore regarded as "highly

54. (U) Ibid., pp. 101-103.

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satisfactory."[55]

(U) LACROSSE I Prototype System Limitations (U)

(U) Strictly from a tactical viewpoint, the LACROSSE prototype weapon system had certain operational limitations and failed to meet the established MC's in a number of major areas. Some of these limitations stemmed from the physical nature of the equipment used, but most of them were the result of design compromise made either to provide the user with an early available system or to satisfy one criterion at the expense of another. The major areas in which the system did or did not meet the MC's are reflected in Table 1. In an effort to define the major shortcomings of the prototype system, Cornell made a study of existing deficiencies and recommended the system improvements outlined in Table 2.[56]

(U) The project had progressed from its inception along the lines of developing a system with a high degree of accuracy. By producing a design acceptable to development engineers for detailed refinement, it had seemed to Cornell that the performance goals could be attained. Because of the stringent accuracy specifications, it became necessary to trade simplicity for accuracy. Another limiting factor that made the problem difficult was that the terminal guidance equipment had to be reasonably simple, rugged, and light in weight. Also affecting the development effort, as originally planned, was the decision that R&D (Cornell) would not build any LACROSSE I missiles because of a reduction in R&D funds and the advantages to be realized from having industrial support early in the program.

(U) It would have been relatively easy for Cornell, along in 1953-54, to have initiated programs for development of more refined equipment, particularly as far as the guidance system was concerned. But this approach, while very nice outwardly, would not produce results

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55. (U) Ibid., p. 104; and Sacher Rept BE-745-T-137, op. cit., p. 131. Also see Sacher Rept BE-745-T-149, op. cit., pp. 207-208.

56. (U) Sacher Rept BE-745-T-149, op. cit., p. 60.

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TABLE I LACROSSE I SYSTEM APPRAISAL

THE TABLE BELOW REPRESENTS THE MAJOR AREAS IN WHICH THE LACROSSE I SYSTEM DOES OR DOES NOT MEET ITS MILITARY CHARACTERISTICS:

CHARACTERISTICS	EVALUATION
A. SYSTEM PERFORMANCE	1. MEETS MC'S FOR ACCURACY, TRANSPORTABILITY, SAFETY, AND SIMPLICITY. 2. DOES NOT MEET MC'S IN THE FOLLOWING: a) NO ECM IMMUNITY. b) RELIABILITY LESS THAN 81% FOR LAUNCHED MISSILES. c) LESS THAN MAXIMUM RANGE FOR AIR BURST. d) LIMITED TARGET LOCATION CAPABILITY. e) NO DEEP TARGET LOCATION CAPABILITY.* f) MINIMUM RANGE GREATER THAN DESIRED.* g) NO BALLISTIC VERSION.*
B. MISSILE	MEETS ALL MC'S EXCEPT RELIABILITY AND ECM REQUIREMENTS OF AIRBORNE GUIDANCE EQUIPMENT.
C. LAUNCH AND HANDLING	MEETS ALL CHARACTERISTICS EXCEPT RATE OF FIRE AND TIME SEQUENCE REQUIREMENTS.*
D. FORWARD GUIDANCE STATION	MEETS VERY FEW OF THE REQUIRED MC'S. DEFICIENT IN: a) ANTENNA COVERAGE OF GUIDANCE EQUIPMENT. b) RANGE AND WEIGHT OF SURVEY EQUIPMENT. c) RESISTANCE TO ECM. d) EQUIPMENTS HEAVIER THAN DESIRED INCLUDING TSU, PPU AND GROUND STATION VEHICLES. e) CANNOT HANDLE OFFSET OR UNOBSERVED MODES OF TARGET ENGAGEMENT AND MEET TIME SEQUENCE REQUIREMENTS.*
E. FIRE DIRECTION CENTER	GENERAL REQUIREMENTS ARE MET BUT TOOLS ARE DIFFICULT TO USE AND MISSION PROCESSING TIME IS MUCH GREATER THAN DESIRED.*
F. COMMUNICATIONS	STANDARD EQUIPMENT SEEMS TO BE ACCEPTABLE FOR LACROSSE APPLICATIONS, EXCEPT FOR ECM VULNERABILITY.
G. TEST AND MAINTAINENCE	EQUIPMENTS FOR 1ST AND 2ND ECHELON ONLY ARE ACCEPTABLE EXCEPT CERTAIN MISSILES PARTS ARE NOT INTERCHANGEABLE.
H. AUXILIARY EQUIPMENT	EQUIPMENT COVERS AND KITS APPEAR ACCEPTABLE, EXCEPT FOR FORDABILITY KIT.
I. ENVIRONMENTAL	GENERAL CONDITIONS OF WIND, HUMIDITY, PRESSURE, STORAGE, ETC., CAN BE TOLERATED. EXCEPTIONS INCLUDE: a) TSU CANNOT WITHSTAND MAXIMUM STORAGE TEMPERATURE. b) CERTAIN EQUIPMENTS MAY NOT WITHSTAND AMPHIBIOUS OPERATIONS. c) INTERFERENCES BOTH BY FRIENDLY AND ENEMY ELECTRONIC ACTIVITIES IS A STRONG POSSIBILITY. d) GUIDANCE RANGES ARE LIMITED BY HEAVY PRECIPITATION.

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TABLE 2 MISSILE IMPROVEMENT ITEMS

ITEM	DEFICIENCY	PROPOSED CHANGES	TIME SCALE
1. ALTIMETER CONTROL	a) ALTIMETER SENSITIVE TO YAW MANEUVERS, RESULTING IN EXCESSIVE PATH OSCILLATIONS. b) MANEUVERS IN TRANSITION FROM LAUNCH TO MIDCOURSE PHASE RESULTS IN REDUCED MAXIMUM RANGE CAPABILITIES.	RELOCATE PITOT TUBE (NOSE CONE) USE OF A CLAMP-TYPE ALTIMETER AND REOPTIMIZATION OF TIMER SETTINGS.	6 MONTHS 6 MONTHS
2. ELEVATOR BIAS	REQUIRES MEASUREMENT OF DYNAMIC PRESSURE AND SETTING AT THE LAUNCHER.	USE OF PRECESSIBLE GYRO CONTROL SYSTEM WOULD ELIMINATE NEED FOR ELEVATOR BIAS MEASUREMENT. MEMORY WOULD ALSO BE PROVIDED DURING TRACKING LOSSES CAUSED BY TERRAIN MASKING.	1 1/2 TO 2 YEARS
3. COMBINED MANEUVER CAPABILITY	INDUCED ROLL CAUSED BY COMBINED MANEUVERS AT LOW SPEEDS RESULTS IN LOSS OF ROLL CONTROL.	MODIFY MISSILE NOTCH NETWORKS TO VARY WITH DYNAMIC PRESSURE (Q), WHICH WOULD REDUCE ANGLE OF ATTACK OVERSHOOTS. MODIFY MOTOR TO INCLUDE SUSTAINER. THIS WOULD PREVENT MISSILE FROM REACHING THE LOW VELOCITY REGION.	6 MONTHS 2 1/2 YEARS
4. MOTOR	a) IMPULSE INSUFFICIENT FOR MAXIMUM RANGE REQUIREMENT. b) MINIMUM RANGE REQUIREMENT NOT MET.	MODIFY MOTOR (AS ABOVE) TO TWO STAGE TYPE. SAME MODIFICATION COULD ALLOW CONTROL FROM LAUNCH, MAY EVEN ELIMINATE LAUNCH ROLL REQUIREMENTS.	2 1/2 YEARS
5. GUIDANCE EQUIPMENT	a) PRESENT ANTENNAS WILL NOT ALLOW LOCATION OF FGS IN MANY AREAS. b) GUIDANCE EQUIPMENT VULNERABLE TO ECM, COSTLY, HIGH POWER REQUIREMENTS.	MODIFY ANTENNAS TO INCREASE COVERAGE. REPLACE ENTIRE GUIDANCE SYSTEM WITH A PASSIVE ONE OF THE LUNEBERG LENS TYPE.	9 MONTHS 3 YEARS
6. WARHEAD	LACKS NON-ATOMIC CAPABILITY AGAINST LIGHT ARMORED TYPE VEHICLES.	DEVELOP ANTI-MATERIEL WARHEAD.	2 YEARS

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and coincide with prescribed schedules. Thus, instead of deferring schedules, Cornell approached the problem with a hardheaded but very practical view: Use what was known to work and, with supplementary budgeting, institute parallel programs. Unfortunately, the planned parallel programs never materialized because of budget restrictions. As a result, the LACROSSE I system was developed—and later deployed—with serious operational limitations, the most important of which centered around the vulnerability of guidance equipment to enemy electronic countermeasures.[57]

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57. (U) LACROSSE Blue Book, op. cit., pp. 17, 24.
4 ~~(C)~~ To resolve the ECM problem, it was decided in early 1956 to develop the MOD I system using all-pulse ranging and tracking techniques in the Ka band region. This effort was started by FTL under subcontract to Martin, but was never completed. LACROSSE I equipment was issued to Army units in Jul 59; MOD I development was terminated by DA Staff decision in Aug 59.

IV. (U) DEVELOPMENT AND PRODUCTION OF THE FINAL TACTICAL SYSTEM (U)

(U) Introduction (U)

(U) The development of the LACROSSE experimental system (XSSM-A-12) into a complete combat-ready general support weapon system was the responsibility of the Martin Company, as prime contractor, with Cornell exercising a certain amount of supervision and control over redesign effort. It was in this phase of the program that an inordinate amount of duplication occurred, chiefly because of the delay in selection of the production contractor and the lack of adequate supervisory provisions in Martin's production engineering contract.[1]

(U) Like the experimental prototype model, the final tactical system evolved from a progressive series of investigations, design refinements, and R&D proof tests. Because of funding problems, Cornell's over-all program had been limited to research activity, and development of final tactical hardware was delayed. In April 1955, the Martin Company was brought in to refine the Group A prototype system in conjunction with Cornell. This was partially accomplished through the six Group B missiles that incorporated certain guidance system refinements. The initial industrial contract for production of the LACROSSE I system was signed in June 1955, and Martin's field crews were phased into the LACROSSE firing tests during the Group B program in 1956.

(U) There is neither time nor space to relate the full technical story of LACROSSE during this 1956-59 period. The files are filled with evidence of numerous component changes and redesigns, some of them not coordinated with or concurred in by Cornell, and some resulting in degradation of system performance capabilities and reliability. To make a long story short and to dispense with personality conflicts,*

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* (U) While there was, quite naturally, a certain amount of animosity and friction between elements of the two contractors, available evidence does not indicate that such conditions actually hindered the program and the subject therefore transcends the scope of this study.

1. (U) See discussion of Contract Philosophy, Chap II, pp. 21-27.

the technical portion of this chapter will be confined to a brief description of the various LACROSSE models, with primary emphasis on system performance in flight tests. Other parts of the narrative will be devoted to the development of, and significant changes in the LACROSSE industrial program and weapon system plan; the extent of Cornell control over system redesign effort; the procedure used in transfer of technical responsibility; and finally, the supplemental R&D effort carried on by Martin and Cornell to improve and/or extend system performance capabilities.

(U) The LACROSSE Industrial Program (U)

(U) Pros and Cons of the Telescoped Program

(U) In any telescoped program, where a complex missile system such as LACROSSE is placed in production before completion of the R&D phase, Army planners must consider the elements of risk involved and be prepared to pay the price, not only in dollars but also in initial quality of the product. The pitfalls normally encountered in such a venture are as numerous as they are expensive, and the end product can be—and very often is—more of a liability than an asset. As a general rule, considerable duplication of effort can be expected in such areas as engineering, component design, tooling, and documentation. Until the R&D design is completed and proved, spare parts requirements cannot be firmly established. Frequent design changes generate Engineering Change Orders (ECO) and result in spiraling hardware and contract administration costs. In programs where the co-contractor concept is applied, a further increase in duplicated efforts and over-all costs can be expected.

(U) One of the key advantages of the telescoped R&D-industrial program is that it provides preparedness insurance. Early industrial entry into a program not only accelerates development of a missile system, but also establishes a production facility and necessary manufacturing know-how that can be called upon to produce a military weapon when required. Hence, if there is adequate assurance that a proposed missile system can be developed into a tactically useful weapon and produced in quantity at reasonable unit cost, the basic Army policy is

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to "crash" the program regardless of the attendant disadvantages. The underlying philosophy in support of this policy can best be summed up in the words of Lieutenant General Carter B. Magruder:

> (U) In a period of great scientific progress such as the one in which we live, wars may well be won by major advances in equipment and weapons not equalled by the enemy. It is very difficult to keep any major advance entirely secret. Accordingly, advantages over the enemy are of relatively short duration and it is therefore essential to maintain progress by improving our equipment and weapons faster than he can improve his. Wars are not won by weapons on the drawing board or even weapons which have been fully developed but not produced in adequate quantity. It is therefore of critical importance that . . . measures [be determined and implemented] that will reduce the time required in the development of new items from conception to availability in quantity in the hands of troops.[2]

~~(C)~~ U Early Planning (U)

~~(C)~~ U The Redstone Arsenal Commander received the initial LACROSSE procurement plan from OCO in late April 1954, a few months after assuming responsibility for technical supervision of the project. At that time the plan was to effect two procurement actions in FY 1955; namely, the negotiation of a contract by 1 January 1955, covering an indoctrination program for the contractor chosen, and a second contract or supplemental agreement for pilot production using FY 1955 funds. By the end of July 1954, Redstone had completed plans for selecting the industrial contractor and a committee was appointed to carry out these plans in conjunction with Cornell Laboratory.[3]

~~(C)~~ U On 30 August 1954, the Chief of Ordnance advised the ACS/G-4 that the LACROSSE weapon system had progressed to the point where it was necessary to extend the program beyond the R&D phase. At the same time, FY 1955 funds were requested for the purpose of establishing an

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2. (U) Memo to Maj Gen J. H. Hinrichs, COFORD, from Lt Gen Carter B. Magruder, Dep Chief of Staff for Logistics, 14 Apr 58, subj "Ordnance Objectives."

3. (U) LACROSSE Blue Book, op. cit., p. 51.

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industrial contractor, obtaining at least pilot lot production, and converting developmental drawings to Ordnance production drawings. The Group A flight test program having started some two weeks before, it was anticipated that sufficient R&D drawings of the missile and ground equipment would be available in time for negotiation of the initial industrial contract by 1 April 1955. To allow sufficient procurement lead time and prevent any delay in the Engineer-User (E-U) test program, initial procurement in FY 1955 was essential. An examination of requirements to support the program after phase-out of R&D established the following as the very minimum for FY 1955 procurement:[4]

50 Missiles	$ 3,500,000
4 sets Ground Equipment	5,200,000
2 sets Maintenance Equipment for Ordnance Support Companies	1,400,000
Production Engineering, Drawings, Technical Reports, Production Engineering Tests, & Interim Manuals	3,000,000
	$ 13,100,000

In requesting authority to proceed with procurement of the above listed items, the Chief of Ordnance pointed out that the quantity of missiles had been reduced from the originally planned 200* to 50. This resulted in a higher unit cost, principally because the smaller quantity of missiles would have to absorb the cost of special tools, dies, fixtures, and gages. Also added to the original estimate was the $3 million for production engineering, drawings, reports, etc. The 50 missiles proposed for procurement in FY 1955 would be produced at the rate of 12 per month for use in the E-U tests. This quantity would be barely enough to support the program until delivery of the 150 missiles then planned for procurement in FY 1956.[5]

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* (U) Included in the Schedule of Commitments, Procurement & Production (P&P) Army Appropriation, 1 Jun 54.

4. (U) Ibid., pp. 41-42.

5. (U) Ibid., p. 43.

(S) One month later, on 30 September 1954, the ACS/G-4 returned the above request without action and asked that it be resubmitted with additional information. Specifically, he wanted a study comparing costs if the production rate for the first lot of 50 missiles were held to six per month versus the planned rate of 12; and an Ordnance proposal for accomplishing initial production at a rate of six per month, increasing to higher rates only after E-U test firings "establish beyond reasonable doubt that this system will attain the required Circular Probable Error."[6]

(S) With the requested additional information, sent to ACS/G-4 on 22 December 1954, OCO furnished a revised FY 1956 schedule, reducing the quantity of missiles to be procured in that year's budget from 150 to 42. Based on the planned missile firing schedule of six per month, it was believed that this lesser quantity would be sufficient to support the program until delivery of missiles planned for procurement with FY 1957 funds.[7]

(U) Meanwhile, the RSA-Cornell survey team visited the plants of four potential co-contractors in August and September 1954, and prepared individual scoring summaries with particular emphasis on the company's experience and ability to do the LACROSSE job. On the basis of this data and an evaluation of contractor proposals, the RSA Technical & Engineering Division selected the Glenn L. Martin Company as the new co-contractor for LACROSSE. Early in November 1954, the RSA Commander sent the final report to OCO with a formal recommendation for approval.[8]

(S) R&D Industrial Contracts (U)

(U) In January 1955, following a presentation by Ordnance representatives on the R&D-Industrial plans for LACROSSE, the Assistant

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6. (U) Ibid., pp. 43-44.

(S) The skepticism reflected here was no doubt engendered by the disappointing results of the first Group A flight test on 17 Aug 54: the missile went out of control and landed some 14 miles from its target.

7. (U) Ibid., p. 44.

8. (U) Sacher Rept BE-745-T-149, op. cit., p. 211.

Secretary of the Army (ASA) approved the Martin Company as the co-contractor and authorized the Chief of Ordnance to proceed with contract negotiations.[9] By the end of March 1955, Redstone Arsenal had received program directives authorizing FY 1955 funds in the amount of $13,193,750. Negotiations between the Philadelphia Ordnance District and the Martin Company resulted in the signing of three CPFF contracts* during the period 1 April to 1 June 1955.[10]

(U) Under Contract ORD-1892, signed on 1 April 1955, Martin agreed to provide those services, materials, and facilities necessary to perform the LACROSSE R&D work specified in RSA Technical Requirements Nr. 15, 13 August 1954, as revised, and in the Ordnance Corps Development Instructions for LACROSSE, revised 19 November 1954. The basic contract was for $699,982 and covered the period through 31 December 1955.**

(U) Contract ORD-2000 was signed on 31 May 1955 for $4,934,074,*** including $350,000 for the fixed fee (7.6351% of cost), $40,000 for facilities, and $4,544,074 for services and supplies. It called for a Phase II Production Engineering Study beginning in June 1955 and continuing through May 1957. The basic objectives of this contract were to have the contractor perform such redesign and production engineering

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* (U) These contracts have been mentioned briefly earlier in this study to tie in the over-lapping CAL-Martin effort during 1955-56 (see summary of Program Plans & Schedules, Chap III). They are described in more detail in succeeding paragraphs of this chapter.

** (U) As of 30 Jun 60, 53 supl agreements had been signed, increasing the total cont value to $27,488,000. Some of this money was allotted for studies and development effort to improve and/or extend LACROSSE capabilities. For example, $11 million went to the MOD I program which was started and terminated under this cont during 1956-59. Other such programs included the Airborne Control System (ABC) and the Helicopter Transportable System (HTS).

*** (U) As of 30 Jun 60, the total value of Cont ORD-2000 was $7,078,053, this including a fixed fee of $477,824 or 7.2395% of cost. Note the reduction of .3956% in contractor's over-all profit (from 7.6351% for basic cont to an over-all rate of 7.2395%).

9. (U) Incl to ARGMA Ltr, 15 Jul 60, op. cit.

10. (U) LACROSSE Blue Book, op. cit., p. 46.

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as necessary to develop essential economical techniques and processes applicable to producing in volume completely interchangeable components for the LACROSSE I system. In performing production redesign on the missile, Martin was required under the contract to maintain functional reliability of all components.

(U) The FY 1955 production contract, ORD-2013, was signed on 1 June 1955 for $8,058,587, including a fixed fee of $550,000 or 7.3255% of cost.* Delivery of end items listed below was to begin in August 1956 and extend through September 1957.[11]

(U)

50 LACROSSE I Prototype Missiles
25 Missile Containers (Reusable)
50 Warhead Compartments
70 Propulsion Units
4 Sets Ground Guidance, Launching, & Handling Equipment

Special Tools & Test Equipment:
2 Sets for Organizational Maint (1st & 2nd Echelon)
2 Sets for Field Maint (3rd & 4th Echelon)

Spare parts to support scheduled firing to 50 missiles and to maintain ground equipment for a period of one year.

Complete set of Ordnance drawings on all the above items excluding the missile.

Handbooks

(U) Coordination between the FY 1955 production contract (ORD-2013) and the Production Engineering Study (ORD-2000) is depicted in Figure 22. The extent of Cornell control over Martin's redesign effort will be discussed later in this chapter.

(U) Follow-On Production Orders and Schedules (U)

(U) The first official Weapon System Plan, published on 25 March 1955 (Figure 11), had been developed on the basis of the above FY 1955

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* (U) Subsequent PEMA obligations during period FY 1956-60 increased the total value of Cont ORD-2013 to $44,171,010, this including an actual hardware cost of $41,747,602 and a total fixed fee of $2,423,408 or 5.8049% of cost. Note reduction of 1.5206% in contractor's over-all profit rate (from 7.3255% for basic cont to an over-all figure of 5.8049%).

11. (U) Ibid., pp. 46-48, 82-83; and Incl to ARGMA Ltr, 15 Jul 60, op. cit.

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COORDINATION BETWEEN PRODUCTION ENGINEERING STUDY AND PRODUCTION CONTRACT FOR FY 55 PRODUCTION OF LACROSSE MISSILE

1955 1956 1957

A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O

CONTRACT DA-36-034-ORD-2000 (PRODUCTION ENGINEERING STUDY)

TASK 1	TASK 2	TASK 3	TASK 4	TASK 5
FEASIBILITY STUDY	PROPOSE REDESIGN. PREPARE TOOLING DRAWINGS. FABRICATE 2 MISSILES. RELEASE OF FIRST SET OF DRAWINGS.	CONTINUE REDESIGN. FABRICATE 3 MISSILES. RELEASE SECOND SET OF DRAWINGS.	CONTINUE REDESIGN. FABRICATE 1 MISSILE. RELEASE THIRD SET OF DRAWINGS.	RE-EVALUATE RELEASE STABILIZED DRAWINGS.

DA-36-034-ORD-2013
(PRODUCTION CONTRACT)

	A	S	O	N	D	J	F	M	A	M	J	J	A	S	
MISSILE SCHEDULE	1	1	1	2	2	3	4	5	5	5	6	6	6	3	FY 56 PRODUCTION
GRD. EQUIP. SCHEDULE	1	1	1	1											
TOTAL	LOT 1 10						LOT 2 19				LOT 3 21				

FIGURE 22

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industrial program. While follow-on production was planned at that time, neither the program objectives nor the funding level for FY 1956 had been firmly established.

(U) During FY 1956, the Army decided to continue the LACROSSE program, though firm objectives for tactical requirements were yet to be established. Based on plans to initiate training activities, and to provide equipment for other non-tactical efforts, Ordnance recommended the procurement of 42 more missiles, seven more sets of non-tactical ground equipment, and prototype Ordnance Maintenance Test Equipment. Industrial (PEMA) funds obligated for these and other miscellaneous items in FY 1956 totaled $19,344,000, of which about $17,220,000 went to the Martin Company.[12]

(U) As the result of a cut-back in FY 1957 procurement funds, the LACROSSE program lost momentum. Although R&D work was to continue, the level of FY 1957 procurement funds available and contemplated budget restrictions for FY 1958 and subsequent years made it necessary to reduce the over-all industrial effort. Only a minimum of engineering effort was to be performed sufficient to complete LACROSSE as an on-the-shelf item. An additional 108 prototype missiles were to be procured with FY 1957 funds making a total of 200* missiles for completion of all tests. Industrial funds authorized and obligated in FY 1957 totaled $10.977 million, in contrast to $19.344 million in the preceding year. About $8.567 million of the FY 1957 obligation went to the Martin Company.

(U) The expected funding shortage for FY 1958 prevented the establishment of firm tactical objectives; however, preliminary planning early in FY 1957 called for 16 full Army battalions ultimately, the first four of which would be activated at reduced strength with the LACROSSE I and later converted to the improved MOD I system.

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* (U) The 50 from FY 55; 42 from FY 56; and 108 with the FY 57 program. These missiles and the 11 sets of ground equipment (from FY 55/56 programs) were considered to be non-tactical equipment.

12. (U) Incl to ARGMA Ltr, Ibid.

Following release of the FY 1957 program to the field in January 1957, the budgetary outlook appeared brighter for FY 1958 and the Army decided to go ahead with firm plans for a tactical LACROSSE. Accordingly, Redstone Arsenal published a revised Weapon System Plan in June 1957, this one superseding the original plan of 25 March 1955. The new plan reflected current program planning for both the LACROSSE I and MOD I, the latter appearing on the schedule for the first time. To place subsequent developments in proper perspective, the key target dates established in this plan (Figure 23) are briefly described below.

(S) Perhaps the most outstanding feature of the LACROSSE I schedule was a slippage of six months in the Ordnance Readiness Date* from July 1958 to December 1958. Delivery of non-tactical production prototypes was to be completed in September 1958 (instead of September 1957), followed by the first tactical deliveries in October 1958. With estimated completion dates for documentation and training extended accordingly, the earliest ORD for the system would be December 1958, the difference of two months being allowed for administrative and preparation time. Tactical equipment deliveries would include 279 missiles and four reduced-strength battalion sets, all planned for procurement with the FY 1958 program.

(S) The over-all Ordnance Readiness Date established for the MOD I system was January 1960. Non-tactical deliveries (204 missiles/19 sets ground equipment) were to begin in April 1958 and continue through March 1960. Tactical deliveries (765 missiles/16 sets ground equipment) were planned to begin in October 1959 to fulfill the 16-battalion Army objective. Beginning in early 1961, LACROSSE I equipment in the field

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* (U) The Ordnance Readiness Date (ORD) is defined as the date by which the Army plans to furnish the first acceptable complete weapon system to the field, and to have all initial capabilities (e.g., trained manpower, technical publications, repair parts, equipment, and facilities) needed for sustained supply, maintenance, and other Ordnance support consistent with the plan or program for that weapon system. It is here that the key disadvantages of a telescoped program began to show up.

would be converted to MOD I by use of retrofit or adaption kits. The initial MOD I buy was to be made with FY 1958 funds and would provide the equipment for test, training, and other non-tactical requirements.

(U) Although the next official revision of the weapon system plan was not approved and published until June 1958, there was abundant evidence of a production effort stretch-out the minute the FY 1958 program hit the field in November 1957. Based on the level of effort provided in this program and the required production lead time of 15 months, the earliest that LACROSSE I tactical equipment could be delivered was February 1959. This, coupled with a corresponding stretch-out in deliveries of non-tactical equipment from the FY 1957 buy, led to an extension of the Ordnance Readiness Date to April 1959. The same effect carried over into the MOD I program, but the over-all slippage was much greater because of technical problems and delays. As a consequence, the MOD I readiness date was changed from January 1960 to October 1960, and it was necessary to defer the first MOD I procurement to the FY 1959 program.

(U) Following this delay in availability of MOD I, and to provide a capability in FY 1960, the Army objective for LACROSSE I was revised from four to eight reduced-strength battalions with a corresponding increase in tactical missiles. These additional items of LACROSSE I equipment were to be procured with the FY 1959 program.

(U) But the funding situation in FY 1959 showed little improvement. Funding guidance was not released to the field until the year was half gone and the funds provided were $10 million short of total program requirements. To procure the additional LACROSSE I items and the first non-tactical MOD I equipment, as mentioned above, a total of $65.0 million was needed in the FY 1959 program. Only $55.0 million was made available.

(U) Meanwhile, the LACROSSE I service tests were suspended in November 1958 because of system deficiencies. Production of LACROSSE I items were immediately suspended and a series of special tests (known as Operation "Pickle Barrel") was conducted to determine corrections

LACROSSE
WEAPON SYSTEM PLAN

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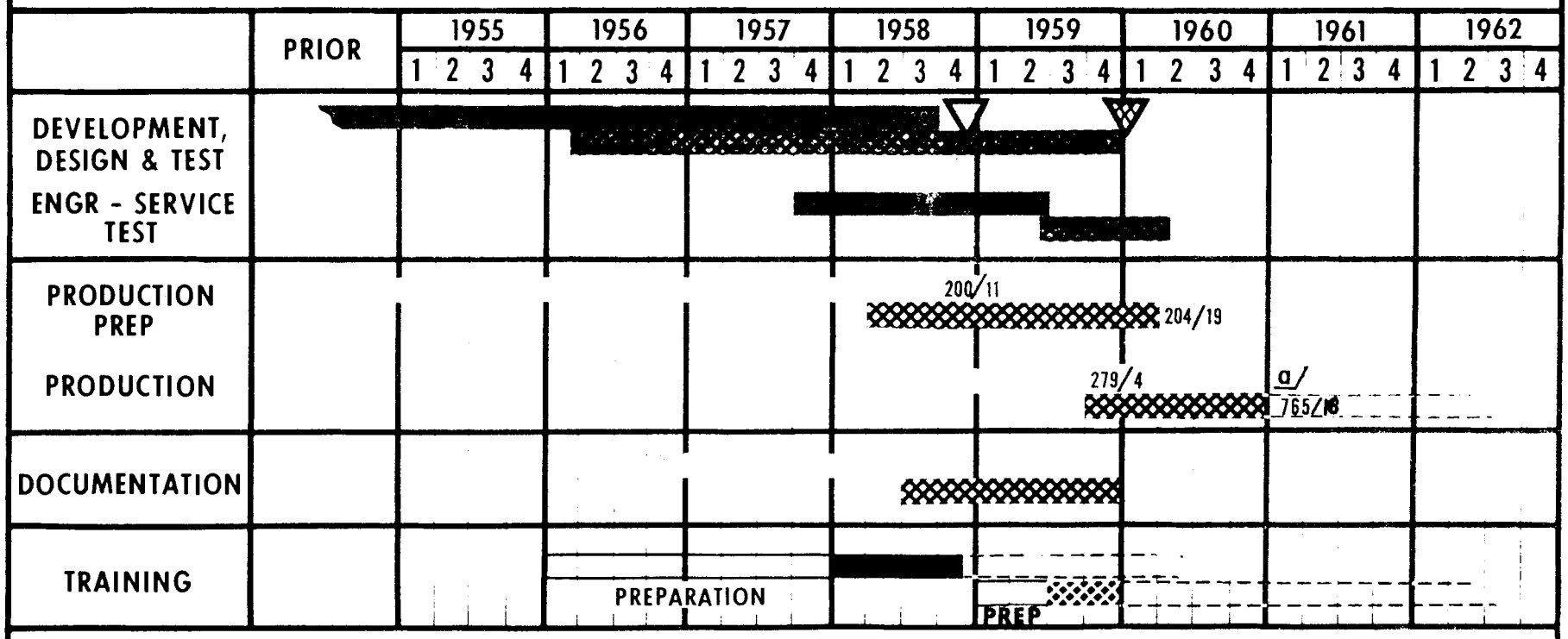
ARGMA

CALENDER YEARS

DATE 14 June 57



ORD

R & D

PROD

SUP

TRNG

LAX I

MOD I

a/ Conversion of Lax I to Mod I

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Figure 23

and fixes required. Appropriate fixes were established in January 1959 and production was resumed. This delay dictated yet another change in the readiness date, this time to July 1959, where it remained for the balance of the program.

(U) Because of the funding shortage and program delay mentioned above, and the funding levels expected for follow-on years, a hold order was placed on procurement of MOD I items. At the same time, the Army reduced its tactical objectives from 16 to 12 battalions. The LACROSSE weapon system plan as revised in January 1959 (Figure 24) reflected the new readiness date of July 1959 for LACROSSE I and extended the readiness date for MOD I from October 1960 to July 1961. Also, the first non-tactical delivery of MOD I items was reduced (it is shown on the chart as it would have proceeded with the FY 1959 program prior to the hold order).

(U) Early in 1959, the Army conducted a complete review of the LACROSSE program. A study compared the costs of providing 12 LACROSSE battalions from the going LACROSSE I program, to continuing the MOD I to an ultimate objective of 12 battalions. This study showed that 12 MOD I battalions would cost over $100 million more than 12 LACROSSE I battalions.

(U) With the Army already short of funds to carry on other projects, the figure of $100 million was definitely out of the question. The Army subsequently recommended termination of further effort on the MOD I; the Chief of Staff concurred in August 1959. Cancellation of the MOD I program left the LACROSSE I without the one crutch which could have made it a completely reliable, field-worthy weapon. For this reason, the U. S. Marine Corps announced its immediate withdrawal from the program.[13]

(U) As Brigadier General H. C. Tschirgi, USMC, ACS/G-4, later told the Subcommittee on Department of Defense Appropriations:

> (U) It takes a very simple device to interfere with the control of the LACROSSE. LACROSSE, as you know, is

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13. (U) Incl to ARGMA Ltr, 15 Jul 60, op. cit.

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controlled by a forward station and it must have the radio signals going back to it. If any radio transmitter gets on the same frequency, the missile is lost.

(U) If you put a nuclear warhead on one of these things, it is going to be a little bit unfortunate if somebody guided it to the wrong place, or if it got to the wrong place without any guidance. It is a $70,000 missile and it can be interfered with by another local station.[14]

(C) The Production Prototype System—Tasks II & III (U)

(C) Extent of Cornell Control Over System (U)

(C) Under terms of the R&D contract (ORD-1892) between Redstone Arsenal and the Martin Company, prime responsibility for technical development of the LACROSSE system resided with Cornell, and the effort was therefore directed by technical work authorizations originated by Cornell.[15] The production engineering contract (ORD-2000) between RSA and Martin did not provide for this element of control by Cornell; however, in performing redesign on the missile, Martin was required under the contract to maintain functional reliability of all components.[16]

(C) Pursuant to its delegated R&D responsibility, Cornell gave Martin a subcontract for LACROSSE I planning early in February 1955. This contract called for over-all program planning and liaison in cooperation with the laboratory; initiation of preliminary design of LACROSSE I missile and launching system; and preparation for fabrication of Group B missiles, including commitments for procurement of critical items, as required.[17] The Group B missile program was also covered in Martin's production engineering contract with Redstone, but with no provision for control by Cornell.[18]

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14. (U) Hearings Before the Subcommittee of the Committee on Appropriations, House of Representatives, Eighty-Sixth Congress, Second Session, 25 Feb 60.

15. (U) Sacher Rept BE-745-T-149, op. cit., p. 212.

16. (U) LACROSSE Blue Book, op. cit., p. 48

17. (U) Sacher Rept BE-745-T-149, op. cit., p. 212.

18. (U) LACROSSE Blue Book, op. cit., p. 47.

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LACROSSE WEAPONS SYSTEM PLAN

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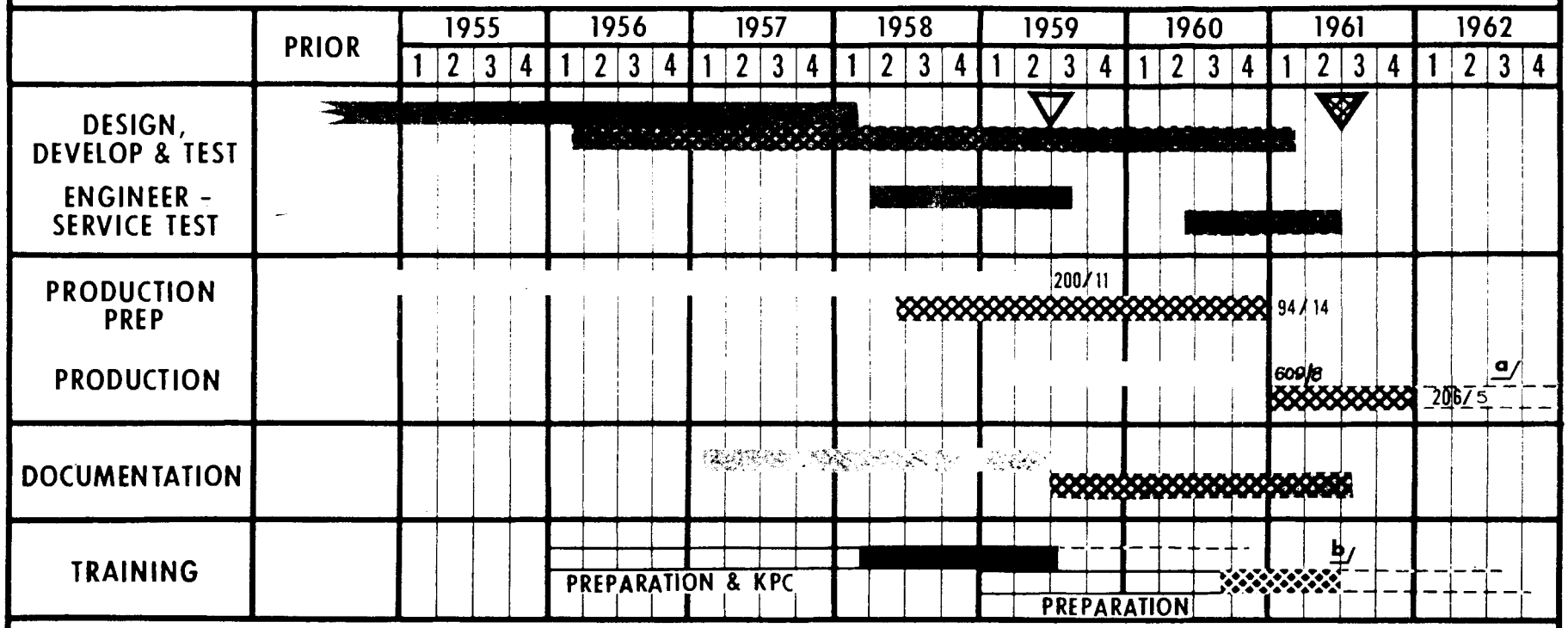
ARGMA

CALENDAR YEARS

DATE 16 January 1959



ORD R & D PROD SUP TNG

LAX I

MOD I

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a. Retrofit LAX I & follow on production

b. 1st MOD I Ordnance Unit

[redacted]

Figure 24

(U) The Cornell Laboratory was primarily a research activity and had no capability for mass production; however, it did have a limited capacity for product design and fabrication as required to formalize designs or conduct critical experiments to demonstrate the feasibility of a system. Once the feasibility of the LACROSSE system had been demonstrated, further development of the system was to be accomplished by the Martin Company.

(U) In establishing the accuracy to which the LACROSSE missile could be guided, Cornell had to produce well developed items of special equipment and conduct rather extensive field tests. Therefore, it was deeply involved in the detail design of equipment and had a somewhat more extensive background in LACROSSE than might be considered normal for a research laboratory. For this reason, a primary objective of the LACROSSE activity at Cornell during the 1956-58 period was the complete and efficient transfer of technical material to the Martin Company. As a part of this transfer, it was essential to assure that full use was made of such material and that Martin could efficiently carry on the development. Further, it was important that the Martin Company "be able to recognize and solve LACROSSE system problems using the past experience of Cornell . . . and their acquired LACROSSE background."[19] When this had been accomplished, technical responsibility for the LACROSSE project was transferred from Cornell to Martin in a phased, item-by-item manner as described later in this study.

(U) Extent of Cornell Design (U)

(U) Aerodynamically, the LACROSSE I missile remained unchanged from its Group A design. Structurally, the detail design changed drastically to accommodate production techniques. The system changes dictated by the LACROSSE I concept were recognized by Cornell and carried through to the breadboard stage prior to transfer of missile responsibility to the production contractor.

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19. (U) Sacher Rept BE-745-T-149, op. cit., pp. 212-13.

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(C) The tactical version of the guidance equipment, developed by FTL while under subcontract to Cornell, was successfully tested during the Group B program. These tests showed that no major redesign was required for LACROSSE I, though further development effort was necessary to improve system operation in the presence of electronic countermeasures.

(C) The LACROSSE launcher developed by Cornell for the Group A and B programs was not a production item. The crane rails were rolled to shape by Bethlehem Steel Company and were supported by a web configuration. For production purposes, Martin found it preferable to cast the rails and rail supports as a single section.

(C) The missile shipping container developed under a Cornell subcontract had a fiberglass impregnated outer shell with a pressurized aluminum inner shell. This container met all specifications; however, to reduce cost, Martin chose to develop a steel container.

(C) Except for the FGS vehicle, the prime responsibility for development of support equipment was assigned to Martin. Cornell activity in this area was limited to reviewing Martin's plans to determine compliance with the basic LACROSSE concept.[20]

(C) Martin's R&D Test Program (U)

(C) Following production of the Group B missiles, Martin started a series of design refinement and production tasks (Figure 22) leading to the ultimate tactical design. The first task was a feasibility study of materials, methods, and processes of manufacture, and did not include actual hardware production. From results of the Task I study, eight Task II first production prototype missiles were developed and flight tested with an engineering goal of 60% of the ultimate missile design. Task III, in turn, was a refinement of the Task II design and included 21 second production prototype missiles. (Task IV effort embraced further design refinement and production of final tactical missiles used in the composite Flight Test Program.) The LACROSSE missile and

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20. (U) Ibid., pp. 209-210.

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airborne guidance development program included a parallel effort on the ground guidance station. Missile ground guidance components were developed in lots concurrently with the missile.[21]

(U) Cornell's participation in the Task II and III flight test program consisted of evaluating test data and discussing results with Martin personnel at system analysis conferences. To assist Martin, a Cornell representative remained at White Sands during the program. Except for lightweight launcher tests, Cornell's participation in LACROSSE I flight test at White Sands was terminated with the transfer of engineering responsibility for the Task IV program in March 1958.[22]

(U) Task II Program (U)

(U) Flight testing of the eight Task II production prototype missiles began at White Sands in January 1957 and continued through 13 June 1957. The FGS used in these tests was the Group B equipment developed by FTL under subcontract to Cornell. All eight of the Task II missiles used the XM-10 rocket motor developed by the Thiokol Chemical Corporation under contract with Redstone Arsenal.

(U) The primary objective of these tests was to demonstrate the over-all accuracy and performance of the LACROSSE I missile. Four of the missiles impacted within the required accuracy, and one other was considered successful but impacted outside the required CPE (8.7 meters low in pitch and 14.3 meters to the left in yaw of the target). Hydraulic system failure downed one of the missiles several thousand meters short of the target. The remaining two missile flights were also marred by component malfunction, one having a yaw error of 54.6 meters and the other a pitch error of 4,448 meters.[23]

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21. (U) "LACROSSE System Description," by Martin Co., Jan 61, p. 5, RSIC.

22. (U) Sacher Rept BE-745-T-149, op. cit., p. 218.

23. (U) Martin Rept OR 6-1, LACROSSE Semiannual Rept for period ending 30 Jun 57, 17 Oct 57, p. v; and Szabo, W. J., "Quarterly Progress Report ... April-June 1957," CAL Rept BE-745-T-26, 15 Jul 57, p. 38, RSIC. See table of Task II firings, Document 13.

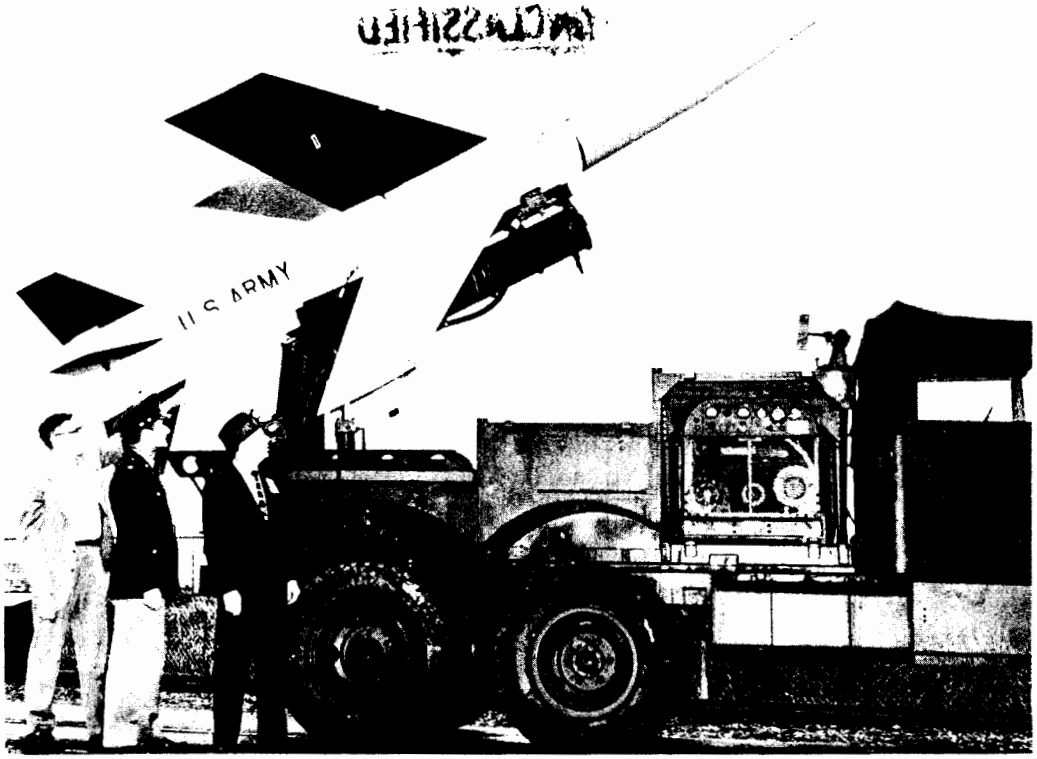

Figure 25. LACROSSE MISSILE UNVEILED AT REDSTONE ARSENAL—The above photo of the Lacrosse missile was the first released by the Army in February 1957. Shown alongside the missile are three Redstone men who played leading roles in its development: (left to right) Norman Bucholz, Lt Col Bruce Pierce, and Johnnie Lynch. (Redstone Rocket, 5 Feb 57)

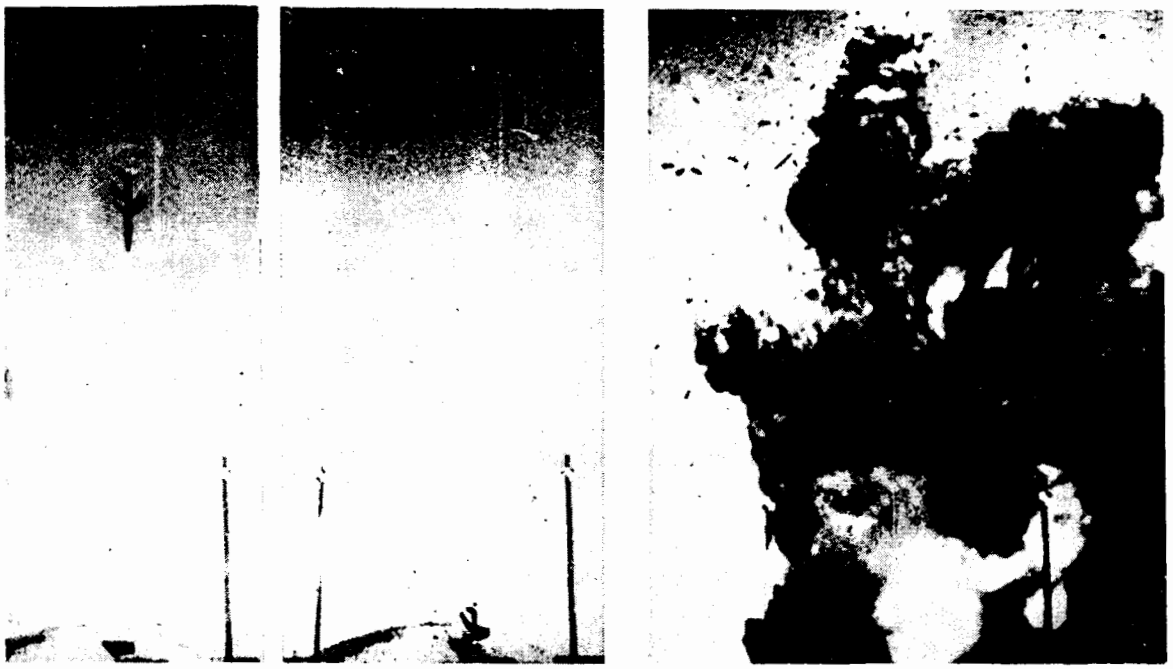

Figure 26. These photographs show a pinpoint hit and destruction of target bunker by a LACROSSE missile. (Aviation Week, 4 Feb 57, p. 31)

(U) Task III Program (U)

(U) Within a week after the last Task II firing, Martin had completed delivery of the 21 Task III (second production prototype) missiles and was ready to begin flight tests on 20 June 1957. The FGS used was the LACROSSE I, Lot I equipment developed by FTL under subcontract to Martin. Two of the 21 rounds were reserved for special firings; three were used in unguided missile flight tests to evaluate the lightweight launcher; and the remaining 16 were used in Martin's R&D evaluation program.

(U) Of the 16 R&D evaluation firings, five or about 31% impacted within the required CPE. One other flight was considered successful but outside the CPE (yaw error 13.1 meters; pitch error 5.8 meters). The remaining 10 flight tests were marred by malfunctions in the guidance and control system. All of these firings were completed by 19 March 1958.

(U) The three unguided flight tests were conducted by Cornell to evaluate the lightweight launcher being developed for the Helicopter Transportable System. Test objectives of the first firing, on 13 December 1957, were not achieved because of a malfunction in the stabilizer element. The second test, on 21 February 1958, was completely successful. In the third test, on 8 May 1958, an oscillograph failure caused the loss of test records; however, the launcher and its redesigned stabilizer appeared to function properly.[24]

(U) Transfer of Technical Responsibility (U)

(U) At the end of the Task III program, the transfer of technical responsibility from Cornell to Martin had been essentially completed.

(U) The transfer of responsibility was effected in an orderly and progressive series of discrete steps. When a particular area of technical activity was sufficiently defined, with its scope and schedule

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24. (U) Spangler, G., "LACROSSE Semiannual Progress Report, January-June 1958," CAL Rept BE-745-T-29, 15 Jul 58, pp. 33, 70-72, RSIC; and Sacher Rept BE-745-T-149, op. cit., p. 218. See table of test results, Document 14.

established, a target date for the transfer was set. The transfer process for each item included a detail check-off list covering objectives and standards of performance for concurrence of both contractors. The target dates established in the original list represented the latest time at which transfer should be effected. It was Cornell's desire to complete the transfer as early as possible and to reach a reasonable degree of technical agreement on each item two or three months in advance of the appointed date. Responsibility for a specific LACROSSE system was transferred with full concurrence of Redstone Arsenal when each technical area of the system had been transferred to and accepted by the Martin Company, and when the Martin Company had demonstrated an adequate R&D ability to insure the continued development and product engineering of that system to the full satisfaction of RSA Project Engineers.

(U) The transfer of technical responsibility for any item of the system or for a complete system indicated to Redstone Arsenal that the R&D effort on that item or system was progressing satisfactorily and that further detailed monitoring by Cornell was unwarranted. It did not mean, however, that the R&D was necessarily complete, nor that the item or system was ready for "production release" by the RSA R&D Division.

(U) Once an item or system had been transferred, Cornell no longer maintained close liaison with Martin. However, in accordance with its responsibilities to Redstone, Cornell did continue to monitor the entire program until transfer of complete responsibility had been effected and asked to be kept advised of all design changes affecting the performance characteristics, schedules, scope, or tactical utility of the LACROSSE system.[25]

~~(C)~~ 4 Supplemental Development Effort (U)

~~(C)~~ 4 With the transfer of technical responsibility for the LACROSSE weapon system to the Martin Company, Cornell's effort was reoriented

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25. (U) Sacher Rept BE-745-T-149, Ibid., pp. 219-21.

toward R&D on items which would improve and/or extend system capabilities. Late in 1957, Redstone gave Cornell a separate contract (DA-30-115-ORD-908) for this supplemental work, some of which had been started under the basic R&D contract (ORD-47). The basic contract was later terminated and the unfinished projects transferred to the new R&D contract.[26]

(U) Most of the supplemental development effort was concerned with the extension of system performance capabilities to meet the revised MC's for a close and general support weapon system. The two items of prime importance here were the Helicopter Transportable System and the Airborne Control System, both developed by Cornell in coordination with the Martin Company. Equally important, if not more so, was development of the LACROSSE MOD I with the objective of improving system performance in the presence of electronic countermeasures (ECM). The latter effort was conducted by FTL under subcontract to Martin, Cornell's responsibility being limited to feasibility studies and technical monitoring and advice on design development. While the total LACROSSE program embraced numerous other special studies and developments, time will only permit a very brief coverage of the three just mentioned.

(U) LACROSSE MOD I (U)

(U) The LACROSSE MOD I was selected for development early in 1956 to provide the LACROSSE system with an electronic counter countermeasure (ECCM) capability. The requirement for incorporation of "anti-jam devices" in the guidance system had been established in the very first

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26. (U) Ibid., p. 228.
(U) Effort under ORD-47 was extended thru 30 Sep 59 by Mod 33 dated 5 Aug 59, at which time the cumulative contract value was $20.958 million. After final settlement had been made and the contract closed out, the net value (including Mods 1 thru 33) was $20,278,082.
(U) As of 1 Jul 62, delivery under Cont ORD-908 had been completed but final settlement was yet to be made. At that time the contract value (including Mods 1 thru 22) was $6,231,518. Ref: List of Active and Closed Out Contracts, 1 Jul 62, published by the AOMC Industrial Directorate.

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set of tentative MC's issued by the Marine Corps in 1947;* however, in the early stages of development the state of the art was not sufficiently advanced to provide this capability and still meet the stringent accuracy specifications.

~~(C)~~ U In connection with the ECM problem, Cornell considered the possibility of using all-pulse radar techniques for ranging and tracking as early as 1953, but the state of technology at that time indicated that the specified accuracy requirements could only be met by use of CW ranging. The use of all-pulse techniques for ranging and tracking was again considered in the first half of CY 1955, during the early part of the Group A test program. At that time, it was decided that the change from CW ranging to radar ranging would result in one to two years' delay in providing an operational weapon. Consequently, Cornell continued development of the LACROSSE I system using CW ranging and formulated plans for a parallel system improvement program. These plans called for a study of the guidance system with the objective of making it an all-pulse system in the K_a band region. As an alternate approach to the ECM problem, the proposed parallel study program would consider the incorporation of noise correlation techniques into the guidance equipment.[27]

~~(C)~~ U A review of the LACROSSE R&D program as of 30 June 1955 indicated that the contemplated FY 1956 budget would permit only preliminary feasibility studies at the very best, and that programs for system improvement would have to be phased into the project with supplementary FY 1956 and subsequent year funding. The evaluation summary went on to say: "If any system modifications come about, it is not foreseen . . . that these changes will be incorporated into the equipments issued to the initial user units. CY 59 should see some equipments which have been modified to some extent."[28]

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* (U) See Document 1.

27. (U) Ibid., p. 213; and LACROSSE Blue Book, op. cit., p. 24.

28. (U) Blue Book, Ibid., p. 37.

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(U) In late 1955, Cornell, Martin, and the Federal Telecommunications Laboratory conducted feasibility studies of advanced guidance systems using the proposed all-pulse K_a band and correlation techniques. These studies, completed in February 1956, indicated that the all-pulse K_a band system—designated the MOD I—offered the greatest ECCM capability with the least delay in engineering and production.[29]

(U) The Federal Telecommunications Laboratory began development of the MOD I system under subcontract to the Martin Company in March 1956. The practical application of the MOD I concept involved, among other things, a complete redesign of the missile center section and an extensive redesign of forward guidance station equipment. In March 1958, FTL delivered the first design of MOD I components (called the Series 100 equipment). Martin conducted closed-loop and ground-to-air tests on the equipment through termination of the program in August. By this time, the Martin Company had completed one set of refined MOD I (Series 200) equipment.[30] R&D funds spent on MOD I development through FY 1959 totaled $11.403 million.[31]

(U) Airborne Control System (ABC) (U)

(U) The initial concept for a close support weapon of the LACROSSE type called for control of the missile by an observer in observation type aircraft. Targets for the LACROSSE weapons system were generally limited to those which could be observed or surveyed from friendly territory. However, artillery experience demonstrated that many targets not visible from the ground could be spotted from the air. Therefore, to insure the utility of the LACROSSE system, DA Staff directed the Chief of Ordnance to investigate possible methods of missile airborne control for close support of land forces. Cornell began a formal study of the over-all problem in January 1956.

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29. (U) Ibid., Supplement 1, pp. 8-9.

30. (U) Incl to ARGMA Ltr, 15 Jul 60, op. cit.; and AOMC "Briefing Notes for Mr. Holaday - 6-7 October 1958."

31. (U) Incl to ARGMA Ltr, Ibid.

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(U) Based on the results of this study, Cornell concluded that a line-of-sight guidance mode was immediately feasible, and that an inertial navigation system might prove feasible with further development. In October 1956, DA Staff approved a two-phase program, the first phase to include development of the line-of-sight airborne guidance system, and Phase II the inertial navigation system.

(U) In Phase I Cornell placed primary emphasis on providing the Army with an early ABC system capability (for demonstration in 1959) with high utility under most battle field situations. This effort continued throughout FY 1957, somewhat hampered by lack of funds. Then, in the middle of FY 1958, Cornell received authority to develop a complete prototype system of the Phase I type. By the end of October 1958, this effort had been completed and one missile (out of eight originally scheduled) successfully flight tested at White Sands. At this point, word came from Washington that no FY 1959 funds would be available for the ABC program. Although the program remained in a stand-by state throughout FY 1959, funds were provided for flight test of two additional missiles at the request of the Signal Corps.

(U) The ABC program was terminated for lack of funds in October 1959. At this time, the Phase II effort had progressed to the point where major subsystems were well defined and subcontractors selected. R&D funds obligated under the ABC program from FY 1956 through FY 1959 totaled $5.644 million.[32]

(U) Helicopter Transportable System (U)

(U) Early in 1956, the Marine Corps established a firm requirement for a Helicopter Transportable System (HTS) and submitted interim MC's for such a system in mid-1956. The Army MC's for LACROSSE, as revised in June 1957, included the HTS requirement.

(U) Development of the HTS began at Cornell Laboratory in 1956. Before all required components could be air transported, two major

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32. (U) Ibid.; and Sacher Rept BE-745-T-149, op. cit., pp. 235-36. The ABC effort was funded under Cornell contracts ORD-47 and 908.

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modifications of the current LACROSSE system were necessary. The launcher had to be totally redesigned to fall within the weight limit, and a new method of both handling and loading the missile was required to eliminate the 2½-ton capacity wrecking crane used for this purpose. Aside from the missile, launcher, and missile handling equipment, the system consisted of checkout units and firing panels, power supplies, forward guidance stations, and fire direction centers. The design weight limit for the heaviest piece of equipment was set at 2,500 pounds.[33]

(U) Design and development effort continued throughout 1957, and Cornell delivered one prototype launcher and handling dolly in January 1958. Subsequent firing tests on these items proved that the system was operationally acceptable. Design of a tactical pre-production system was then begun early in October 1958. This equipment was delivered in August 1959. Arctic tests on the system were successfully conducted in January and February 1960.

(U) Because of funding limitations, no Army requirements for production type systems were established. It should also be noted here that the HTS was developed to meet requirements established by the Marine Corps. As stated earlier, the Marine Corps pulled out of the program when development of the MOD I system was terminated in August 1959. Development funds spent on the HTS from FY 1957 through FY 1960 amounted to $2.732 million. Marine Corps contributions to the LACROSSE program during Fiscal Years 1957, 1958, and 1959, totaled $4.354 million.[34]

(U) LACROSSE I Tactical Weapon System—Task IV (U)

(U) The Task IV phase of LACROSSE I development was the sole responsibility of the Martin Company. Having relinquished engineering responsibility for the Task IV system in March 1958, Cornell withdrew

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33. (U) Sacher Rept, Ibid., p. 228.

34. (U) Incl to ARGMA Ltr, 15 Jul 60, op. cit.

its representatives from the test site at White Sands and ceased to participate in the flight test program, except for those firings involving evaluation of the HTS launcher.

(C) This final tactical stage of LACROSSE development was actually a continuation of system testing begun with the Task II and Task III missiles in 1957. The Task IV system, however, represented the ultimate tactical configuration which would have to pass extensive firing and non-firing evaluation tests preparatory to troop issue. The physical and operational characteristics of the missile system finally released for deployment are depicted in Figures 27, 28, and 29.[35]

(C) LACROSSE Composite Test Plan (U)

(U) The primary purpose of the integrated test concept adopted for the LACROSSE was to provide an accelerated missile system test program which would result in an approved weapon system with a minimum expenditure of time and funds. The main theme of the plan centered around interparticipation, mutual confidence, and free exchange of data among the participating agencies. Under the integrated test procedure, one agency (the Martin Company, WSMR, or the Artillery Board) was designated as the principal test agency for each firing and delegated responsibility for conducting that firing. Other agencies were invited to monitor the test, and to specify secondary objectives as long as the primary objective was not compromised. At the beginning of each quarter, ARGMA generally scheduled a meeting of the firing test subcommittee to analyze past tests and resolve details for the next quarter.[36]

(U) The scope of the composite test program, as revised in April 1960, is reflected in Figure 30. It was designed to provide a thorough evaluation of the technical adequacy of the system, including accuracy and over-all effectiveness, and to determine maintenance suitability,

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35. (U) For a detailed description and discussion of the operational LACROSSE Weapon System, see Martin Rept OR 1312, "LACROSSE System Description," Jan 61, RSIC.

36. (U) LACROSSE Composite Test Plan, AOMC TP-1, revised 1 Apr 60, pp. 1-2.

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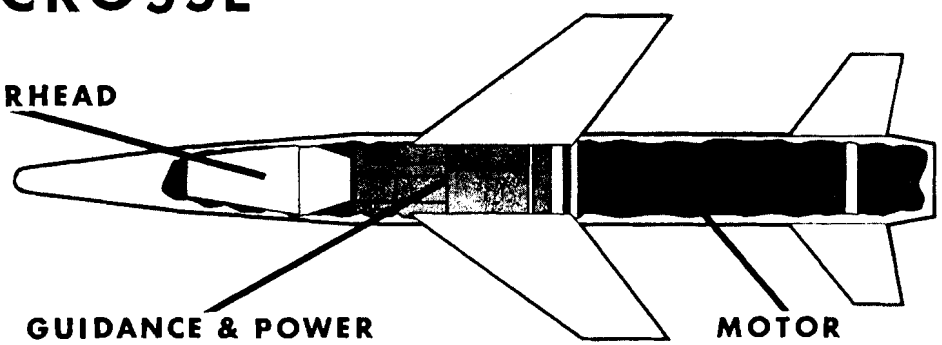
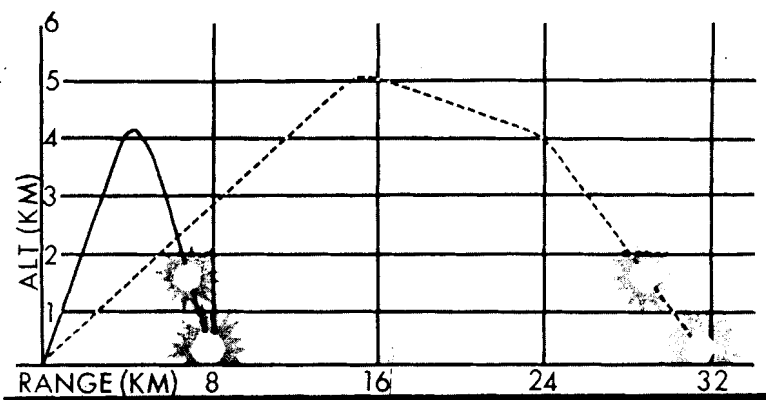
LACROSSE





DIA - 20.5 in.

WT - 2360 lb.

PAYLOAD - 540 lbs

LENGTH - 19 ft. 2 in.

RANGE - max. 30 km
- min. 8 km

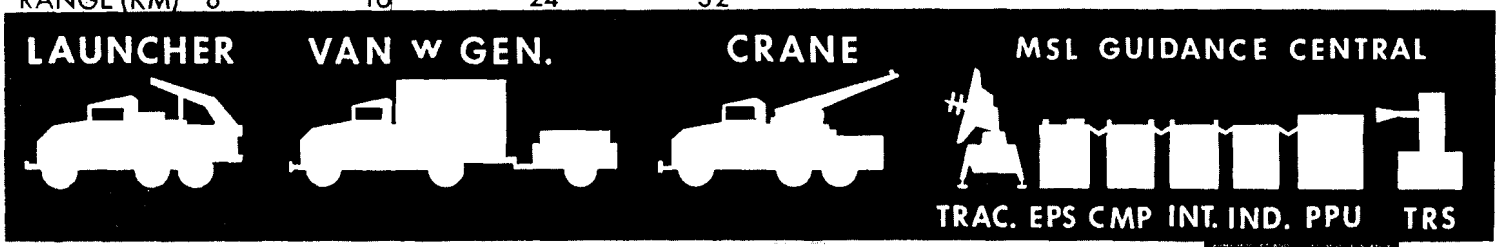


Figure 27

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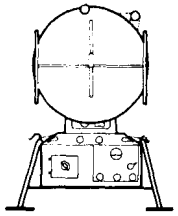
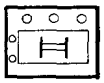
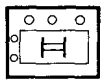
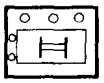
LACROSSE MAJOR ITEMS


TRACKER

MISSILE GUIDANCE CENTRAL


DME


INTERR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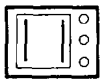
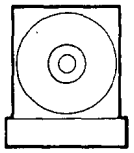
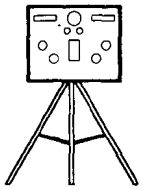

COMPUTER


TRS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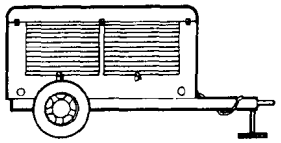
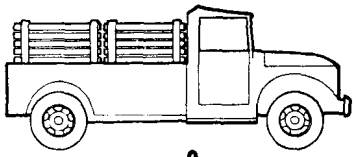
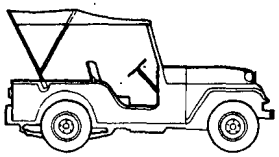
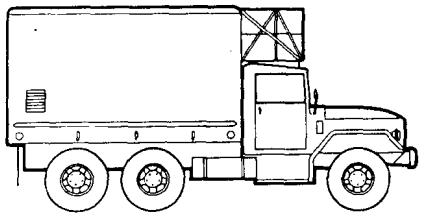
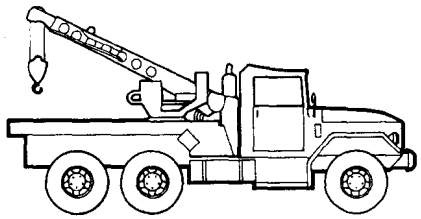

GENERATOR 45 KW


TRUCK, 3/4 TON


TRUCK, M 38 A1E2


TRUCK, XM 512


CRANE, M 108

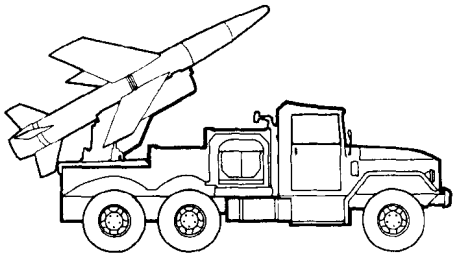

LAUNCHER, XM 398

Figure 28

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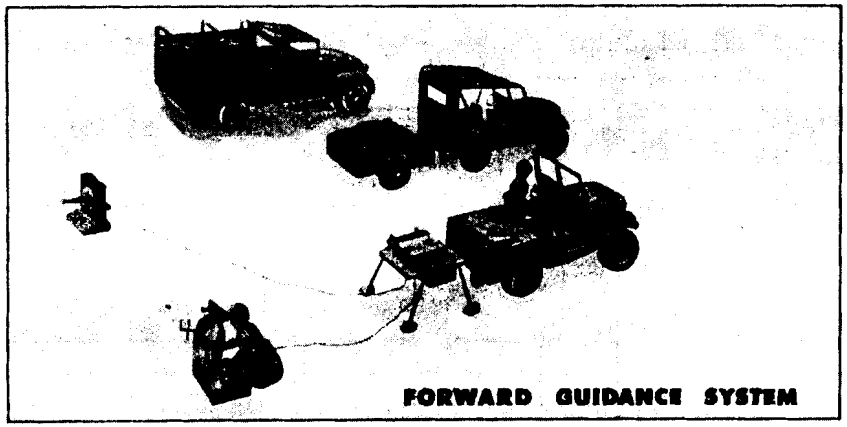
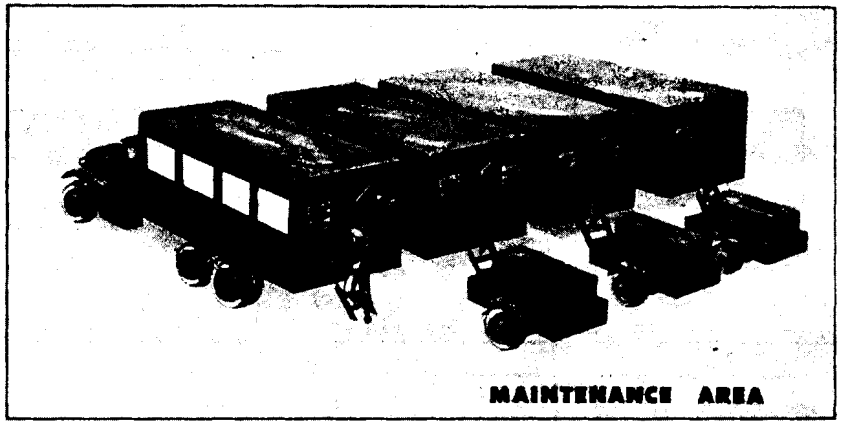
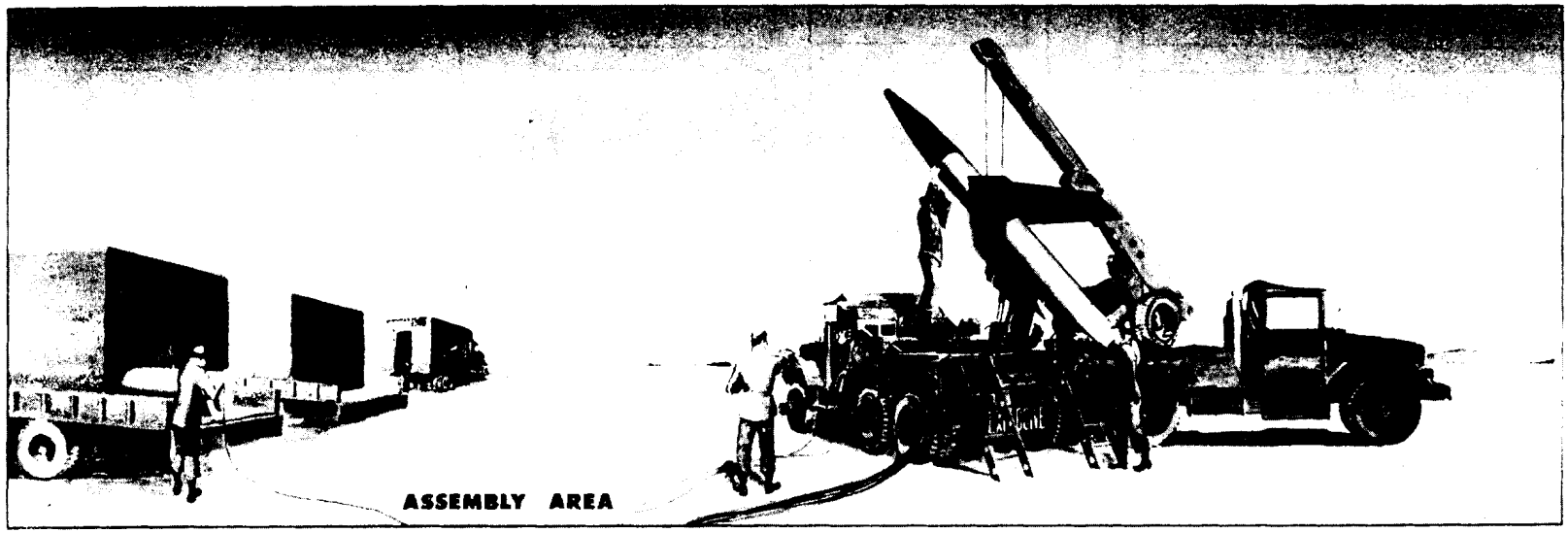
LACROSSE *GROUND HANDLING EQUIPMENT*



FORWARD GUIDANCE SYSTEM



MAINTENANCE AREA



ASSEMBLY AREA

ARMY ROCKET & GUIDED MISSILE AGENCY

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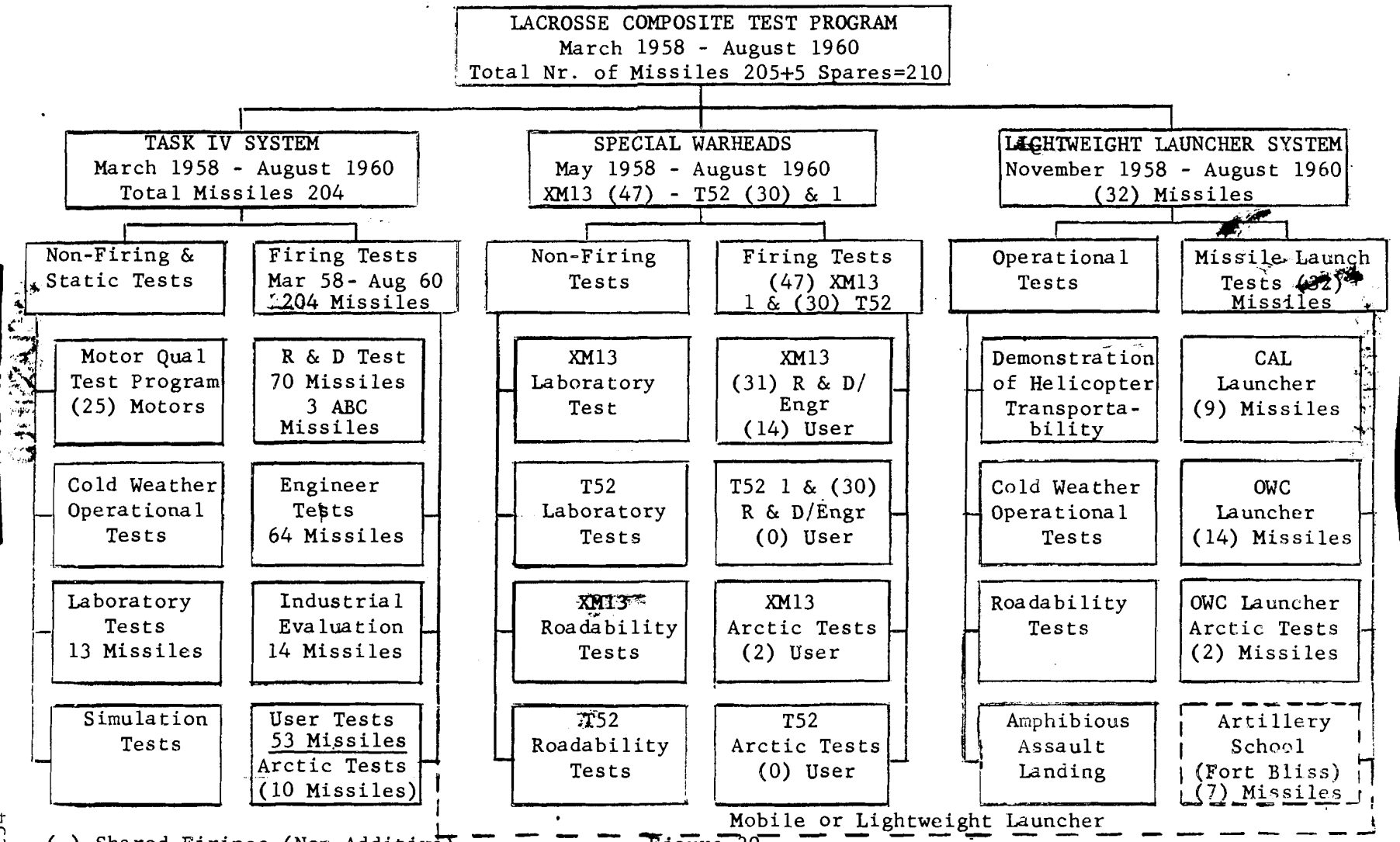

( ) Shared Firings (Non-Additive)

Figure 30

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performance deterioration under field conditions, and maintenance requirements for test equipment. Other objectives of the program were to determine performance of the production engineered missile with respect to system requirements, and to establish whether any failures were attributed to shortcomings in the industrial inspection or quality control programs.[37]

U ~~(C)~~ Task IV Firings (U)

U ~~(C)~~ Task IV evaluation firings started at White Sands Missile Range on 19 March 1958. As of 9 April 1960, 181 of the scheduled missile firings had been conducted by agencies indicated below.[38]

Agency	Nr. Missiles	Test Period
Martin Co. (R&D)	59	19 Mar 58 to 11 Sep 59
Artillery Board	44	23 Mar 58 to 2 Feb 60
STD-OM*	55	2 Sep 58 to 25 Mar 60
Army	23	29 Jan 60 to 9 Apr 60
	181	

U ~~(C)~~ The fact that Martin had not been able to maintain functional reliability of missile components in performing redesign became evident very early in the evaluation program. Of the first 13 Task IV missiles fired through July 1958 (12 by Martin; 1 by the Artillery Board), eight were unsuccessful because of various component failures.[39] In addition, what appeared to be serious deficiencies had shown up in the non-firing cold weather tests conducted at Eglin Air Force Base.[40]

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* (U) System Test Division of the Ordnance Mission (WSMR).

37. (U) Ibid.

38. (U) Martin Rept OR 1294, "LACROSSE TASK IV Flight Test Program," 22 Nov 60, pp. 66 ff, RSIC.

39. (U) Ibid.

40. (U) AOMC TP-1, op. cit., pp. 61-62

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(U) These reported deficiencies were the subject of a meeting held at the Pentagon on 30 July 1958. The results of this meeting* revealed general problem areas in engineering, quality control, and maintenance, as well as a lack of satisfactory communication channels among Ordnance agencies and the user. Based on a review of known technical problems, Ordnance could see no reason for delay in supply of equipment to troops (the LACROSSE I Ordnance Readiness Date at that time being April 1959). It was concluded that deficiencies occurring in missile firing tests could be corrected and fixes applied to initial equipment for troop use, and that deficiencies revealed in cold weather tests were not serious enough to delay the tests then scheduled at Fort Churchill during the winter of 1958-59.[41]

(U) By 27 November 1958, a total of 38 TASK IV missiles had been flight tested** with a disappointing score of 21, or 55.3% unsuccessful. Of these 21 failures, 19 were aborts resulting from such conditions as noise and radio interference, DME ranging errors, and malfunctions in the transponder, beacon, and battery.[42] As a result of firing difficulties being experienced by the Artillery Board, the Commanding General of CONARC recommended that further testing of the LACROSSE system be suspended and that plans for cold weather tests at Fort Churchill be delayed until the winter of 1959-60. The reasons given for the recommendation reflect the unsatisfactory state of the over-all program at this point:

1. (U) Low reliability of LACROSSE system. Of the 13 missiles fired, 8 were unsuccessful. Delays in firing of from 30 minutes to 4 hours were encountered in most tests.

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* (U) Attended by representatives of OCO, CONARC, Deputy Chief of Staff for Logistics (DCSLOG), Deputy Chief of Staff for Operations (DCSOPS), and Office, Chief of R&D (OCRD).

** (U) 17 by Martin, 8 by STD-OM crews, and 13 by the Artillery Board—these including the first 13 firings mentioned above.

41. (U) Ltr, Col B. J. Leon Hirshorn, OCO, to ARGMA Comdr, 8 Feb 60, subj "LACROSSE Case Study," and incl thereto, same subj. (The latter document hereinafter referred to as LACROSSE Case Study.)

42. (U) Martin Rept OR 1294, op. cit.

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2. (U) Development agencies did not have immediate solutions to the in-flight problems encountered in the user tests.

3. (U) Continued modifications to the missile, guidance station, missile automatic checker prevented testing of a truly tactical item ready for troop issue.

4. (U) More and more restrictions were being placed on the Board's firing parameters by the developing agencies in an attempt to overcome system peculiarities.

5. (U) Only a few of the necessary non-firing tests have been made by the Board because the Ordnance post firing examination and pre-firing checkout keeps equipment away from Board personnel for days at a time.

6. (U) Complicated procedures involving the use of an aircraft are being taken to check the missile and guidance equipment before the user firings.

7. (U) A reasonably high standard of system performance to be used in analyzing cold weather test results have not been achieved.[43]

(U) Operation Pickle Barrel. In view of the above circumstances, LACROSSE firings and production were suspended effective 28 November 1958. From this date through 12 December 1958, Martin and ARGMA conducted a special firing program (known as Operation Pickle Barrel) to determine and establish fixes for existing deficiencies. In addition, ARGMA undertook an intensive quality assessment program beginning at the contractor's plant and carrying through to the firing site. In this exercise, quality control deficiencies during manufacture were noted and corrected. Twelve missiles were fired under this special program (10 by Martin and 2 by the Artillery Board). Many technical problems were discovered in the operation, some of them having long histories and others appearing for the first time. Four out of the 12 missile firings were marred by in-flight malfunctions. Transponder failure caused two missiles to abort; yaw loop malfunction caused one to abort; and one missile lost control after a beacon failure. The remaining eight missiles were successfully delivered to the target with desired impact accuracy.[44]

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43. (U) Quoted from LACROSSE Case Study, op. cit., pp. 9-10.

44. (U) Martin Rept OR 1294, op. cit., pp. 56-57.

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(U) During the first half of January 1959, the Martin Company completed its analysis of the above firings and presented the results and recommended corrective actions to a joint meeting of ARGMA, WSMR, Artillery Board, Ordnance Guided Missile School (OGMS), and Cornell representatives. Because of the interruption of LACROSSE production and firing programs, and the time required to install corrections to equipment in the field, it was impossible for Ordnance to meet the April 1959 readiness date. The number of R&D warhead tests and Ordnance engineering tests which could be conducted prior to April 1959 would be insufficient to permit an adequate system evaluation. Moreover, the first set of 3rd Echelon production test equipment would not be available until 30 June 1959, and OGMS could not adequately train direct support detachments until that date because of the shortage of Type IV Test Equipment. Consequently, the LACROSSE program schedule was reoriented on 19 January 1959 and the Ordnance Readiness Date extended to 1 July 1959.[45]

(U) Martin completed the installation of appropriate equipment fixes and resumed R&D firings under the composite test program on 27 February 1959. This was followed by resumption of LACROSSE production and Ordnance evaluation tests early in March 1959. To assure delivery of a complete tactical system by 1 July 1959, ARGMA dispatched a task force to Martin's Orlando plant, in March, to monitor the contractor's effort in the areas of engineering, quality assurance, field service documentation, and hardware deliveries. In addition, an ARGMA team performed a thorough evaluation of Martin's quality control program, and assisted in the establishment of improved management controls within the contractor's complex. A new inspection manager was added to Martin's Quality Division, and a Weapon System Test Department was created to perform acceptance inspection of major end items.[46]

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45. (U) LACROSSE Case History, op. cit., p. 10; and "LACROSSE Missile System Monthly Progress Report," ARGMA, Jan 59, p. 1.

46. (U) LACROSSE Progress Rept, Mar 59, p. 1.

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(U) As a result of the foregoing actions, Task IV equipment began to show a great improvement both in reliability and accuracy. Out of 41 evaluation firings conducted between 27 February and 26 June 1959 (19 R&D; 22 STD-OM), all test objectives were achieved in 28, including three successful T52 warhead tests. The Artillery Board then resumed its evaluation program on June 26th and conducted six flight tests through June 29th. All of these missiles were successfully guided to the target area, with CPE accuracy ranging from 0.9 to 2.1 meters.[47]

(U) LACROSSE equipment for the first reduced-strength Artillery battalion and its Ordnance Support Detachment was delivered to Fort Sill, Oklahoma, on 1 July 1959.[48] The Ordnance Readiness Date thus had been achieved, but many field support problems were yet to be solved.

(U) Upon completion of the R&D portion of the Task IV evaluation program in September 1959, ARGMA had most of Martin's firing test crew withdrawn from WSMR, leaving ten personnel to furnish technical assistance and plant backup as required for components and parts.[49] While the results of subsequent user and Ordnance engineering tests showed a drastic improvement over earlier firings in 1958, the system reliability index continued to fluctuate from poor to fair and never fully met user requirements.[50]

(U) LACROSSE Production Summary (U)

(U) The tactical equipment delivered on 1 July 1959 for activation of the first LACROSSE battalion at Fort Sill was made up of the following items:

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47. (U) Martin Rept OR 1294, op. cit.

48. (U) LACROSSE Case History, op. cit., p. 10

49. (U) AOMC TP-1, op. cit., p. 2.

50. (U) Results of the 181 Task IV firings conducted under the Composite Test Program between Mar 58 and Apr 60 are presented in Appendix, Document 15.

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4 ~~(6)~~ 2	Launchers	4	Missile Automatic Crackers & Associated Equipment
5	Generator Trailers	2	Primary Power Units
5	Vans (Type IV Test Equipment)	2	Target Survey Units
2	3/4-ton Trailer Trucks	2	Forward Guidance Stations
4	Jeeps		

All of this equipment was considered "tactical" with exception of the Primary Power Unit (PPU), which ARGMA personnel described as an unreliable "soft engineered item."[51] Among the irregularities noted in the unit were cracked frames, poor ignition, and poor voltage and frequency control. To eliminate these deficiencies and make the unit more fieldworthy, extensive last-minute changes were necessary, including complete change of the ignition system to an aircraft type, modification of the engine frame to provide more strength, and various other changes to improve reliability and reduce breakage and vibration.[52]

(U) Subsequent deliveries of LACROSSE missiles and equipment were maintained on or ahead of planned monthly schedules. The status of LACROSSE production and other phases of the program through 31 March 1961 is depicted in Figure 31.

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51. (U) TT, CG AOMC to COFORD, Jun 59.

52. (U) LACROSSE Progress Rept, Aug 59, pp. 5-6.

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LACROSSE

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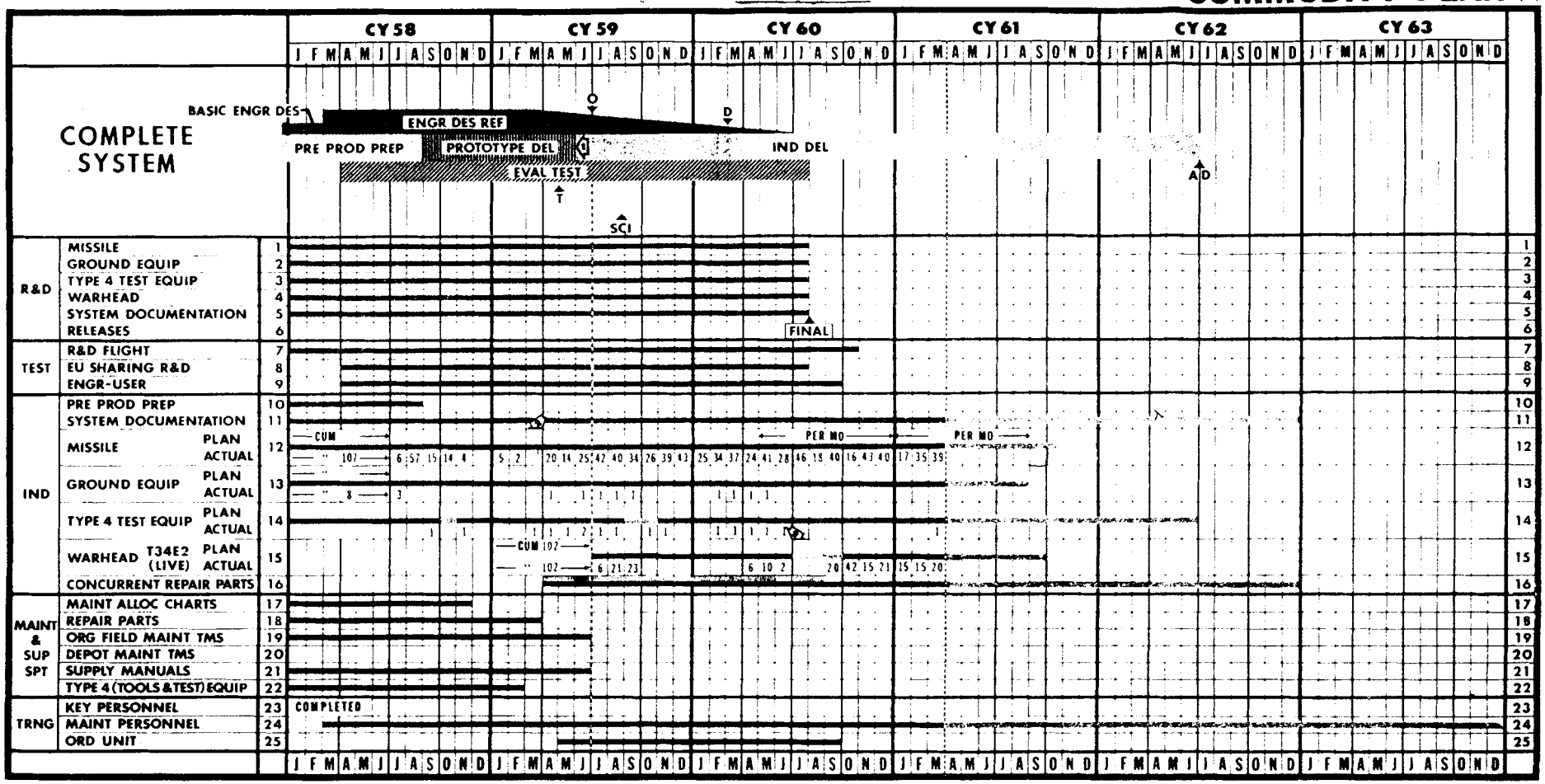
COMMODITY PLAN (U)



PLAN	AD FUNDED DELIVERY	IT BEGIN INSTRUCTOR TRAINING
PROGRESS	B BUDGET PROP SUBM FOR FUNDS TO	O ORD READINESS DATE
DELAY	BD BUDGET PROP SUBM FOR DEL TO	P PROGRAM AUTH REQ
DELAY ELIMINATED	D DEPLOYMENT	SD SYSTEM DEMONSTRATION
POTENTIAL PROB AREA	E IND ECO CONTROL	T BEGIN ORD UNIT TRAINING
SPECIAL NOTES	F FUNDS REQUIRED	

ECI ENGR CONCEPT INSP
DCI DESIGN CHARACT INSP
DRI DESIGN RELEASE INSP
PEI PROD EQUIP INSP
SCI SPEC COORD INSP

PROTOTYPE TEST EQUIP FURNISHED BY R&D.

PRIOR CONTRACTOR DELIVERY REQUIREMENT REVISED TO REFLECT ACTUAL DELIVERIES. FUTURE PLANNED DELIVERIES REVISED.

ARMY ROCKET & GUIDED MISSILE AGENCY
CHART NO. L747 REV L
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Figure 31

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V. (U) THE LACROSSE TRAINING PROGRAM

(U) Development of the Program

(U) The responsibility for the LACROSSE training program, like all other new items of equipment, was included in the over-all mission of The Ordnance Training Command. Established in October 1950, The Ordnance Training Command was charged with the mission of rendering direction, guidance, and surveillance necessary to accomplish the Ordnance training mission. Ordnance Corps Order 30-53, dated 27 August 1953, further assigned Redstone Arsenal the responsibility of insuring the initial transfer of knowledge from the developer to the appropriate military using agency for all items for which it had commodity management responsibility.

(U) Early planning for LACROSSE training centered around, and was dependent upon the Ordnance Readiness Date. From this date, personnel of the RSA National Mission Technical Training Branch worked backward, allocating time to each of the different phases outlined in the general training concept. It was their responsibility to provide trained personnel to operate and maintain the new equipment in accordance with planned deployment.

(U) LACROSSE training was divided in two specific phases: New Equipment Training and Resident Training. The purpose of new equipment training was to provide a staff of trained instructors for technical and user service schools and to train key maintenance personnel requiring an early knowledge of the weapon system. The Resident Training Phase had a two-fold objective: 1) to train selected military personnel in Ordnance service schools in Military Occupational Specialties (MOS's) as required to activate units to support and maintain LACROSSE missile systems in the field; and 2) to train military personnel in user service schools as required for firing units to operate and perform organizational maintenance on systems in the field.

(U) As the producer and co-developer of the LACROSSE weapon system, the Martin Company was expected to train key personnel in the operation and maintenance of the system. The Martin Company submitted its training

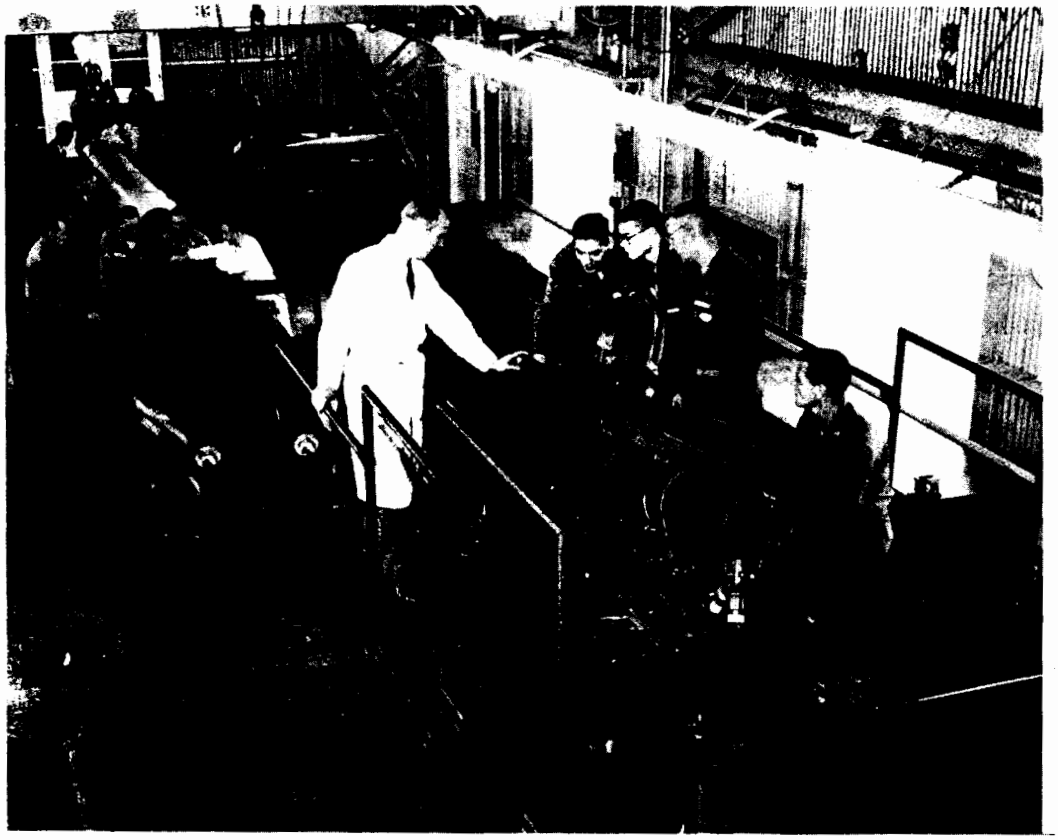

Figure 32. Martin Company instructors Jess Sweetser, Jr. (foreground), Bob Burrow (at jeep), and Gil Baten (background) are shown demonstrating operation of LACROSSE equipment at Redstone Arsenal's Training School. (RSA Photo, July 1957)

Figure 33. LACROSSE training session at the Ordnance Guided Missile School. (OGMS Photo, April 1958)

proposal and cost estimate to Ordnance in September 1955. The Philadelphia Ordnance District awarded Martin two training contracts early in CY 1956. Contract 2216 provided for preparation of 150 Staff Orientation Manuals, 100 Guidance Manuals, 75 Mechanical Manuals, and 225 Operators' Manuals. Under Contract 2244, Martin was to provide Ordnance with 4072 hours of classroom instruction.* Martin assigned ten qualified instructors to Redstone Arsenal in October 1956.[1]

(U) New Equipment Training Courses

(U) The initial transfer of knowledge of the LACROSSE system from the developer to key civilian and military personnel was accomplished in New Equipment Training Courses conducted at RSA by Martin instructors. The courses began at the RSA New Equipment Training Center on 24 October 1956 and ended in November 1957. The courses taught and the number and source of personnel completing each course are shown in Table 3.[2]

Table 3
NEW EQUIPMENT TRAINING COURSES

	Course Titles/Number of Students			
Organization	Electro-Mech	Guidance	Operators	Total
Fort Sill.....	5	3	17	25
Fort Bliss.....	2	3	10	15
WSMR.....	10	18	21	49
Erie Ordnance Depot..	1	1	0	2
Aberdeen Proving Grd.	0	1	0	1
Benicia Arsenal.....	1	2	0	3
Pueblo Ord Depot.....	1	3	0	4
OGMS.....	10	17	1	28
Redstone Arsenal.....	6	7	3	16
TOTAL.....	36	55	52	143

Three-day Staff Orientation Course - 134.

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* (U) See list of Martin contracts in Document 26.

1. (U) LACROSSE Blue Book, op. cit., pp. 73-74, and Supplement 1 thereto, pp. 31-32. Also see LACROSSE Missile System Plan, ARGMA MSP-3, 31 Mar 60, p. G-1.

2. (U) ARGMA MSP-3, Ibid., pp. G-2 and G-3.

(U) Resident Training Program

(U) Training of individuals and units required for Ordnance support of LACROSSE was accomplished through resident training at the Ordnance Guided Missile School, Redstone Arsenal, Alabama. Individuals and units required to support LACROSSE firing units and battalions were trained in resident courses at the Artillery and Guided Missile School, Fort Sill, Oklahoma. LACROSSE training began at OGMS on 3 March 1959 and at Fort Sill on 18 June 1959. Both of these training programs were continued as long as a requirement existed. Table 4 shows a breakdown of courses, with corresponding MOS numbers, length, and number of students per course.

Table 4
RESIDENT TRAINING COURSES

Ordnance Courses (OGMS)	MOS	Length	Nr. Students
Supervisor.....	4815	29 weeks	36
Internal Guidance.....	247	11 weeks	119
External Guidance.....	248	18 weeks	182
Electro-Mechanical.....	434	9 weeks	122
User Courses (Fort Sill)			
LACROSSE Officer's Course.....	--	4 weeks	20
LACROSSE Firing Battery Control.....	166.6	4 weeks	20
LACROSSE Fire Control Operations.....	167.6	5 weeks	12

(U) The three user courses at Fort Sill were conducted concurrently. The First Field Artillery Missile Brigade conducted advanced individual training for filler personnel to be assigned to LACROSSE battalions. Upon completion of individual training, they participated in unit training conducted in accordance with the LACROSSE Army Training Program 6-585. Unit training was conducted by the battalion commander under supervision of the First Field Artillery Brigade. Upon completion of this training cycle, the unit was ready for preparation for overseas movement and deployment to meet Department of the Army schedules.[3]

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3. (U) Ibid., pp. G-3, G-4.

VI. (~~S~~) LACROSSE DEPLOYMENT AND FIELD SUPPORT (U)

(U) Introduction

(U) As noted earlier in this study, the 1 July 1959 readiness date for Ordnance support of the LACROSSE system was achieved. Equipment deliveries and activation of Artillery battalions and Ordnance support detachments were keyed to that date. Unit deployments, based on equipment deliveries and activations since the readiness date, are shown in Table 5.

(U) Prior to mid-1955, participation of the RSA Field Service Division in the LACROSSE program consisted mainly of planning future activities, training of personnel, formulating documentation and repair parts requirements, and keeping informed on system development progress. To fulfill Ordnance requirements for participation in the design and development of materiel, the Field Service Division assigned a Project Engineer to LACROSSE in May 1955. Field Service participation became much more active in June 1955, when the industrial contract was signed with the Martin Company.[1]

(~~S~~) Field Support Problems (U)

(U) Throughout the first 18 months after initial delivery of tactical LACROSSE equipment to the user, the ability of Ordnance to provide full and effective field support was severely impaired by hardware and documentation deficiencies. These support problems stemmed largely from the decision to press the weapon system into field use before all the "bugs" had been worked out. In a telescoped program such as this, some technical deficiencies could be expected; however, the nature of deficiencies still existing in LACROSSE equipment at the time of deployment far exceeded the normal "Product Improvement" type effort. Some of the more serious deficiencies had been disclosed in the flight test program the year before, but the lack of adequate and timely funding guidance prevented a satisfactory level of corrective action. This problem was not necessarily confined to the LACROSSE

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1. (U) LACROSSE Blue Book, op. cit., p. 67.

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TABLE 5

LACROSSE UNIT DEPLOYMENT (U)

ARTILLERY UNIT	DEPLOYMENT		SUPPORTING ORDNANCE UNIT	DEPLOYMENT DATE
	DATE	AREA		
5th Bn, 41st Arty	Dec 1959	CONUS	17th	
5th Bn, 42nd Arty	Mar 1960	Europe	18th	March 1960
4th Bn, 28th Arty	Apr 1960	Europe	169th	April 1960
6th Bn, 8th Arty	Apr 1960	Korea	177th	April 1960
		Europe	7th (GS)	April 1960
5th Bn, 40th Arty	Aug 1960	STRAC	572nd	
5th Bn, 39th Arty	Sep 1960	Europe	178th	July 1960
5th Bn, 33rd Arty	Oct 1960	Europe	163rd	October 1960
2nd Bn, 22nd Arty	Nov 1960	Europe	165th	November 1960
		CONUS	167th	September 1960

ABBREVIATIONS:

Arty - Artillery
Bn - Battalion
CONUS - Continental United States
GS - General Support
STRAC - Strategic Army Corps

SOURCE:
LACROSSE Weapons System Evaluation Report, ARGMA, April 1960.

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system, but prevailed throughout the Ordnance guided missile program. Indeed, as late as December 1958, the Chief of Ordnance had told DCSLOG:

> (U) I have continued to stress telescoping of development and procurement to reduce the time required from conception to availability of an item. The broad rules which are in effect today are workable and the desired telescoping can be accomplished within them. Funding and program decisions can, and have, caused delays in the past, and my efforts are directed to making these delays, and the individuals who cause them, conspicuous. However, I should like to emphasize that we pay a price for crash programs, both in dollars and in initial excellence of product, and speed and ease of training. I do not suggest that we bemoan these facts. I do suggest that we make every effort to educate all echelons to recognize them as facts.[2]

(U) The 68 DA Technical Manuals (TM's) and 26 Supply Manuals (SM's) required for initial support had been printed and distributed at the end of September 1959. Field Service then began the task of revising these publications to keep them current with equipment changes. For example, nine "quick changes" to TM's, resulting from test equipment modifications, were forwarded for printing in November 1959, and ten other changes were in process.[3] A continuing effort of up-dating Supply and Technical Manuals would be required through the life of the system.

~~(C)~~ Repair parts deliveries moved much slower. Delays in this area continued to present major support problems for well over a year after unit deployments, partly because of the steady stream of ECO's that had to be cranked into the system. To cite a typical example of the resulting problem, the LACROSSE battalion which had been shipped to Korea in April 1960 still lacked 1874 line items to complete its basic load as of 5 November 1960. Reported the Ordnance Officer at that site: "So far with two missile systems in Korea, . . . and Lacrosse, we are batting absolutely zero." In addition to the shortage of line items mentioned above, he noted: "The Lacrosse launchers are deadlined for a Signal

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2. (U) Memo from Major Gen J. H. Hinrichs, to Lt Gen Carter B. Magruder, DCSLOG, 11 Dec 58, subj "Ordnance Objectives."

3. (U) LACROSSE Progress Repts: Sep 59, p. 5; Nov 59, p. 8.

Corps item which Signal advises us will be available in January 1961. . . ."[4]

(U) Through the concentrated efforts of ARGMA and contractor personnel, repair parts delivery was gradually improved and the problem eventually solved. While early planning for LACROSSE support did not include the use of contractor representatives after the Ordnance readiness date, it later became apparent that some technical representatives would be necessary. Three were provided to Post Ordnance at Fort Sill, two at Fort Bliss, and one at ARGMA. One technical representative was also required for each Ordnance support unit.[5]

~~(S)~~ U LACROSSE Improvement Program (U)

~~(S)~~ U The LACROSSE system initially placed in the hands of Army troops in July 1959 was considered a basically acceptable weapon, but it was by no means a fully reliable, perfected system. The Commanding General of AOMC was fully aware of this as early as May 1959 and advised the Chief of Ordnance of the improvements needed to bring the system in line with user requirements. In the improvement plan submitted at that time, he pointed out that the current LACROSSE system could not be satisfactorily improved in the ECM area without essentially reinstating the MOD I program.* The cost of the MOD I program was estimated to be about $250,000,000 for system development, test, and delivery of 12 full-strength battalions with associated test equipment and missiles. This figure also included the cost of retrofitting eight reduced-strength LACROSSE I battalions to MOD I type. The Chief of Ordnance subsequently approved this improvement plan and accepted it as the official Ordnance position. However, DA Staff rejected the plan and directed termination of the MOD I program on 18 August 1959.[6] This was

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* (U) As noted above, a hold order had been placed on procurement of MOD I items in Jan 59 because of funding problems.

4. ~~(S)~~ U Ltr, Lt Col Frank E. Napper, Ord Off, 7th Logistical Command (C), APO 612, to ARGMA Comdr, 5 Nov 60.

5. (U) LACROSSE Weapons System Evaluation Rept, Apr 60, p. 1.

6. (U) LACROSSE Case History, op. cit., p. 11.

followed in quick succession by the withdrawal of the Marine Corps from the LACROSSE program.[7]

(U) During a briefing to the Chief of Ordnance on 11 November 1959, the ARGMA Commander emphasized that the LACROSSE system then in the field was not a solid, dependable weapon and would not be until funds and authority were provided to make it so. Less than a week later, the Artillery Board submitted a report on "Service Test of the LACROSSE Missile System," pointing out certain equipment deficiencies yet to be corrected. Convinced that positive action would be required at higher level, the Commanding General of AOMC wrote to the Chief of Ordnance, in December, calling his attention to the Artillery Board's complaint. "It is significant," he said, "that the major shortcomings in LACROSSE . . . approximate those which we have long known. Our proposals for correction have not been supported by DA staff and so we are left with serious defects in the system such as its ECM vulnerability. . . . I strongly urge that you again focus the attention of Staff on this problem and try once more to prod them into action."[8]

(U) In response to further user queries, General Medaris sent the Chief of Ordnance a 14-page teletype in January 1960, which outlined the current LACROSSE limitations in terms of the MC's.[9] After a careful review of this message, the aforementioned Artillery report, and the AOMC letter of 18 December 1959, General Hinrichs concluded that AOMC should have a qualified team conduct a review of the progress being made toward eliminating LACROSSE problems. In a letter to AOMC on 22 January, he observed: "As I look at this program I am astounded at the similarity between LACROSSE and DART. You remember how the improvements on the latter were always 'just around the corner.' To me, the fundamental difference is that LACROSSE is basically a good system. The difficulty

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7. (U) See footnote 14 and discussion relating thereto in Chap IV.

8. (U) Ltr, Maj Gen J. B. Medaris to Lt Gen J. H. Hinrichs, COFORD, 18 Dec 59. See Document 16.

9. (U) TT ORDXR-CR-503, CG AOMC to COFORD, Date-Time-Group (DTG) 07/1800Z Jan 60. See Document 17.

is that the corrections for the known deficiencies . . . to date are marginal." To the extent permitted by available funds, he urged AOMC to actively pursue means of improving the LACROSSE, with emphasis on getting sound corrections for known deficiencies. With this done, it would then be time "to consider the further improvements incorporated in our 29 May proposal."[10]

(U) During a conference held at Martin's Orlando plant, 17-18 March 1960, Ordnance and Artillery representatives outlined critical problem areas remaining in the LACROSSE system and received assurance from the contractor that every effort would be made to expedite solutions. In a concluding speech, Mr. H. R. Staudt, LACROSSE Project Director at the Martin Company, reiterated that the outstanding problems could be cleaned up "with proper support" in the immediate future. He went on to say:

> (U) I am greatly concerned, however, that when we have solved these problems . . ., you will not be satisfied with LACROSSE because of the basic deficiencies which go back to fundamental limitations which have never changed . . . [here referring to the ECM problem which the MOD I was to correct]. We, together with Ordnance, have gone a long way . . . toward the development of a solution for this problem, and are at the present time almost in suspended animation due to lack of programming authority. The [MOD I] program was terminated due to lack of funds last August, and we have been working with a skeleton crew for the past six months, and my time has run out for permission to continue to use company funds.
>
> (U) Our plan at present is a 'poor man's approach' for a three phase program to get all then existing airborne and ground units retrofitted in the field where they will exist. . . . The basic difference in the proposed program as distinguished from the LACROSSE program planning of the past is that we would like to have time to solve problems in our own back yard and then give you, the customer, a finished product instead of delivering hardware to you, the user, prematurely shortly after it has reached a development milepost. One of the basic reasons that we are having so many little difficulties with LACROSSE I in the field today is the fact that we were forced to deliver . . . hardware to

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10. (U) Ltr, Lt Gen J. H. Hinrichs, COFORD, to Maj Gen J. B. Medaris, 22 Jan 60. See Document 18.

the field before we had had the normal minimum time span to solve and debug the problems in our own shop.[11]

(S) Less than 30 days later, an ARGMA team completed the program review suggested by OCO and published its findings in the "LACROSSE Weapons System Evaluation Report," in April 1960. The report contained a detailed discussion of some 133 deficiencies, the most serious of which were in guidance package calibration, air-borne component design, and ECM vulnerability. Among the calibration problems were the extensive maintenance operations required to repair, align, and calibrate the guidance loop of the system in order to maintain the required system accuracy. The team concluded that the enemy did possess equipment capable of jamming LACROSSE with cognizant or brute force techniques, but such equipment would have to be deployed properly and its operation timed to the critical portions of the LACROSSE trajectory.[12]

(S) On 27 April 1960, General Medaris sent the evaluation report to OCO, strongly recommending immediate diversion of funds toward provision of a Second Generation LACROSSE system within three years, in lieu of mere improvement of the existing system over the same time span. The estimated cost of a three-year improvement program within the current system limitations was $17,441,000.[13] Despite continued Artillery Board complaints about system deficiencies and low reliability, OCO rejected this proposal in July 1960 on the basis that the price tag was too high and the risk too great. In view of these and other factors, OCO indicated that consideration was being given to recommending to DA Staff that LACROSSE procurement be held to the current eight battalion commitment, and that the LITTLEJOHN* or MISSILE A be considered for

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* (U) If LITTLEJOHN were selected, Marine Corps requirements still would not be filled. In February 1960, Gen Tschirgi of the Marine Corps had told the Appropriations Subcommittee that the LACROSSE and LITTLEJOHN systems "were not satisfactory for our purposes and, therefore, we are out of those two programs. . . ." See footnote 14, Chap IV.

11. (U) Minutes of Artillery-Ordnance-Martin Meeting on Lacrosse, 17-18 Mar 60.

12. (U) LACROSSE Evaluation Rept, Apr 60, op. cit.

13. (U) Ltr, CG AOMC to COFORD, 27 Apr 60, subj "LACROSSE Weapons System." See Document 20.

any additional troop requirements in this area.[14]

(U) Meanwhile, the Martin Company had submitted a formal recommendation that the 3-phase "poor boy's" plan described during the March 1960 conference* be adopted in lieu of spending more money on correction of LACROSSE I deficiencies. The Chief of Ordnance balked at the price. Another version of the plan was then submitted, in August 1960, which proposed to incorporate the improved guidance system into the LACROSSE program on an expedited, low cost basis. Martin argued that failure to reorient the program would result in the production of unmodified hardware and this would further complicate and increase the cost of the ultimate retrofit program.[15]

(U) ARGMA refused to accept Martin's new plan until it had been revised to include all necessary elements and refined to a minimum possible cost. The revised plan totaled $96.7 million; however, in considering the $22.3 million budget for FY 1961, 1962, and 1963, and the funds recoverable from possible contract termination, the three-year requirement was reduced to $66.1 million additional funds.[16]

(U) On 5 September 1960, ARGMA sent OCO a brochure on the status of the 133 system deficiencies which had been reported earlier in the year. By October, 43 of these deficiencies had been completely corrected; 32 had been engineered and were nearing completion; 40 had been determined to be either "nice to have" or uncorrectable; 7 were still under investigation; and no action could be taken on the remaining 11 deficiencies because of the long lead times required.

(U) But as ARGMA saw it, the only solution to the biggest headaches—vulnerability to ECM and inability to provide adequate

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* (U) See footnote 11 and quotation from Staudt speech, above.

14. (U) Ltr, OCO 00/60S 3645 to CG AOMC, 22 Jul 60, subj "LACROSSE Program." See Document 21.

15. (U) Martin Co. Ltr 60-7775 to ARGMA Comdr, 25 Aug 60, subj "Improved Guidance Program - Lacrosse Weapon System."

16. (U) ARGMA Hist Summary, Jul-Dec 60, p. 122.

maintenance for the system—was to revive the MOD I program. With $66.1 million additional funds, all eight LACROSSE battalions could be retrofitted to the improved guidance concept, including direct support units and training devices. Moreover, the LACROSSE could be fielded with 90% effectivity instead of the existing 60%. LACROSSE had already cost Ordnance over $300 million, and an additional $66.1 million, or 20% of the initial investment, would provide a battle-worthy, reliable weapon to the troops.[17]

(~~S~~) By late October 1960, the LACROSSE had been subjected to a "kill or cure" exercise which left the program in a reduced-strength, buy-out, terminal status in early 1961. The basis for the final Ordnance/DA decision was a brochure prepared by ARGMA in response to 36 pages of handwritten questions concerning six possible courses of action that could be taken with LACROSSE.[18] The DA Deputy Chief of Staff for Operations took the position that Ordnance could go one of four ways on LACROSSE: 1) continue with the present version without additional funds for correcting deficiencies; 2) continue the present version but include the $7 million needed to correct deficiencies; 3) go to the MOD I program—$66.1 million; or 4) terminate the program. DA Staff members ruled out the fourth alternative as not feasible, and the third alternative as not feasible for lack of dollars. This left the first and second alternatives or a combination of these.[19]

(~~S~~) The final decision was to continue the LACROSSE I version and provide $7 million for correction of deficiencies. Anything beyond this would not be considered.[20] The MOD I program was dead, but the ECM problem was still very much alive.

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17. (U) Ibid., pp. 120-23.

18. (U) Ibid., pp. 120, 123. See Document 24.

19. (U) Journal Entry, E. K. Charlton, Dep Chief, ARGMA Control Ofc, 20 Oct 60.

20. (U) Journal Entry, ARGMA Comdr, 2 Nov 60.

~~(S)~~ U Revised LACROSSE Inventory Objectives (U)

~~(S)~~ U The axe officially fell on 4 January 1961. The DA Staff decision, sent to AOMC by teletype from OCO, established ten inventory objectives for the LACROSSE system. When translated into units and equipment, the decision meant that eight reduced-strength battalions (Europe - 3, Pacific - 1, CONUS - 4) would be maintained. The missile inventory objective was 95 per battalion (as opposed to full-strength of 120) by the end of FY 1962, with the following years' inventories reduced in proportion. Support, ground, test, and ancillary equipment, and parts inventories were to be curtailed accordingly.[21]

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21. (U) TT DA 988100, quoted in OCO TT to CG AOMC & ARGMA Comdr, DTG 04/1539Z Jan 61. See Document 25. For details relating to final procurement and inventory actions, see ARGMA Hist Summary, Jan-Jun 61, pp. 108-109, 118-20, and 207.

VII. (U) LACROSSE PROGRAM COST SUMMARY

(U) The net cost of the LACROSSE program from September 1947 through June 1962 amounted to about $295,491,000 (see Table 6). At one point, the total funding program exceeded $300 million, but a good portion of this amount was recovered through termination of certain development contracts and cut-back in LACROSSE I production.

(U) Based on available contract data presented in Appendix Document 26, about 83.8% of the total net expenditure went to two contractors—$220,900,569, or about 74.7%, to the Martin Company, and $26,934,015, or about 9.1%, to the Cornell Aeronautical Laboratory.

TABLE 6

LACROSSE COST SUMMARY

Research, Development, Test & Evaluation		
Army - FY 62 & Prior	$73,600,000 a/	
Marine Corps - FY 1957-59	4,354,000 b/	
Navy - FY 1948-50	410,000 b/	
Total RDT&E		$ 78,364,000
Procurement, Equipment & Missiles, Army		
Missiles, Adaption Kits, Warheads	$152,000,000	
Launchers, Type IV Test Equipment, Etc	57,000,000	
Industrial Facilities	4,400,000	
Total PEMA - FY 1962 & Prior		$213,400,000 a/
Operations & Maintenance, Army		
FY 1961-62		3,727,000 c/
GRAND TOTAL		$295,491,000

a/ Information provided by Mr. G. S. Wicker, Office of the Comptroller & Director of Programs, U. S. Army Missile Command.

b/ LACROSSE R&D Funding Summary, FY 60 & Prior (Incl to ARGMA Letter, 15 Jul 60, op. cit.)

c/ Information provided by Mr. W. B. Stuart, General Support Division, Directorate, Proc & Prod, U. S. Army Missile Command.

VIII. (U) SUMMARY (U)

(U) In summary, the LACROSSE Weapon System was in the field, and it was still having its troubles. It was not a perfect weapon by any means. But it could have been made so with some additional time, a little more patience, and a relatively small amount of additional funds.

(U) Though originally based on a technically sound concept, the LACROSSE system turned out to be technically deficient and unacceptable to the user for which it was developed. It was the victim of financial anemia and acute indecision and inaction. If adequate funds had been provided for the improved guidance system when the need became apparent in FY 1956, or if the MOD I program had been reinstated as AOMC suggested in May 1959, the LACROSSE story no doubt would have had a much brighter ending. As General Hinrichs told DA Staff in May 1959:

> (U) As a result of inadequate funding, we have frittered away over a period of time considerable sums of money on some development programs with very small returns. . . . I have advised the C/R&D that I believe the initiation or continuation of any development project at a funding level less than that necessary for efficient prosecution of the project is not worthwhile, and that, if necessary, we should do fewer things in a more complete manner.
>
> (U) Funding controls, in most instances, the quality as well as the rate of progress. We cannot expect limited funds to fund unlimited programs regardless of how promising. . . .[1]

(U) General Hinrichs was probably tempted to recite this philosophy in testimony before the House Appropriations Subcommittee on 23 February 1960. During these hearings, he heard the LACROSSE alternately referred to as "a pile of junk," "a highly questionable weapon," and "half a weapon." Though admittedly deficient in certain respects, the LACROSSE system even at that time was far from a "pile of junk." And the very members of the House Subcommittee who were so critical of the system in 1960 probably voted against the funds needed by the Army in and after FY 1956 to correct the deficiency. One of the committee members

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1. (U) Memo, Maj Gen J. H. Hinrichs, COFORD, to Lt Gen Carter B. Magruder, DCSLOG, 29 May 59, subj "Ordnance Objectives."

stated: "The LACROSSE missile in its development has gone on and on like Tennyson's brook, it has slipped and slipped and slipped."[2] This, of course, was perfectly true. But the fact that the project had existed on irregular funding all these years was not mentioned as one of the key contributing factors.

(U) An excellent retrospective view of the LACROSSE program is given in the following excerpt from the LACROSSE Case History prepared at OCO level:

> (U) The funding and planning for the LACROSSE system has fluctuated from one extreme to the other, with the results that Ordnance and the contractors have been unable to establish, maintain, and execute a logical progressive development schedule. It is not meant to imply that the funding was solely responsible for all slippage or deficiencies which have resulted. Technical problems have also contributed to the difficulties, although these difficulties would probably have been different if the funding had been completely adequate throughout the program. (For example: It is believed that additional reliability work would have been performed at a higher level of funding.)
>
> (U) When requirements were changed it was considered that they would not seriously interfere with the program. However, it is doubtful that a realistic assessment of the impact was always made. It is believed that the changes and new requirements contributed to the difficulties.
>
> (U) In addition, it is felt that the move of the Martin Company from Baltimore to Orlando, as well as contractor personnel transfers from the project, also contributed.

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2. (U) See footnote 14, Chap IV.

LACROSSE IN ACTION

Ordnance Magazine, Vol XLIII No. 231
November-December 1958

The Lacrosse warhead, above, is being hoisted into place by a mobile crane to be affixed to the missile on its truck-mounted launcher.

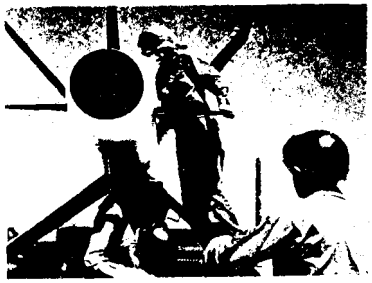
After assembly and preliminary test, the missile is elevated and the firing cable is attached as shown above. This cable will pull off as the Lacrosse leaves its launcher when fired.

After the warhead is attached, the four wings are installed, as shown above, then the tail fins are snapped into place, below. The fins are movable and control pitch, yaw, and roll.

When the missile is assembled, it is moved to the launching site and tested. Technician, above, uses antenna test tool while circuits are checked, below.

Missileman at left, above, checks firing cable while technician at right uses automatic circuit tester mounted on truck. Below, the missile is bore-sighted in preparation for flight.

Fire! Using a solid-propellant rocket motor, Lacrosse heads toward its target directed by a mobile forward guidance station, resulting in accuracy of a high order.



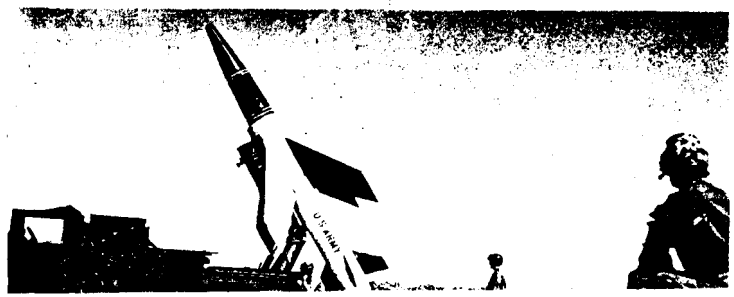


Figure 34

A P P E N D I X

DOCUMENT 1

E X T R A C T

LACROSSE

AN INVESTIGATION OF THE FEASIBILITY OF A GUIDED MISSILE FOR CLOSE SUPPORT (U)

1 July 1948

THE JOHNS HOPKINS UNIVERSITY, APPLIED PHYSICS LABORATORY

and

CORNELL AERONAUTICAL LABORATORY

* * * * * * * *

2. INTRODUCTION

2.1 Early in 1947 discussions of a guided missile for close support of ground troops were initiated by the U.S. Marine Corps. These culminated in the approval, by the Bureau of Ordnance, of proposals, submitted by the Applied Physics Laboratory, for a study of the feasibility of the development of such a missile. On 15 September 1947 there was established at the Applied Physics Laboratory, the Project Lacrosse, and the Lacrosse Board was appointed to formulate the program of study and advise in its prosecution.

The Lacrosse Board consisted of:

A. G. Ennis, APL, Group Supervisor - BBD
P. J. Larsen, APL, Unit Supervisor - Task B
J. T. Massey, APL, Ass't Group Supervisor - BBG
P. F. Mooney, APL, Group Supervisor - CL-7
H. S. Morton, APL, Group Supervisor - BBW
G. C. Munro, APL, BBG-7, Analysis
E. C. Stevenson, APL, Group Supervisor, Project Lacrosse
H. E. Sunde (Alternate for P. J. Larsen)
K. D. Swartzel, CAL, Head, Engineering Physics Dept

Subsequently, the participation of the Cornell Aeronautical Laboratory, Buffalo, N. Y. in the Lacrosse study was secured.

The thinking of the Lacrosse Board and the direction of effort of the working groups have been guided and influenced by the basic philosophy and military characteristics following:

2.2 Basic Philosophy of Lacrosse Study

Determine the feasibility of a Lacrosse missile in the light of the present state of the art; investigations of unknowns involving basic research are beyond the scope of this study.

2.3 Military Characteristics of Project Lacrosse

2.3.1 General

(a) A ground-launched guided missile is envisaged which will serve as a useful supplement to artillery, naval gunfire, and aerial bombardment in the close support of landing forces.

(b) It is intended that the missile should be launched from a ground position (or from a nearby ship) in response to a request from a ground observer (or from an air-borne or shipborne observer) who has sighted an appropriate ground target.

(c) The missile would be caused to fly with preset controls in the general direction of the target. At an appropriate time the observer would take control of the missile and direct it accurately to the target.

2.3.2 Launching

(a) Launching Site - Ground position in rear of front lines

(or ship lying offshore).

(b) Launching Equipment - Readily transportable and easily set up under field conditions.

(c) Missile Handling - Missile to be of sufficiently small size that power handling equipment is not required. Missile to require a minimum of assembly or preparation at the launching site. No special fuel handling equipment to be required.

2.3.3 Control

(a) Target Identification - By observer located on ground (or in observation type aircraft or offshore craft).

(b) Initial Control - Preset guidance carrying missile into field of view of observer.

(c) Terminal Control - Command guidance exercised by observer.

(d) Control Station Equipment - to be capable of operation in front line position (or in observation type aircraft of offshore craft). To require not more than two operators, including observer. To weigh not more than 150 pounds. To break down for pack-board carry into not more than 7 loads, each weighing not more than 25 pounds. To be capable of servicing under field conditions.

(e) Inclement weather or poor visibility not to limit operation. Consideration to be given to illumination of target and missile by such means as radar, infrared, etc.

(f) Means to be provided for destruction of the missile in flight, either on receipt of signal from controlling observer or on loss of control.

(g) Anti-jam devices to be incorporated.

(h) Command link to be used for communication between observer and launching site if practicable.

2.3.4 Range

(a) Maximum - Not less than 20,000 yards.

(b) Minimum - Not more than 1,000 yards.

2.3.5 Accuracy

(a) Probable error in any direction not more than 5 yards.

2.3.6 Flight Performance

(a) Subsonic velocity with high maneuverability.

(b) Combination of velocity, time of flight, and trajectory to provide maximum immunity from antiaircraft fire.

2.3.7 Warhead

(a) Type - Interchangeable at launching site. Choice of armor-piercing, shaped change, high explosive, incendiary, or chemical.

(b) Weight - Approximately 100 pounds.

(c) Fuze - Impact, delayed impact, VT, or observer controlled.

2.4 Initial Attack

2.4.0 The dominant requirement, recognized as such from the outset is:

Accuracy - Probable error in any direction not to exceed 5 yards.

The stringency of this figure suggests at once that the problem of guidance may be the most difficult. At its first meeting, the Lacrosse Board recommended that work begin with a study of terminal guidance, and with the simplifying assumption that the target has been completely identified.

2.4.1 First CAL Assignment

The proposed military characteristics suggest command guidance from the forward station. This would require tracking of the missile, and pulse radar techniques are believed to be the best so far developed for this purpose. Pulse radar is such a logical contender for a place in nearly any proposed non-homing system, that it was thought best to investigate the limiting accuracies of ranging and tracking of which the method is capable, before the synthesis of a particular system was undertaken. Accordingly, the Cornell Aeronautical Laboratory agreed to carry out this assignment as its first problem under a program of study of non-homing guidance.

2.4.2 First JHU/APL Assignment

Although guidance by homing introduces unique problems of target marking or survey, the belief by many that only this method of guidance might be capable of meeting the accuracy specification, required that some consideration be given to it. Mathematical analyses of homing guidance systems for the Bumblebee CTV were already being carried out by Dr. Munroe of APL, so the APL Lacrosse working group undertook as its first assignment the preparation of a homing dynamic analysis problem for a Lacrosse missile.

The accomplishments of these initial undertakings and the succeeding investigations are reviewed in Sec. 3.1 - 3.5 and written up in detail in the Appendices I - V.

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3. REVIEW AND SUMMARY OF THE SEVERAL INVESTIGATIONS

3.1 Homing Guidance

3.1.1 The investigation of terminal guidance accuracy by homing was begun with the assumption that the target could be accurately marked. Basic control loops . . . were drawn for systems using two types of homing signals: (1) the time rate of change of true bearing of the target line-of-sight . . .; and (2) the interferometer characteristic signal . . . .

3.1.2 The non-linear set of differential equations describing the

motion in pitch of a typical airframe was entered in the differential analyzer at the University of Pennsylvania, and the best values of the parameters were determined for which rapidly damped stable motion resulted. When preliminary runs showed a high-speed missile to have only marginal stability, attention was directed to a missile having a speed of 200 ft/sec. Using the optimum values of the parameters found for this missile, arbitrary imperfection in the performance of the system was introduced in the form of lumped dead space, equivalent to a minimum value of the error signal. The resulting steady-state motion, after the initial transient had disappeared, was a slightly damped nearly sinusoidal oscillation of the missile's velocity vector about the target line-of-sight. The amplitude and frequency of the oscillation were functions of the magnitude of the dead space. A statistical analysis of the curves obtained for various values of the dead space indicated a tolerable upper limit of 0.01 rad/sec for this quantity. With this much dead space equivalent, half of the missiles having the assumed flight characteristics would strike a target circle of 5.0 yds. radius if control were lost at a residual range of 275 feet.

3.1.3 Drift of the missile due to wind was investigated by introducing target velocity in some cases. No adverse effects were observed.

3.1.4 Although motions in roll and yaw were not studied extensively it is believed that the results of the pitch investigations may be used in formulating design specifications which, if met, will yield satisfactory over-all aerodynamic performance.

3.1.5 The homing investigations lead to the conclusions that: Seeker, gyro, servo, etc., components exist which, if incorporated into a slow-speed highly maneuverable airframe, can be expected to make the missile home upon a suitably marked target with an aerodynamic precision of guidance satisfactory for Lacrosse. The homing signal may be that obtained from a seeker which holds the line-of-sight to the target or that given by the dual horn interferometer. However, homing as a guidance system for Lacrosse should not be adopted until field tests have shown that a workable beacon can be placed accurately upon the target by a method tactically acceptable to the Marines.

3.2 Radar Accuracies, Weights, and Volumes

3.2.1 The search (Appendix II, Sec. 4) for estimates of the best accuracies to be expected from radar measurements began with a study of those existing sets having the greatest precision, notably automatic fire control radar. Significant data were obtained from results of field tests of the SCR-584 (X and S-band), Mk. 35, and AN/APG-3; all conical scan pulse radars. Experimental results with short pulses, of the order of a few hundredths of a microsecond, were also reviewed; and the opinions of recognized authorities were sought.

3.2.2 The following conclusions were drawn:

1. Measurements at the minimum ranges envisaged for Lacrosse can be made by radar.

2. Under the present state of the art, the best

accuracies obtainable are:

Range	± 5 yards
Azimuth & Elevation angles	± 1 mil
Range rate	± 5 yds/sec.) with 2 sec.
Angular rate	± 0.25 mil/sec.) smoothing time.

3. Maximum improvement to be expected within the next two or three years:

   Range error reduced 50%.
   Angle error reduced an order of magnitude.

3.2.3 Correlations were made of weight and volume as functions of the accuracies of measurement of existing radar sets (Appendix II, Sec. 5), and the conclusion was reached that a satisfactory tracking radar of conventional design and operation would be too heavy and bulky to meet the Lacrosse specifications for the forward control equipment. However, it was shown (Appendix II, Sec. 5.3) that the use of a responder beacon in the missile should so reduce the ground station power requirements and improve the accuracy of tracking that portable control equipment could be built. Also further advantages might be expected if the radar were designed specifically for the chosen guidance system and if the possibilities for cooperative behavior of the missile were fully exploited.

3.2.4 Because the best radar measurement accuracies are only marginal for Lacrosse, and because the suggested extrapolations may be over-optimistic, the recommendation is made that the use of radar in a Lacrosse system of guidance should not receive top priority.

3.3 Radar Guidance of Lacrosse Missile

3.3.1 Having found that the best radar measurement accuracies to be expected in the near future are not seriously deficient for guidance purposes (Appendix II, Sec. 4); and having found that radar field equipment required at the forward control station might be built to the specifications for size and weight (Appendix II, Sec. 5.3), it was decided to carry through analyses of typical systems of guidance by command employing radar at the observer's position in order to have estimates of the probable errors of miss at the target. A machine was not available for handling the complete set of non-linear equations describing a system, but it was possible to treat the system as a complex servo mechanism whose behavior, in some respects, could be predicted well enough by servo mechanism theory using linearized equations. Specifically, the stability of each system was investigated and the principal contributions to the total error were estimated. (Appendix III). /See extract from Appendix III./

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3.4 Range-Only Radio Location Accuracies

3.4.0 A realization of the limiting accuracies of measurement which can be had with radar pulse techniques naturally forced attention to phase

comparison (cycle-counting) methods where the indicated precision of range measurement was orders of magnitude better.

3.4.1 It was found (Sec. 7, Appendix II) that practical field tests have already proved conclusively that range measurements between a roving test point and fixed ground points could be made to ± 0.5 ft. with compact, light equipment which meets all Lacrosse requirements in these respects.

3.4.2 The analysis of a terminal guidance system, employing cycle-counting missile-to-control-point range information only, requires a knowledge of the accuracies to be expected in the computation of the three-dimensional position coordinates of the tracked missile. These accuracies have been investigated (Sec. 8, Appendix II) in order to determine the dependence of their magnitudes upon geometry, and, hence, the required ranging station configurations.

3.4.2.1 Range data give the following information:

(1) Single range station - Spherical surface position; the zone of uncertainty being the spherical shell of thickness equal to the uncertainty in range.

(2) Two range stations - Circular "line" of position; the zone of uncertainty being:

(a) The annular space common to two intersecting spherical shells, or

(b) The annular space common to a hyperboloidal shell (range difference) and an intersecting ellipsoidal shell (range sum).

(3) Three range stations - "Point" position; the size and geometrical shape of the zone of uncertainty depends upon the magnitudes of the range errors and upon the particular combination of ranges, range-differences, and range-sums used to define the position.

3.4.2.2 It was found (Sec. 8.2, Appendix II) that regardless of the treatment given the range data, if only range stations on the ground are used, the position in the vertical will be known with the least precision as the missile approaches the target, and, specifically, the quality of the altitude position measurement deteriorates rapidly as the ratio: (ground range / missile altitude) exceeds 4 of 5.

3.4.3 It is concluded that to have adequate control in the vertical, three ranging stations must be established within 500 feet of the target, if range measurements are uncertain to 0.5 foot. From the tactical viewpoint these conditions are very severe, and probably unacceptable. However, position accuracies in ground range and azimuth would be extremely good under realizable station configurations so that the discovery of an auxiliary means of controlling the missile in let-down would permit the synthesis of a Lacrosse system in which nearly all the final error in striking the point of aim would be due to aerodynamic error.

3.5 Shuttlecock

3.5.1 Although Mr. Swartzel proposed a helicopter for the Lacrosse missile in the early discussions of the problem of terminal guidance, its potentialities were investigated seriously only after the limitations of alternative schemes appeared. The Cornell Aeronautical Laboratory's studies (Appendices IV and V) considered the two important questions:

(1) Can a rocket-helicopter (Shuttlecock) be designed which would serve for Lacrosse?

(2) What are the possibilities for guidance of this type of vehicle?

3.5.2 Shuttlecock Design

3.5.2.1 The proposed shuttlecock (Appendix IV) combines the characteristics of a rocket in its launching and mid-course phases; and the controllability, maneuverability, and speed range of a helicopter in the terminal phase. It consists of two main assemblies indicated in Fig. 1, Appendix IV: (1) the tail unit of rocket and stabilizing fins; and (2) the helicopter head consisting of rotor ram-jet powered at the blade tips, fuel, controls, intelligence system, and warhead. When the projectile reaches the control area over the target, the tail section is cast off; the rotor blades unfold; and the helicopter proceeds under either authoritative or powered flight.

3.5.2.2 The composite design applies principles already successfully employed in rotor sustained aircraft. When under power, stabilized motion in the vertical may be varied from 20 ft/sec climb to 80 ft/sec descent by means of collective pitch control of the rotor blades. Horizontal velocities to greater than 150 ft/sec can be attained by axis tilt of the rotor. It is estimated that a helicopter capable of delivering a 100 lb. warhead will have a gross weight of about 325 lb. and its rotor span will be 10 ft. in diameter. The additional weight of the rocket assembly for a missile having a total range of 12,000 yards would be 525 lbs.

3.5.3 Helicopter Guidance

3.5.3.1 There is no suggested method of terminal guidance, from the simplest to the most complex for which the helicopter, because of its unique maneuverability, is not ideally suited. The report (Appendix V) is devoted largely to a consideration of the fact of the forward observer's visual contact with the target, and of the possibility of using simple optical equipment for acquiring and tracking the helicopter missile. Command guidance by signals from a manually operated controller would be feasible with this system, because of the ability of the helicopter to hover.

3.5.3.2 Since the helicopter can come into the target on a steep, or even vertical, trajectory, automatic control utilizing range only data should be easy to achieve.

3.5.4 Warhead

3.5.4.1 Any system of command guidance will require the establishment of

[redacted]

a "known" direction in the missile for purposes of control. It seems entirely possible to work from this reference to orient the shaped charge warhead in any desired direction and thereby increase the usefulness of the missile against a variety of targets.

3.5.5 Vulnerability

The most serious question of the acceptability of a helicopter type missile for Lacrosse is its vulnerability during the final approach to the target. Given the time to maneuver the craft as slowly as is required to settle it upon the target, or the opportunity to make successive approaches, there is little doubt that a satisfactory hit can be made. The missile's small size, and its ability to come in high, low, or from any angle are factors in its favor; but it is believed that field tests should be made to place this point of debate outside the area of pure speculation.

3.5.6 Taken together, the shuttlecock proposals show that this missile would meet admirably many of the Lacrosse Military Characteristics most difficult to achieve, but no analysis leading to a numerical estimate of the accuracy of guidance is possible without data on an actual small unmanned helicopter. Development of the latter is a research problem which must be the first step if these proposals are followed up.

4. TARGET SURVEY PROBLEM

4.0 Proper identification or survey of the target would remain an inescapable duty of the forward observer, even if automatic guidance were to relieve him of all responsibility for controlling the missile. No matter what system of guidance is chosen, the estimate of the total error of miss must also include the errors of target survey. Figures for the latter are still largely speculative, and more reliable ones can be got only after a precise statement is made of what is required.

4.1 For Homing Guidance

4.1.1 This survey problem consists of making or illuminating the target by placing upon it something which the missile can identify and use to home upon. The statistical probable error of maker placement is the fundamental quantity required. This is a measure of the random dispersion existing after the announcement is made that a marker has been placed on the target.

4.1.2 Systematic errors of observation are possible, but it is expected that the principal elements will be the primary error of miss in throwing, lobbing, and dropping, or shooting the beacon or flare; and the secondary error of bounce or roll after impact. With radio beacons there is also another possible source of secondary error; namely, the spurious indications due to reflected images. Determination of the latter may be most difficult.

4.2 For non-homing guidance

The problem here is to assign to the target three numbers which are its position coordinates with respect to a given set of coordinate axes or a known reference point. The fundamental quantities required

are the probable errors of each of the three numbers which are placed in the computer.

4.3 Many systematic errors may be eliminated if the guidance system employs the same instrument or technique for determining the missile position as is used to locate the target; but there will remain the accumulated random error due to errors of observation, scale reading, translation of data, etc.

4.4 It should be pointed out here, that where let-down is a serious problem (Sec. 3.4), the same difficulties in locating the missile in the vertical direction are encountered when the vertical position of the target is sought.

5. GENERAL CONCLUSIONS AND RECOMMENDATIONS

5.0 This study has shown that there are several possible ways of achieving the guidance accuracy required for Lacrosse. It is believed that the most promising, and therefore deserving of first consideration, are: Homing, Guidance Along a Way established by Cycle-counting, and Shuttlecock Development. Each of these has secondary problems of considerable importance and of a character requiring a different approach for their solution than that used so far.

5.1 The choice of a system for intensive development can better be made after practical laboratory and field tests have given the answers to a number of questions having both technical and tactical aspects:

1. For the purpose of homing, can a beacon be placed upon the target by a method which is accurate enough and also tactically acceptable?
2. For guidance from a control point or along a way, can the target position coordinates be determined by a method which is accurate enough and also tactically acceptable?
3. Can missile let-down be achieved by independent guidance method which is accurate enough and tactically acceptable?
4. From flights with a manned helicopter is it possible to judge the acceptability of the proposed shuttlecock as regards accuracy and vulnerability?
5. Can the calculated limitations of measurement in the vertical by cycle-counting techniques be verified by experiment?
6. If used against a fixed ground target suitably marked, would homing systems now under development be accurate enough for Lacrosse?
7. To what extent would a beacon in the missile and further cooperation of the missile improve the

tracking and reduce the size and weight of ground station radar equipment?

8. Are there existing airframes of conventional design which would serve for Lacrosse?

9. Can the helicopter part of the shuttlecock be build?

10. Can beacons suitable for homing or for cycle-counting target identification be built?

5.2 If the same basic philosophy, hitherto followed, is retained in seeking the answers to the above questions and in choosing and synthesizing the Lacrosse system, a very close liaison must be established with other projects so that their most recent results may be used at the time of final decision. Specifically, the flights now being carried out in the Meteor, Kingfisher, and Bumblebee programs will provide important design data on airframes, seeker systems, and control equipment as well as information on guidance performance; field tests now being made by Raydist and others employing cycle-counting techniques are of particular significance to the Lacrosse survey and guidance problems; unmanned remotely controlled helicopters have many military applications other than Lacrosse, and, if their development were undertaken by Bell, Goodyear, Hiller, McDonnell, or CAL, for mine-laying, beacon placement, etc., the results would be very valuable in the proper evaluation of this proposed vehicle.

5.3 It is recommended that further investigations in the following three directions be undertaken:

1. Field tests by the Marine Corps which will attack the problems of target survey and missile let-down, and which will attempt to assess the maneuverability and vulnerability of the proposed helicopter under combat conditions.

2. Follow-up of other projects (Kingfisher, Meteor, Raydist, etc.,) making arrangements for tests of particular significance to Lacrosse.

3. Modest development programs to show:

   (a) That the remotely controlled helicopter is feasible; and

   (b) That suitable beacons can be built for marking or surveying-in a target.

APPENDIX I

Homing as a Means of Terminal
Guidance for Lacrosse

The Johns Hopkins University
Applied Physics Laboratory

1 July 1948

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3.5 Summary and Conclusions of the Homing Guidance Analysis

3.5.1 Differential analyzer investigations of the equations of the pitch motion of a slow speed conventional type airframe have shown that the probable aerodynamic error, using homing guidance signals of the rate of change of target bearing or the interferometer approximation thereto, will probably lie within the Lacrosse specifications even with considerable allowance made for system "dead space".

3.5.2 Seeker, gyro, and servo components exist which may be expected to meet the performance specifications assigned to them by the mathematical analyses.

3.5.3 Although motions in roll and yaw were not investigated with comparable thoroughness, it is believed that the results for pitch may be used to set design requirements which, if met, will yield satisfactory performance in roll and yaw. These requirements do not appear to be overly severe.

3.5.4 The problem of target survey for homing, i.e., the placement of a suitable beacon or marker upon the target by a method which is accurate enough and tactically acceptable, has not been investigated, and the adoption of a homing system for Lacrosse is not recommended until practical field and laboratory tests have supplied survey data upon which a fair judgment of homing in comparison with alternative methods of guidance can be made.

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APPENDIX II

SUMMARY REPORT ON
INVESTIGATIONS OF NON-HOMING GUIDANCE TECHNIQUES FOR LACROSSE

Cornell Aeronautical Laboratory, Inc.
Buffalo, N. Y.

Report No. UB-524-P-3
Contract No. NOrd-10057

30 June 1948

By Engineering Physics Department

D. T. Hamilton, Project Engineer
H. G. Iddings, Section Head
K. D. Swartzel, Department Head

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3.1 Investigations have shown considerable evidence of feasibility in utilizing a helicopter type missile in Lacrosse applications. The proposed Shuttlecock (combination rocket-helicopter missile) offers a means of bringing together extremes in technical specifications for missile guidance which are dictated by the military need for a highly maneuverable close support missile, capable of being guided with high precision to a pinpoint target. Of the several non-homing guidance techniques investigated during the course of this project, the Shuttlecock technique is considered to be the most promising for Lacrosse.

3.2.1 Radar accuracy investigations have led to the conclusion that the best accuracies associated with the present state of the radar art are as follows: $\pm$ 5 yards p.e. in range and $\pm$ 1 mil p.e. in angle; $\pm$ 5 yards/sec. p.e. in range rate and $\pm$ 0.25 mils/sec. p.e. in angle rate for 2 second smoothing time. On the basis of estimates and opinions from several sources, the most optimistic forecast on improvement in the state of the radar art during the next few years may be expressed as follows: under favorable operating conditions, microwave radar may be improved by about fifty percent in range accuracy and by an order of magnitude in angle accuracy. It is concluded that pulse echo radar offers marginal accuracy as a measurement method for the use in Lacrosse and that equipment weight would be excessive for Lacrosse.

3.2.2 If the Lacrosse missile is equipped with a radar beacon, the possibility of designing portable radar equipment for a Lacrosse guidance system appears quite favorable. However, the $\pm$ 5 yard p.e. desired for Lacrosse accuracy at the target is not considered a feasible goal for the near future if the radar guidance equipment must be of the man-pack variety.

3.2.3 Investigations of the possibility of guiding a Lacrosse missile with required precision were conducted on the basis of assuming (a) radar performance somewhat better than that presently attainable, and (b) reasonable allowances for engineering compromises to obtain rugged, portable equipment. In the case of guidance along a preset trajectory, the ground radar is simple and amply accurate, but the

missile response to control orders is such that the overall accuracy cannot be securely met. In the case of guidance along a homing-type course, the missile performance is adequate, but measurement and computation noise appear almost too high. The utilization of radar for Lacrosse is regarded a fair (even if costly) gamble, which should take less than top priority as compared with other promising methods.

3.3 Range-only radio location accuracy investigations have established that both the measurement accuracy and bulk characteristics of phase comparison ranging equipment satisfy Lacrosse specifications. Representative range-only guidance systems were analyzed on the basis of investigations dealing with the inter-relation of uncertainties in range measurement, uncertainty in missile position, and range station configuration. It was concluded that if three-dimensional terminal guidance based on range-only radio location of the missile were subject to Lacrosse accuracy requirements, the forward stations would have to be very close to the target - exactly how close depends upon the magnitude of range-measurement uncertainties encountered under tactical conditions. For an uncertainty in range measurement of 0.5 feet, it is doubtful that the forward stations could be more than a few hundred feet from the target. With the realization of anticipated improvement in the precision of phase comparison ranging methods, the possibilities of utilizing range-only radio location in Lacrosse terminal guidance would be more favorable.

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APPENDIX III

RADAR GUIDANCE OF LACROSSE MISSILE

Cornell Aeronautical Laboratory, Inc.
Report No. UB-524-P-2

28 May 1948

By M. G. Foster
Karl D. Swartzel

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Discussion and Recommendations

5.50 The residual uncertainties of any theoretical design study are large or small according to the availability of similar systems or experimental data from which to extrapolate. In the case of this report, several of the essential data had to be prophesied rather than reported, and the residual uncertainty is therefore not small. Furthermore, the results do not speak with assurance that the accuracy specified (± 5 yards probable error) can or cannot be obtained, although they do leave a slight bias in favor of their possible future realization. Because of the augmenting effect of simultaneous error in both pitch and yaw motions of the plane, the bias in favor of realization is small.

5.51 The possibility of developing Lacrosse as a weapon usable in combat is barely good enough to justify the cost of the enterprise if there is real tactical need for such a device with its inherent limitations. Some of these limitations are the following:

(a) Guidance outpost exposed to enemy fire.

(b) Radar dish must usually be able to see the target and will probably be above the horizon at all times while in use.

(c) Missile moves 200 ft/sec, which is a fairly slow airplane speed; thus the missile is vulnerable to enemy fire.

(d) Electro-mechanical computers of the required accuracy are precision instruments whose engineering into mud-proof shock-proof units is not impossible, but will require very careful engineering to have a chance to provide weapons as rugged as they should be. Field maintenance will be difficult.

(e) The training and experience required by personnel of the forward party are not small. The acquiring of a missile would be difficult and exacting work for men under fire.

(f) The system is vulnerable to know radar countermeasures.

5.52 It appears that the key decisions as to whether experimental and development work should be done on the Lacrosse radar problem are that of whether (a) radar guidance is the best available, and (b) the infantry needs the Lacrosse weapon badly enough to gamble a million dollars or so (and two or three years time of a competent crew of scientists) on what appears practically an even chance. This theoretical investigation shows that such a program would provide a missile guidance system whose accuracy might be as good as present requirements. (There is scant margin for the future refinement of performance which is usually demanded in practice.) It is recommended that the decision on Lacrosse radar development future be sought on the basis that it is a reasonably good gamble, but no certainty. Any other method that looks better should take priority.

5.53 The point where this investigation is least conclusive is in the angular noise level of simultaneous-lobing tracking radar. Further exploration of this problem is recommended as more performance data became available from such projects as that described in Reference (m).

5.54 The time and data available did not permit a conclusive investigation of overall guidance error in the homing-type course to be made. It is recommended that the noise level and loop-stiffness result specified in Section 4 be scrutinized in connection with homing data in possession of APL/JHU so as to establish the estimate of accuracy (paragraph 5.42) on firmer ground.

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APPENDIX IV

DESIGN STUDY OF A COMBINATION ROCKET-HELICOPTER MISSILE FOR LACROSSE

Cornell Aeronautical Laboratory, Inc.
Report No. BE-365-S-3

12 May 1948

By Aero-Mechanics Department

Prepared by: H. Hirsch, Section Head
Approved by: A. F. Donovan Dept. Head

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GENERAL DESCRIPTION OF SHUTTLECOCK

The Lacrosse problem requires a missile which, after launching from a rear base, can be guided with extreme accuracy to the target by means of a portable guidance system carried by a forward observer. Desirable characteristics of such a missile appear to be:

1. High delivery speed, preferably supersonic, to the point where the forward observer assumes control.
2. Extreme controllability and maneuverability during the period of terminal guidance to the target.
3. Light weight, low cost, and simplicity.
4. Adaptability to a simple command guidance system in the terminal phase.

A missile configuration, designated the "Shuttlecock" because of the similarity of its flight path to that of the badminton shuttlecock, has been conceived specifically to meet these requirements. Whereas an aimed, unguided rocket would meet the requirement of high speed delivery to the general region of the target, extreme accuracy in final placement of such a missile would require a very complicated guidance system. By contrast, a slow speed, highly maneuverable missile can be positioned very accurately by a simple manually operated command system. The Lacrosse problem, therefore, appears to require a missile which has the ballistic flight path of a rocket in its launching and mid-course phases and the controllability, maneuverability, and speed range of a helicopter in the terminal phase. The Shuttlecock is a hybrid aircraft which possesses these properties. Essentially it consists of the two main assemblies indicated on Figure 1 These are (1) the tail assembly unit consisting of launching rocket and stabilizing fins and (2) the Shuttlecock helicopter unit consisting of sustaining rotor and controls, intelligence system, and warhead. The Shuttlecock helicopter unit remains airborne at all stages following launching. Following delivery of the Shuttlecock projectile to the target area, the tail unit is dropped and the Shuttlecock helicopter remains in flight. Control of the Shuttlecock helicopter following separation from the tail unit can be

accomplished partially by automatic means and partially by radio command signals from the ground operator, as described in Reference I.

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CONCLUSIONS

It is concluded from the foregoing investigation that the proposed design of a Shuttlecock missile fulfills the requirements of Lacrosse. It is indicated that the development of a satisfactory Shuttlecock missile is practical, and that such development can be accomplished by combining a series of separate developments which have been successfully demonstrated to date. It appears that an adequate Shuttlecock development would entail a basic research and development program which, in turn, would require major substantiating experimental and flight test investigations.

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APPENDIX V

GUIDANCE OF HELICOPTER-TYPE LACROSSE MISSILES

Cornell Aeronautical Laboratory, Inc.
Report No. UB-524-P-1

12 May 1948

By Engineering Physics Dept.

Prepared by: R.E. Reinnagel
D.T. Hamilton

Approved by; H.G. Iddings
Karl D. Swartzel

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2.0 INTRODUCTION

2.1 In considering a helicopter type missile for Lacrosse, it is well to reflect momentarily on the basic Lacrosse philosophy as formulated in early meetings of the Lacrosse Board: In the Lacrosse operation, visual contract of a forward observer with a selected pinpoint target must enter into the terminal guidance of a Lacrosse missile if the guidance accuracy requirements are to be considered feasible.

2.2 A guidance system which makes direct use of the forward observer's visual contact would conceivably achieve greater accuracy than one which must accept errors in the target survey or target marking, and which also must accept errors in the application of this observed information to missile guidance. A homing guidance system must utilize the forward observer's visual contact in marking the target, e.g., in lobbing a beacon or flare onto the target. The non-homing systems considered thus far for Lacrosse must utilize the forward observer's visual contact in making a survey to obtain target position data. With a helicopter type Lacrosse missile, direct use may be made of the observer's visual contact to accomplish target demolition coincident with target marking.

3.0 DISCUSSION

3.1 General Guidance Considerations

3.1.1 Several possibilities for guidance or remote control of a helicopter type missile can be conceived, involving degrees of automatic control ranging from typical drone operation by remote radio to fully automatic control based on automatic tracking, homing, or some other guidance medium. Remote radio control of a helicopter type missile is considered to be of first interest in Lacrosse, however, because such control is highly compatible with the basic Lacrosse Philosophy, as reviewed in Section 2.1.

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3.4 Shuttlecock Guidance

3.4.1 As described in reference 1, the Shuttlecock is a helicopter type missile which would be launched as a projectile, and would continue

in flight along a selected trajectory until within visual range of the forward observer. At that time, the aft section (rocket motor and tail section) of the projectile would be shed, leaving a sub-unit, the Shuttlecock helicopter, which would be flown along an auto-rotative guide path into the immediate vicinity of the target, employing a lifting rotor which would unfold after the separation. (Note sequence A, S, B, C along the trajectory in drawing P-1-2695). At an appropriate time, subsonic ram jets in the rotor blade tips would be placed in operation, and the Shuttlecock flown into or hovered over the target.

3.4.2 To facilitate visual acquisition by the forward observer, it would be desirable to have the delivery of the Shuttlecock projectile occur along a trajectory terminating at a region in space specified by the forward observer. Of course, a region as close to the target as possible would be selected not only to facilitate the forward observer's visual acquisition but also to minimize the vulnerability of the Shuttlecock to enemy fire. The forward observer could exercise wide choice in selecting such a region, thus allowing target attack from almost any direction.

3.4.3 Many field situations may be conceived where the Shuttlecock projectile may be delivered on the basis of ballistic data with sufficient accuracy to "hit" a region in the sky specified by the forward observer. Visual acquisition would thus be facilitated not only by delivery to a point specified by the forward observer, but also by the fact that conversion from a high-velocity projectile to a low-velocity helicopter missile would occur at a time best suited to aid visual acquisition. Equipment at the launching site probably will include facilities for tracking the Shuttlecock. Accordingly, the launcher may aid visual acquisition by the forward observer if necessary. That is, Shuttlecock position data could be sent over the communication link between the launcher and the forward observer to keep the latter informed of Shuttlecock position until visual acquisition had been confirmed. After visual acquisition, the forward observer would guide the Shuttlecock as a drone, utilizing its hovering capabilities as required during the final let-down.

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4.0 SUMMARY AND CONCLUSIONS

4.1 Investigations conducted thus far have shown considerable evidence of feasibility in utilizing a helicopter type missile in dealing with the Lacrosse guidance problem. The proposed Shuttlecock Lacrosse missile offers a means of bringing together extremes in technical specifications for missile guidance which are dictated by the military need for a highly maneuverable close support missile, capable of being guided with high precision to a pin-point target. It is recommended that the Bureau of Ordnance consider development of the Shuttlecock and other helicopter type missiles.

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DOCUMENT 2

E X T R A C T
(pp. 15-17)

LACROSSE SUMMARY REPORT

TASK I

June 1949 - March 1950

CORNELL AERONAUTICAL LABORATORY, INC.

REPORT NO. BE-635-S-2
Under Contract NOrd-10629
With Bureau of Ordnance, U. S. Navy

BY: Aero-Mechanics Dept.

APPROVED: A. F. Donovan, Head
Aero-Mechanics Dept.

DATE: March 22, 1950

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SUGGESTED LACROSSE MISSILE SYSTEM DEVELOPMENT PROGRAM

In this section a program is outlined leading to development and flight test of prototype Lacrosse missiles in a three year period. It is proposed to accomplish this result by first developing the guidance system and flight testing it in a piloted airplane. Tests of the guidance system by having it control an airplane through an autopilot are believed to be advantageous in shortening the development time, reducing the test cost, and permitting more complete instrumentation and evaluation of the system. Basic design of the system would be accomplished before flight tests through use of analogue computer studies and by the construction and operation of a simulator. Following successful airplane flight tests the actual missile design would be completed and flight tested.

A chart listing the steps believed necessary for the development program and the proposed schedule is included as Fig. 12.* The proposed program begins with the extension of the analogue computer studies, performed under the current task, to more nearly optimize the system. Concurrently with the analogue computer studies, design and construction of the simulator for use in testing the actual system components would be started. Operation of this simulator upon its completion would serve to optimize the system constants and test out the components as they are developed. During this period a radio pure range measuring system, suitable for use in airplane tests of the complete system, would be designed and built by a suitable contractor. As a first phase in the development of this equipment, helicopter flight tests of the effects of altitude on the accuracy of radio range measuring equipment would be made. An available optical tracking unit would be selected and adapted for use in the airplane flight test program. The computer necessary for converting the tracking and range data into missile commands would be developed and suitable standard radio command equipment for operating the airplane autopilot would be selected. An SNB airplane, or equivalent, equipped with autopilot is believed suitable for the flight test. Following simulator tests of the combination of radio range equipment, optical tracking unit, and computer and command link, installation of the necessary equipment would be made in the airplane and flights commanded through a designated point in space. The performance of the system would be evaluated by measuring the miss distance with photo-theodolites or equivalent equipment. It is contemplated that work up through the preliminary stages of the flight tests could be completed during fiscal 1951. In addition to this flight test of the basic components of the system to evaluate the suitability for continued development, design of the final optical tracking unit, of the optical range finder, the missile airframe design and development of the miniaturized range measuring system would be instituted. It is also believed that a small effort should be

*This chart is included in the narrative as Figure 3.

devoted to the study of alternate radar tracking heads to replace the sight system for possible all weather operations. Some effort should also be devoted to following the developments in recoilless direct fire weapons which might be applicable to beacon placement and maintaining contact with possible developments in the field of microwave beacons capable of withstanding extreme accelerations.

In fiscal 1952 it is proposed to perform the majority of the flight tests on the piloted airplane and to complete this phase of the project. The development of the packaged radio range measuring equipment would be completed and flight tested as part of that work. Construction of the optical tracking unit and an improved range finder would be undertaken. Concurrently, design of the airframe and packaging of all equipment would be completed. Selection and tests of a preset gyro stabilized mid-course guidance system would be made. Problems of launching and launcher design would be treated. A few basic airframes would be constructed and flight tested to obtain missile aerodynamic response characteristics. While it has been possible to define the work for fiscal 1951 quite accurately, that outlined for 1952 is necessarily somewhat more vague and will require subsequent revision as the work proceeds. Assuming, however, the items outlined are completed in fiscal 1952, the principal work remaining for fiscal 1953 is the construction and flight test of a small quantity of prototype missiles. This work would encompass, of course, the elimination of bugs and the improvement and refinement of the Lacrosse missile.

The time scale presented is believed to be on the order of the minimum achievable with reasonably constant and efficient effort applied to the resolution of the problems. Unforeseen development difficulties, contractual delays and budgetary limitations might easily extend the time scale by one to three years. As required by the task statement, estimates of the cost of the various items in the development program are given on page 17. While believed to be of the right order of magnitude, the figures listed are in many cases based on incomplete data and are not to be considered for contractual purposes.

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APPROXIMATE COST ESTIMATE - WORK OUTLINED FOR FISCAL 1951

I. STEER Command System Flight Tests in Piloted Airplane

1.	Analogue computer studies	$ 25,000
2.	STEER simulator design and construction	50,000
3.	Simulator tests of system	10,000
4.	Radio ranging equipment - breadboard development	150,000
5.	Optical tracking sight - adaptation of existing unit.	5,000
6.	Command computer development	25,000
7.	Radio command link - adaptation of standard units	5,000
8.	Install system in airplane and make preliminary test flights	40,000
	Total for Guidance Test	$310,000

II. Preliminary Work on Final System Components

1.	Special optical tracking unit design studies	$ 10,000
2.	Optical range finder design	50,000
3.	Missile airframe design	10,000
4.	Miniaturized radio range equipment development	50,000
	Total for Final Components	$120,000

III. Miscellaneous Items

1.	Coordination of work of associated contractors	$ 20,000
2.	Continued study of direct fire beacon items for possible future alternate homing system	5,000
3.	Study of alternate radar tracking head for bad weather operation	5,000
	Total Miscellaneous	$ 30,000

IV. Total Estimated Cost - Fiscal 1951 Program $460,000

DOCUMENT 3

E X T R A C T
(pp. 33-36)

SUMMARY REPORT

PROJECT LACROSSE

CORNELL AERONAUTICAL LABORATORY, INC.

Report No. BE-712-S-1

Contract DA-30-115-ORD-11

BY: A. Ahlin

APPROVED: R. Schedvin

DATE: 15 February 1951

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RECOMMENDATIONS

Generally speaking, the work performed under this contract has reaffirmed the tactical feasibility of the Lacrosse system, particularly with respect to the action of key components. As a result of this work, it has been recommended to the Office, Chief of Ordnance, Department of the Army, that the Lacrosse Project be continued and that full effort be applied to the development of a prototype missile system based on the STEER and STEER-1 concepts. The following summary is a general outline of these recommendations:

1. System Tests -

It is recommended that a flight test program be conducted using a Beechcraft airplane, or equivalent, to act as a simulated missile. The purpose of this test program is to determine the prospective accuracy of the system using interim components such as the optical tracker, proportional command radio link, distance measuring equipment and command signal generator.

2. Simulator Tests -

It is recommended that an analogue computer be adapted to serve as a simulator for dynamic analyses of system performance. Machine computations would permit evaluation of system components prior to full scale tests and would permit selection of the most promising components while they are still in the breadboard stage.

3. All-Weather Operation Studies -

The all-weather operation aspects of Project Lacrosse will require electronic components such as high frequency electronic angular trackers. Currently available radar equipment will not satisfy the requirements of Lacrosse but will suffice for interim tests of the feasibility of electronic tracking. It is recommended that a radar tracking device be developed or procured suitable for tests with the Beechcraft and that a development program be undertaken for a high frequency electronic angular tracker suitable for Lacrosse accuracies.

4. Missile Development -

Although the Beechcraft flight tests of the Lacrosse system will provide a check of total system performance, it will be necessary to conduct tests with a Flight Test Vehicle, incorporating miniaturized airborne components, to permit analysis and evaluation of operations with a missile. The FTV should be fully instrumented to record this operation of the missile and its response to the radio command link. Tactical conditions could be simulated during the FTV tests to demonstrate the probable success of the system.

The FTV program should be paralleled with a prototype missile development based to a large degree on the FTV results. This development program should be coordinated with the development of all components into miniaturized tactical configurations for both ground based and airborne equipment.

Therefore, it is recommended that airframes be procured for Flight Test Vehicles and that these airframes be practically "off-the-shelf" variety to permit testing of the system as soon as possible. Development of a full scale prototype missile should be undertaken, to meet the requirements of Project Lacrosse, consistent with results of the FTV test program.

Anent the above recommendations, it is proposed that a development and test program be pursued as follows:

PROPOSED LACROSSE TASK STATEMENT

"C.A.L. shall undertake a research and development program of ten months duration which is to be part of a longer program directed towards the development of a direct support guided missile system designated Lacrosse. This program shall first complete the design and construction or procurement in breadboard form of the guidance components of the Lacrosse system recommended for development at the conclusion of the evaluation phase of Lacrosse under Contract NOrd 10629 and initiated under Contract DA-30-115-ORD-11. The components of this system consisting primarily of a radio command link, electronic ranging equipment, an optical tracking unit, and a command computer shall first be tested individually. Dynamic analyses of the system performance shall then be made by procuring and adapting an analogue computer to serve as a simulator.

"Following simulator tests, the system shall be connected to a conventional airplane which shall be adapted to respond to the guidance control system. Pilot-monitored, system evaluation, flight tests will be run to determine the prospective accuracy of the guidance system. Instrumentation and other essential equipment for the airplane tests will be provided as required.

"In addition to the work on the development and test of the system with an airplane, studies of means of operating system under all-weather conditions shall be made. Design and possibly development or procurement of a radar tracking device to replace the optical tracker shall be undertaken. System performance analyses and design studies employing radar tracking means and other promising alternate approaches to direct support missile guidance shall be conducted.

"Preparation for tests in a missile control test vehicle and for subsequent development of a prototype Lacrosse system will be undertaken. Accordingly, procurement and necessary redesign of a control test vehicle shall be accomplished along with such preliminary studies,

tests, procurement and evaluations of the prototype missile system, its components and its operations as are necessary to an over-all integrated Lacrosse development. The desired Lacrosse system performance characteristics are to be defined in consultation with the Office, Chief of Ordnance, U. S. Army, as the work progresses in accordance with the objective of obtaining a useful direct support weapon of high accuracy in the shortest feasible time.

"The work shall include cooperation and joint activity as may be feasible with those groups in the Armed Services and other agencies which are actively concerned with the development, testing, production and use of similar or related weapon systems and missiles for the United States Government. The work also includes responsibility for selection of subcontractors and assignment of subcontracts as well as the technical supervision and guidance of subcontractors selected to work on the Lacrosse program."

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DOCUMENT 4

(U) HISTORY OF CORNELL AERONAUTICAL LABORATORY, INC.

The Cornell Aeronautical Laboratory (CAL), a wholly owned subsidiary of Cornell University, Ithaca, New York, operates under a business franchise of the State of New York. The laboratory located at 4455 Genesee Street, Buffalo 21, New York, was a gift to the university by the Curtiss-Wright Corporation.

The prologue to CAL reaches back to February 1943, when the Airplane Division of the Curtiss-Wright Corporation dedicated its Research Laboratory and appointed Dr. Clifford C. Furnas as director.* The early organization was comprised of three technical departments, 124 personnel, and 90,000 square feet of laboratory space. Its tasks included investigation of problems of aircraft and associated equipment under development by Curtiss-Wright and some contract research for the armed forces.

At the end of World War II, Curtiss-Wright sought to convert its Research Laboratory into a public research organization. In December 1945, Cornell University accepted the laboratory and equipment as a gift from Curtiss-Wright and simultaneously six eastern aircraft companies contributed generously to a working fund. The Research Laboratory was then given the name of Cornell Aeronautical Laboratory and dedicated to "the interests of aviation and the welfare of the nation."[1] It was incorporated as a nonprofit stock corporation of New York in 1958, and thus became an independent unit not involving the university in its business transactions, though a subsidiary of the same.

By May 1954, the laboratory space had been expanded to some 240,000 square feet. Assets of the corporation were valued at $6 million, about one-half of which was invested in a variable wind tunnel and the rest in research tools and equipment, real estate, and working capital. Gross sales in FY 1954 exceeded $10 million. A large part of these sales came through Government R&D contracts, including such projects as the PLATO and LACROSSE. Cornell did not participate in production of any kind.

By mid-1956, CAL was ending its first decade of growth. In these progressive years, its annual volume of research had increased from $2

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* Dr. Furnas remained in this position until 1948, and served as Executive Vice President until his resignation in 1954. He was appointed Assistant Secretary of Defense in 1956.

1. Bibliography, Reference 1, p. 8.

million to $12 million; the number of technical departments had expanded from three to ten; and its personnel had grown from 124 to 1100. The volume and diversity of CAL's technical accomplishments had more than tripled. And in the process the laboratory had indeed served "the welfare of the nation" through its immeasurable contributions to the advancement of aeronautical technology.

BIBLIOGRAPHY

1. "A Decade of Research, 1946-56," CAL, Buffalo 21, N. Y., 1956, AOMC Tech Library

2. Alvin E. Green, Assistant Contract Manager, CAL, letter to CG, Redstone Arsenal, subj "Facility Data - Cornell Aeronautical Laboratory, Inc.," 26 May 54, ARGMA Industrial Operations File.

3. Henry K. Moffitt, CAL Assistant Director - Business, "The Business Operation of Cornell Aeronautical Laboratory, Inc.," 1 Jul 53 and 19 Nov 54, ARGMA Industrial Operations File.

DOCUMENT 5

HISTORY OF THE MARTIN COMPANY*

The Martin Company is almost as old as powered flight itself. Today, its products and activities have gone far beyond aircraft to include the design, development and production of missiles and space systems, electronic components and systems, and specialized nuclear power applications.

The Company began when Glenn L. Martin, a 19-year-old son of a hardware dealer of a Santa Ana, California, read a newspaper account of the Wright Brothers' early flights. To him, the Wright machine was simply a boxkite with a motor and closely related to the boxkites that he had built since he was six.

By 1908, young Martin had decided to build an adaption of the Curtiss biplane. Through hard work and extensive research, he saw it to a greater future. On August 1, 1909, the boxkite airplane was flown over meadows near Santa Ana, California. To combat public skepticism and finance his continuing efforts, Mr. Martin began a series of flight exhibitions in November, 1910.

His search for backing reached fruitation on August 16, 1912, when The Glenn L. Martin Company came into being as a business. With the formal incorporation of the business, the first Martin plant began operation in Los Angeles, California, with 14 employees. Buyers for Martin planes were scarce—Lincoln Beachey, an outstanding flyer; and William Edward Boeing, who was to later build planes in his own name. Into the business came some of the best brains of the time—Donald Douglas, a chief engineer; Lawrence Bell, as factory superintendent; and J. J. "Dutch" Kindelberger (North American), all of whom were later to head their own aircraft companies. The combination achieved some notable results.

In 1916, Mr. Martin merged interests briefly with those of the Wrights in the Wright-Martin Company. The merger was dissolved the following year and Martin was again an independent company. With the backing of Cleveland financiers, the plant was moved to Cleveland, Ohio, in 1918. Here the Martin-Douglas-Bell-Kindelberger team built the MB bomber, the first step in the U. S. in the production of "a useful article" for air warfare.

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*Information pamphlets covering the history of The Martin Company furnished by the Martin Company Branch Office, Huntsville, Alabama.

By 1929, the Cleveland facilities had outgrown the Company's venture. The plant was moved to Baltimore, Maryland, for its proximity to Washington, D. C., where most of its business originated with the Armed Forces, and for a water front to test the new Martin seaplanes. Here was also afforded a mild year-round climate for flying and good rail connections. At Baltimore were built most of the planes that made the name "Martin" an aviation byword. Among these were the BM-1, the first practical dive-bomber; the B-10 of the early 1930's, a revolutionary bomber which made almost every other military aircraft in the world obsolete overnight and which won the Collier Trophy; the internationally famous CHINA CLIPPER; the rugged B-26 MARAUDERS of World War II; the giant MARS flying boats; and the independent Navy seaplanes—from the PM-1 of 1930 to the P5M MAKLIN of the 1950's. In 50 years, Martin, a major manufacturer of military and commercial aircraft, built more than 12,000 planes.

Following World War II, fast-changing military technology brought about an equally vast change in the nature of Martin products. The shift was so profound that it became a new firm, with emphasis on missiles, electronics, nucleonics, guidance systems, and space vehicles. The Company now has production facilities at Baltimore, Maryland; Denver, Colorado; and Orlando, Florida, along with a separate division at Cocoa, Florida, created to supervise field testing of missiles at Cape Canaveral. Martin employes some 40,000 people, including more than 7,500 engineers, 3,000 of whom specialized in electronics.

One of the Martin Company's first significant post-war projects (in the late 1940's) was the Navy's VIKING, a single-stage, high altitude research rocket, which established Martin as a leader in this field. Experience gained in this program gave valuable background for Project VANGUARD, under which the Company designed and built three-stage rockets to launch significantly-instrumented, earth orbiting satellites. On March 17, 1958, a VANGUARD test vehicle lifted a radio-equipped satellite into orbit. Two additional satellites were subsequently launched by Martin-built VANGUARD rockets.

As the Air Age gave way to the Space Age, Martin was in the forefront of new developments. As part of its shift to the new era, the Company simplified its name on April 22, 1957, to The Martin Company. In 1959, 72 per cent of the firm's backlog was in missiles. After half a century, Martin was still a pioneer—but in fields far different from that in which it began. As stated by Board Chairman George M. Bunker: "For practical purposes, we are out of the aircraft business.... You might say we were the first in and the first out." The Company phased out of aircraft production in 1960 and now concentrates entirely in the advanced aerospace technologies.

In October, 1961, Martin and American-Marietta companies were consolidated to form Martin Marietta Corporation. In the new corporate organization, Martin Company is the aerospace division of Martin Marietta

The corporation operates other divisions in the construction materials, chemical and paint fields.

The following shows the financial and personnel status of The Martin Company, based on 1961 figures:

FINANCIAL: Sales: $830,000,000
Annual Payroll: $322,500,000
Purchases: $371,400,000
Purchases from small business firms: $119,300,000 (32 per cent of total)
Number of suppliers: 7,694

PERSONNEL: Total employment: 40,365
Baltimore area (includes Space Systems, Nuclear, Electronic Systems & Products Divisions, RIAS, and General Offices): 10,888
Denver Division: 17,813
Orlando Division: 10,682
Canaveral Division: 982
Scientific and engineering personnel of all types account for approximately 12,000 of total Martin employment.

DOCUMENT 6

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
Washington, D. C.

ORDTU 11 January 1954

SUBJECT: Assignment of Responsibilities for Project LACROSSE, DA-516-05-002, TU1-2020

TO: Commanding General
Redstone Arsenal
Huntsville, Alabama

REFERENCE: a. Ordnance Corps Order 43-52, dated 29 September 1952.

b. RSA letter 322/56, subject: "Transfer to RSA of Technical Supervision of Rocket and Guided Missile Projects, " with 1st and 2nd Indorsements thereto.

1. Reference a. outlines and defines the functional responsibilities involved in the prosecution of Ordnance Research and Development Projects.

2. Reference b. recommended that research and development responsibility of all guided missile projects be transferred to Redstone Arsenal.

3. Responsibilities as defined by reference a. are hereby assigned to Redstone Arsenal for technical supervision of Project LACROSSE.

4. Assigned responsibilities include close technical liaison with other Government field installations involved in developments related to the LACROSSE Missile System. Current related projects are:

Dept of Army Number	Project Title	Responsible Field Agency
416-16-014	500# Incendiary Warhead for LACROSSE	Chemical and Radiological Laboratories Army Chemical Center, Edgewood Arsenal.

ORDTU
SUBJECT: Assignment of Responsibilities for Project LACROSSE, DA-5-16-05-002, TU1-2020.

Dept of Army Number	Project Title	Responsible Field Agency
516-16-009	Warhead for LACROSSE Surface-to-Surface Guided Missile	Aberdeen Proving Ground and Picatinny Arsenal
517-10-028	JATO 3ES32000 T 52 Booster	Picatinny Arsenal
505-02-023	Fuze, Warhead T1405	Frankford Arsenal

5. Part of the LACROSSE development is being conducted by installations which are under the control of the Research and Development Division Branches other than ORDTU. It is desired that recommendations be submitted through ORDTU regarding changes, improvements, cancellations or accelerations that may be required to maintain proper phasing within the LACROSSE Project.

BY COMMAND OF MAJOR GENERAL CUMMINGS:

LESLIE E. SIMON
Major General, USA
Assistant Chief of Ordnance

cc:
Cornell Aeronautical Laboratory
Project LACROSSE, Buffalo, New York

Rochester Ordnance District
Sibley Tower Bldg, Rochester, N. Y.

CG, WSPG, Las Cruces, New Mexico
CO, Picatinny Arsenal, Dover, N.J.
CO, Frankford Arsenal, Phila. 37, Pa.
CG, Aberdeen Proving Ground, Aberdeen, Md.

DOCUMENT 7
ORDNANCE COMMITTEE
ITEM 36066
19 JAN 56

U682
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DEPARTMENT OF THE ARMY
Office of the Chief of Ordnance

MAHawkins/gta/54091
4 October 1955

FROM: Subcommittee on Guided Missiles

TO: The Ordnance Technical Committee

SUBJECT: CLOSE SUPPORT ARTILLERY GUIDED MISSILE SYSTEM - DOA Project 516-05-002 (TU1-2020) - Project LACROSSE - Statement of Military Characteristics (U)

1. REFERENCES:

a. OCM 33399, 31 August 50, "Surface-to-Surface Guided Missile (LACROSSE)".

b. OCM 34980, 24 Sep 53, "Security Classification of Guided Missile Projects".

c. OCM 34981, 24 Sep 53, "Warhead for LACROSSE (XSSM-A-12), Surface-to-Surface Guided Missile - Initiation of Development".

d. File 00/5S-5871, 5 Jul 55, "Military Characteristics for a Close Support Guided Missile System".

2. DISCUSSION:

a. Project LACROSSE was established by the Department of the Navy to fulfill a requirement of the Marine Corps for a highly accurate surface-to-surface guided missile system which would be tactically acceptable for employment in the close support of amphibious and or ground operations. In 1950, the Secretary of Defense, upon recommendation of the Joint Chiefs of Staff, transferred the LACROSSE Project from the Department of the Navy to the Department of the Army for the continuation of research and development (ref 1a).

b. Reference 1d forwards military characteristics for a close support guided missile system and recommends that Project LACROSSE, DOA 516-05-002 (TU1-2020) be continued to meet these characteristics.

3. RECOMMENDATIONS: The subcommittee recommends:

a. That military characteristics for a Close Support Field Artillery Guided Missile System outlined in attached project card (Appendix 1) be approved.

b. That Project LACROSSE, DOA Project No. 516-05-002 (TU1-2020), Priority 1A, Technical Objective LC-16, and Modernization Code X be continued to meet these military characteristics.

c. That security classification rules contained in attached Security Check Lists (Appendix 2) be approved.

d. That this subcommittee report be classified CONFIDENTIAL, and that the Security Check Lists (APPENDIX 2a, 2b, and 2c) be UNCLASSIFIED.

* * * * * * * *

Action by: Rocket Br, Ord Res & Dev Div
Approval of higher authority is required.

APPROVED
/s/ CHARLES L. REGISTER
Col, Ord Corps
Chairman Pro Tem

APPROVED BY ORDNANCE COMMITTEE
19 JAN 56
/s/ A. W. STODDARD
Col, Ord Corps
Secretary

APPROVED BY ORDER OF
THE SECRETARY OF THE ARMY

/s/ CHARLES L. BEAUDRY, Col, GS

For the Chief of Res. and Dev., OCS

E X T R A C T

RESEARCH AND DEVELOPMENT PROJECT CARD
(Appendix 1 to OTCM 36066)

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21. BRIEF OF PROJECT AND OBJECTIVE

a. Brief:

(1) Operational Concept: The primary mission of this close-support guided missile system is to destroy heavy fortifications and other stationary "hard" targets with precision fire. A secondary mission may be the attack of materiel and personnel targets with appropriate warheads. Forward observer teams for this system will be organized and equipped to work in conjunction with division artillery in direct support of infantry battalions. All forward guidance equipment will be man-transportable, and each forward observer team will be capable of operating either from a 1/4 ton-truck or dismounted. It is not contemplated that this missile system will be used against any target which could be attacked more economically or efficiently by another weapon.

(2) Organizational Concept: The basic fire unit for the close support guided missile system will be a separate battery capable of independent operation. A battery will contain four self-propelled launchers, two sets of assembly and loading equipment and two forward guidance stations. The basic load of missiles will be four per launcher. The basis of allocation will be one close support guided missile battery per corps. During the period when only the shaped charge warhead is available, the close support guided missile battery may be attached to a division for specific missions. Following development of atomic and/or optimum fragmentation warheads for this weapon system, the basis of its allocation will be reviewed to provide battery strength support per division. This might be by assignment of one battalion per corps, or one separate battery per division.

(3) Consideration of Tripartite, Navy, Air Force, and Marine Corps Development Activities: A review of development projects of other services and tripartite nations discloses no system whose characteristics are such as to fulfill the requirement for a surface-to-surface missile as herein described.

(4) Feasibility of Development: The development of the close-support guided missile system having the characteristics herein described is considered feasible and practicable. If during the development phase it appears to the design agency 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 serve as a detriment to the military

value of the item, such matters will be brought to the immediate attention of Department of the Army and Continental Army Command for careful consideration before incorporation in the final design.

(5) Configuration:

(a) General - The size and weight of all major components of the system shall be the minimum attainable, compatible with their intended employment, characteristics specified, and subject to such limitations as are imposed by:

(1) SR 705-30-10

(2) AR 700-105 (use loading table on page 9, column headed "Most Foreign Lines (Berne International) Standard Gauge").

(b) Guidance and Control. The equipment required in the forward guidance station shall be as light as possible, and shall be capable of being broken down into man-transportable loads.

(6) Performance:

(a) Ranges.

(1) Maximum missile range.

(a) Required. Not less than 20,000 meters.

(b) Desired. Not less than 30,000 meters.

(2) Minimum missile range.

(a) Required. Not more than 8,000 meters.

(b) Desired. As short as possible consistent with other requirements.

(3) Maximum guidance range (using target survey unit data).

(a) Required. Not less than 5,000 meters.

(b) Desired. Not less than 8,000 meters.

(4) Maximum guidance range (using external data) (see subpara g below).

(a) Required. Not less than 15,000 meters.

(b) Desired. Not less than 20,000 meters.

(5) Minimum guidance range.

(a) Required. Not more than 250 meters.

(b) Desired. As short as possible consistent with other considerations of the system.

(b) Midcourse guidance. Provision will be made to guide the missile by inertial means between launch and acquisition by terminal guidance equipment.

(c) Accuracy. Since this assault guided missile system is required specifically to destroy hard "point targets," accuracy and lethality are its most important characteristics. The degree of accuracy which can be achieved by the system has a very important effect on the flexibility of employment of the system in that accuracy governs the size of target which may be attacked effectively. An extremely high degree of accuracy will permit the efficient attack of relatively small fortifications which are far more numerous than large fortifications: hence accuracy will determine to a major degree the usefulness of the weapon. If a forward guidance station is employed it is believed that certain of its elements will normally be emplaced so that they are masked from the target by terrain, in order to minimize hostile countermeasures. This usage of the system shall not cause degradation of the missile accuracy. Under all conditions specified in this and in paragraph (1) above, the system shall have the following accuracy:

(1) Required. CPE not to exceed five meters.

(2) Desired. CPE not to exceed two meters.

However, if the system is utilized to fire upon targets located by external sources (see subpara g below), the desired accuracy requirement of the system will be 30 to 40 meters CPE at 20,000 meters.

(d) Lethality. Assuming a direct hit on a hard target, the missile warhead shall have sufficient lethality to destroy fortifications of the type normally encountered in a deliberately prepared defensive position. A capability of penetrating a minimum of six feet of reinforced concrete at 60° obliquity or twelve feet at 0° obliquity is required. In addition, warhead design shall be such as to produce beyond-penetration effects rendering inoperative personnel occupying the defeated fortification.

(e) Speed. In order to reduce the vulnerability of the missile to small arms and antiaircraft artillery automatic weapons fire, the speed of the missile shall be the maximum commensurate with the maneuverability and control required to accomplish the accuracy specified in subparagraph c above.

(f) Propulsion. A solid propellant rocket motor is required and shall be integral to the missile.

(g) Guidance and Control. Any system of guidance which will accomplish the accuracy requirement stated herein throughout the required range will be acceptable. The following characteristics are desired of the guidance system:

(1) The system shall permit engagement of targets within a 360 degree sector around the forward guidance station.

(2) Line of sight will not be required between launcher and ground guidance equipment.

(3) Suitable antijamming features shall be designed into the missile and into the ground guidance equipment to minimize the effect of enemy electronic countermeasures and effectively reduce interference from friendly control stations or other electronic devices. It shall be possible to operate simultaneously two or more guidance stations, each controlling a missile, in the same vicinity without mutual interference.

(4) It shall be possible that two or more sets of launchers can support the same forward guidance station, when required, with no more than minor adjustments in the system.

(5) It is required that the guidance system be capable of successfully attacking targets not observable from the forward guidance station because of darkness, inclement weather, or terrain masking; or targets beyond the range of the target location equipment. For this reason, the ground guidance equipment must be capable of accepting firing data obtained from outside sources such as map or survey data, or target location data previously determined by the target location equipment. It is realized that the system accuracy will be degraded by terrain masking, target location error, and extended ranges. It is required that the equipment accept such data for targets as far as 15,000 meters from the ground guidance equipment, but it is highly desirable that this capability be extended to 20,000 meters.

(h) Rate of Fire.

(1) The cyclic rate of fire shall be not less than four missiles per hour per launcher provided the launcher is loaded at its launching site.

(2) A single guidance station shall be capable of handling 8 missiles per hour where each missile is guided to a different target.

(i) Launcher. Because of the smoke and dust stirred up by the exhaust gas of a rocket motor and the cone of flame emanating from a burning rocket motor, guided missile launching positions are highly susceptible to location by hostile observation facilities. Furthermore, a missile launcher with a missile in place prepared for launching is highly susceptible to detection by hostile aerial observation. These conditions dictate that the missile launcher for a relatively short range guided missile system will probably have to be moved frequently and must have high mobility to permit this movement in as short a time as possible.

(1) A self-propelled launcher for this application is very desirable.

(2) The missile launcher shall be capable of transporting an assembled missile cross country from an assembly area

in the vicinity of the launching site to the launching site.

(3) Being in close vicinity to a prepared launching site and loaded with a previously checked out missile, in traveling position, no more than fifteen minutes shall be required to emplace the launcher, orient in azimuth and elevation, make final missile check, and fire.

(4) The missile launcher shall be capable of going "out of action" and into traveling position in not more than ten minutes.

(5) The missile launcher shall be equipped with the necessary sighting, traversing, leveling, and elevating mechanisms to permit rapid positioning of the missile for launching. The launcher and/or its on-carriage fire control system shall compensate for cants up to 10° and forward or reverse slopes up to 10°. Standard field artillery sighting and laying equipment are desirable for laying in azimuth and elevation. Provision for manual elevating, traversing, and leveling is required. Power assist is desirable.

(6) The missile launcher shall provide for traversing the launching rails at least 10 degrees (15 degrees desirable) either side of center without moving the launcher mount and without the use of outrigger stabilizing jacks. The missile launcher shall be capable of being repositioned rapidly throughout 360 degrees to a new center when azimuth shifts greater than the capability of the on-carriage traverse is required. It is desired that this repositioning be accomplished in less than two minutes.

(j) Missile.

(1) Safety to crew members and ease of handling shall be stressed in the missile design.

(2) The missile shall be so designed that it may be removed from its container and assembled with the expenditure of not more than one man hour of labor.

(3) The missile shall be so designed that rapid functional tests can be performed with the expenditure of not over one man hour of labor.

(4) The missile shall be designed so that a "go-no-go" check can be made immediately prior to firing in an elapsed time of not more than five minutes.

(5) Warhead.

(a) The following warheads shall be developed in order of priority.

(1) Shaped charge or other penetration type with lethality as specified in subparagraph d above.

(2) Practice warhead for training. This warhead should be of the cheapest inert construction that will permit normal performance of the missile. No spotting charge or fuze is required.

(b) Feasibility studies should be conducted to determine the practicability of the use of the following warheads with the missile system:

(1) An atomic warhead whose development time scale will be commensurate with the missile system development time scale.

(2) An optimum fragmentation warhead that might be developed.

(c) Fuzing and Arming.

(1) The warhead fuze shall be armed by command while the missile is in flight.

(2) The warhead and fuze system shall be so designed as to prevent detonation, or at least high-order detonation, of an unarmed warhead on impact.

(3) The fuze systems required with the warheads, listed in subparagraph (5) (a) above, shall be designed so as to maximize standardization of components.

(7) Durability and Reliability.

(a) Ruggedness. All elements of the system, including the missiles, must be sufficiently rugged to withstand without damage those conditions of transportability and environment as required in paragraphs (8) and (10) below

(b) Reliability. The reliability of the missile system should be such that:

(1) At least 90% of the missiles removed from six months storage (depot or field) must pass all prefiring checkout tests with only minor adjustments or component replacement by battalion or battery personnel.

(2) Of the missiles which pass the pre-firing checkout tests, not more than 5% may fail to launch at the designated time due to system malfunction throughout a 72 hour period following checkout.

(3) In the absence of effective counter-measures, those missiles which launch must have an in-flight reliability of 95%. This is the degree of assurance that after launch, the missile will not abort due to failure of missile or ground components, but will

deliver its payload to the specified target within the normal dispersion limits associated with the required accuracies.

(c) Simplicity. Insofar as possible the missile and its associated equipment shall be designed so that all operations from removal from storage to firing can be accomplished with the minimum of personnel. It shall be possible to train operating and maintenance personnel quickly and easily. Checks and tests shall be accomplished by simple test equipment, preferably of the "go-no-go" type, usable by semiskilled personnel.

(d) Readiness.

(1) Total preparation required at the launcher shall be held to a minimum.

(2) The missile shall be capable of standing on the launcher in a "ready" condition for at least 24 hours. The reliability requirement stated in subparagraph (7)(b)(2) above, applies if the missile is fired at any time during the period of readiness.

(3) Missiles shall be capable of being removed from "ready-to-launch" condition and returned to storage.

(4) Electrical components which have a significant delay after being turned on, due to warm-up before operation, should be capable of being kept in a "ready-to-launch" state for extended periods.

(e) Safety. Maximum safety provisions shall be incorporated to reduce hazards to using troops, friendly personnel and installations.

(8) Transportability. It is required that the complete system be highly mobile and all elements of the system including missiles be capable of being transported without damage by:

(a) Organic transportation over unimproved roads and field terrain. It shall be at least as mobile as medium field artillery. Specially designed transport, if any, should employ standard chassis to the maximum extent possible. If practicable, standard Army trailers will be used. The weight, dimensions, and wheel loading of the vehicles adopted or designed for this missile system shall not exceed the limitations prescribed in Section II of AR 700-105.

(b) Air. In Phase II of the airborne operation (SR 705-30-10). The design of major items of the missile system shall provide for center of gravity markings, and the necessary tie-down fittings required for transportation in military cargo aircraft.

(c) Rail (AR 700-105).

(d) Ship.

(e) Landing craft. In amphibious operation (SR 705-125-10).

(9) Associated Equipment.

(a) Checkout and test equipment.

(1) General. All test and checkout equipment shall be as simple, reliable, compact and rugged as possible, and shall be designed to:

(a) Permit functional type tests which will, in themselves, indicate whether the item being tested is operating properly.

(b) Utilize multi-wafer or "gang" switches, labeled functionally.

(c) Trouble shoot, calibrate, and prepare all individual major elements for the system for operation except during final checkout when test equipment will indicate "go-no-go".

(2) Missile test equipment. This test equipment shall be designed so that:

(a) Rapid functional tests on the missile can be performed.

(b) Major missile components, which are non-functioning or operating beyond tolerance limits are immediately indicated.

(c) Any defective, plug-in type, components can be rapidly isolated except during final checkout when test equipment will indicate "go-no-go".

(b) Training equipment and manuals. Concurrently with the development of the missile system it is required that training aids necessary for the conduct of troop training and Army school training be developed. These include:

(1) Manuals. For all equipment not standard to the Army on:

(a) Theory of operation.

(b) Maintenance and repair.

(c) Operators instructions.

(2) Wall charts and slides.

(3) Mock-ups and breadboards.

(4) Practice and dummy warheads.

(5) Dummy missiles.

(c) Tools and parts lists. Concurrently with the development of the missile system it is required that there be developed:

(1) Standard and special tool lists.

(2) Spare parts lists.

(d) Packaging. The missile system shall be so packaged as to withstand transport by rail, ship, or aircraft, by motor vehicle over rough roads and cross country, landings through surf and across beaches, and the normal hazards of loading, unloading, and handling incident to transport and storage.

(10) Environmental Conditions.

(a) General. The missile system shall be capable of operation and storage under environmental conditions as set forth in SR 705-70-5 and MIL-STD-210, 1 June 1953.

(b) Special requirements.

(1) Operability.

(a) The equipment is required to have the inherent capability of acceptable performance within an air temperature extending from 125°F (minimum exposure of 4 hours with full impact of solar radiation (360 BTU/sq ft/hr)) down to -40°F (minimum exposure of 3 days without benefit of solar radiation).

(b) If it can be accomplished with relatively small increase in cost and without material increase in size and weight, it is desirable that the design provide acceptable performance in air temperature down to -65°F.

(2) Storage and transport.

(a) The equipment is required to be capable of safe storage and transportation without impairment of its capabilities from the effects of temperatures from -40°F (for periods of at least 3 days duration) to 140°F (for periods as long as 4 hours per day).

(b) If it can be accomplished with relatively small increase in cost and without material increase in size and weight, it is desirable that the equipment be susceptible to safe storage and transportation without impairment of its capabilities from

the effects of temperatures from -80°F (duration of 24 hours, preceded and followed by equilibrium at -40°F) to 160°F (for periods as long as 4 hours per day).

(3) Barometric pressure.

(a) It is required that the equipment shall be designed to permit launching at atmospheric pressures encountered from sea level to 10,000 feet altitude above sea level.

(b) It is required that the equipment shall be designed to withstand, without damage, pressure encountered at 25,000 feet altitude while being air transported.

(4) Humidity. It is required that the system perform its intended function at all relative humidities up to 100% at all temperatures below 90°F and in those temperatures above 90°F at all relative humidities up to the maximum obtainable (not in excess of that corresponding to a vapor pressure of 36 inches of mercury if necessary).

(5) Wind. The system is required to withstand, without damage, surface gusts up to 75 miles per hour, and be capable of design performance in gusts up to 50 miles per hour and steady surface winds up to 40 miles per hour.

(6) Other conditions. The system is required to withstand without damage and be capable of acceptable performance when subjected to:

(a) Wind blown objects such as snow, sand, and dust.

(b) Extreme precipitation in form of rain, snow, sleet, hail, and freezing rain.

(c) Salt spray as encountered in a beach location.

(d) Swarms of insects.

(e) Fungus.

(11) Kit Requirements.

(a) Low Temperature operations. The development of kits that may be necessary to permit an operating range down to -65°F shall not delay the system.

(b) Fordability. Waterproofing kits as may be required by SR 705-125-10 to meet the fordability characteristics required for combat and tactical operations.

(12) Other Requirements.

(a) Over-all system. This shall be an integrated system of equipment which will provide for handling, servicing, launching, guidance of the missile to the target, and destruction of the target. Necessary tools, checkout equipment, spare parts, training aids, instruction manuscripts, SNL's and TM's shall be included.

(b) Blackout. The system shall be capable of performing its mission effectively under all conditions of weather and visibility both day and night where the position of the target can be accurately fixed by visual or other means. The system shall be designed for operation under conditions of complete blackout.

(c) Arctic clothing. All elements of the equipment must be operable by personnel dressed in heavy arctic clothing.

(d) Minimum operating personnel. Consistent with other requirements of the system, it should be so designed to require the minimum of personnel both for operation and maintenance.

(e) Interchangeability. Where practicable, due consideration should be given to the use of standard items and/or components which would permit interchangeability with similar components of other standard systems or equipment.

(f) Storage. The missile system must be capable of dead storage for periods of three or more years and storage under field conditions for at least one year with only minor maintenance and preparation for active use.

(g) Alternate employment. Studies should be made concerning the feasibility, both from a technical and tactical viewpoint concerning all possible combinations of launching from ground, ship or Army aircraft (including helicopters) and guiding from ground, ship, or air (including helicopters) with changes in equipment being minimized.

(13) Order of Priority. In the case of competing characteristics, the developing agency will give priority in the following order of absolute essentiality:

(a) Accuracy.

(b) Lethality.

(c) Immunity to countermeasures.

(d) Reliability.

(e) Safety.

(f) Simplicity.

(g) Range of effective guidance.

(h) Minimum size and weight.

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OTCM 36527
APPROVED - 13 JUN 57

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DEPARTMENT OF THE ARMY
Office of the Chief of Ordnance

EHayer/bh/73916
16 May 1957

FROM: Subcommittee on Guided Missiles

TO: Ordnance Technical Committee

SUBJECT: GENERAL SUPPORT FIELD ARTILLERY GUIDED MISSILE SYSTEM - LACROSSE - DOA Project 516-05-002 (TU1-2020) - Revision and Restatement of Military Characteristics (U)

1. REFERENCES:

References pertinent to this project are contained in paragraph 21a of attached Appendix I, DD Form 613.

2. DISCUSSION:

a. The approval of the operational and organizational concept for the LACROSSE General Support Field Artillery Missile in reference to atomic and conventional warheads requires a revision in Military Characteristics to include the additional requirements for the missile system. This subcommittee report, in addition to a statement of the Military Characteristics reflecting the expanded tactical mission, also includes the modification of certain characteristics to reflect the results of system performance being achieved during development and test. This subcommittee report is a complete rewrite of OTCM 36066

b. Appendix I, DD Form 613, attached, includes other information pertinent to this project

c. Security check lists for components of the LACROSSE system were published as OTCM 36482, dated 14 March 1957.

d. Funds for this project are available in the Ordnance Corps, Department of the Army

3. RECOMMENDATIONS:

The Subcommittee recommends:

a. That the revised Military Characteristics for a General Support Field Artillery Guided Missile System - LACROSSE, be approved.

b. That Project LACROSSE, DOA Project 516-05-002, (TU1-2020) with Priority 1A, Technical Objective LC-16 and Modernization Code X, be continued to meet these revised Military Characteristics.

c. That security classification of CONFIDENTIAL for the project be continued but that this paper be classified SECRET.

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This item is of interest to the USMC.

/s/ Edward Hayer
C. W. CLARK
Col, Ord Corps
Chairman, Subcommittee

E X T R A C T

RESEARCH AND DEVELOPMENT PROJECT CARD
(Appendix I to OTCM 36527)

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21. b. Approach:

Additional requirements of the missile system envisioned for LACROSSE in respect to atomic and conventional warheads requires a revision in Military Characteristics to include these added requirements. The expanded tactical mission as reflected in the revised Military Characteristics attached and the modification of certain characteristics as recorded in results of system performance presently being achieved will influence the development now underway.

c. Subtask:

(1) TU1-2020A - LACROSSE Missile and Related Equipment

(2) TU1-2020B - JATO, XM10 for LACROSSE Missile.

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e. Other Information:

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(3) The following nomenclature has been assigned:

(a) GUIDED MISSILE, ARTILLERY, XM4 (OTCM 36066)

(b) JATO UNIT, XM10 (OTCM 36066)

(c) FUZE, WARHEAD, PIBD, T1405 (OTCM 36066)

(d) LAUNCHER, GUIDED MISSILE, TRUCK MOUNTED, XM398 (OTCM 36066)

(e) CONTAINER, SHIPPING, MISSILE BODY, XM374 (OTCM 36066)

(f) WARHEAD, GUIDED MISSILE, T34, T34E1, T34E2 (OTCM 36218)

(g) WARHEAD, GUIDED MISSILE, T34E3 (Same as T34E1 except for modifications to provide a new method of attachment).

(h) WARHEAD, GUIDED MISSILE, INERT, T47 (OTCM 36218)

(i) WARHEAD, GUIDED MISSILE, T48 (OTCM 36218)

(j) WARHEAD, GUIDED MISSILE, INERT, T50 (OTCM 36218)

(k) IGNITER, JATO UNIT, XM47 (IGNITER for JATO UNIT, XM10

serving as an arming and disarming device for the missile propulsion system).

*(l) ELECTRONIC SHOP, TRUCK MOUNTED, XM411 (Consists of TRUCK, VAN, SHOP, 2½-TON, 6x6, M109 containing special tools and test equipment for the Ground Guidance Electronic Equipment).

*(m) ELECTRONIC SHOP, TRUCK MOUNTED, XM412 (Consists of TRUCK, VAN, SHOP, 2½-TON, 6x6, M109 containing special tools and test equipment for the missile electronic guidance and control system).

*(n) MAINTENANCE SHOP, SEMI TRAILER MOUNTED, XM413 (Consists of a SEMI TRAILER, VAN SHOP, 6-TON, 2-WHEEL, M146, containing special tools and equipment for field maintenance of the hydraulic, electrical and propulsion system of the XM4 guided missile body, and also for the wings and fins).

(o) TRUCK, HAND, GUIDED MISSILE BODY, XM414 (A welded tubular steel frame with pneumatic tires and capable of being separated into three separate units for supporting the forward sections, aft section and Jato during repair and maintenance.

(p) SLING, JATO UNIT, XM7 (A steel "strong back" type sling for use during installation and removal of the jato unit from the missile).

(q) SLING, GUIDED MISSILE, XM8 (A steel "strong back" type sling for use in handling of the LACROSSE missile body).

(r) SLING, GUIDED MISSILE, XM9 (A steel "strong back" type sling for use in handling of the XM4 guided missile).

f. Future Plans:

Development of Mod I and Phase I and Phase II Airborne Guidance Systems is to be continued. Work will be performed to meet the additional requirements as contained in the attached Revised Military Characteristics.

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* These items will be revised upon determination of the final test shop requirement.

REVISED MILITARY CHARACTERISTICS FOR A GENERAL SUPPORT FIELD ARTILLERY GUIDED MISSILE SYSTEM (S)
(Inclosure 1 to Appendix I, OTCM 36527)

1. Operational Concept:

a. The General Support Field Artillery Guided Missile System will be employed as corps artillery in general support and reinforcing roles against appropriate personnel and materiel targets, including heavy fortifications. The system will be capable of delivering accurate close support fires. The mobility of the General Support Field Artillery Guided Missile System will permit tactical employment similar to that of medium artillery. In order to insure a high degree of mobility and flexibility of operations in certain tactical situations, the system will have the capability of being helicopter transportable. Although the General Support Field Artillery Guided Missile battalions will normally be attached to artillery group headquarters to facilitate control by corps artillery, a battalion may be attached to a division in special situations. A LACROSSE battery having an assault landing capability during Phase I airborne operations will be organic to the new airborne division if the missile system proves to be the best general support weapon.

b. The General Support Field Artillery Guided Missile forward observer sections will be organized and equipped to work in conjunction with division artillery in support of airborne, infantry, and armor units. All forward guidance equipment will be man-transportable and each of these sections will be capable of operating either dismounted or from a 1/4-ton truck (with minimum number of items dismounted).

c. The battalion will be capable of a maximum rate of fire of at least four (4) missiles per launcher per hour for one hour provided the launcher is loaded at its firing position and a sustained rate of fire of at least eight (8) missiles per launcher per day.

2. Organizational Concept:

a. The basic General Support Field Artillery Guided Missile unit for corps artillery will be a small, separate battalion consisting of a headquarters and service battery and a firing battery. The battalion will have two sets of assembly and loading equipment (presently each set contains one (1) launcher), four launchers, and four forward guidance stations, and will be organized so as to be self-sustaining to the maximum extent practicable.

b. The basis of allocation will be three General Support Field Artillery Guided Missile battalions per corps. If the missile system proves to be the best general support weapon, one LACROSSE battery will be included in each airborne division.

c. The battalion will have 100 per cent tactical mobility.

3. Consideration of Tripartite, Navy, Air Force, and Marine Corps Development Activities:

A review of development projects of other services and tripartite nations discloses no system whose characteristics are such as to fulfill the requirement for a surface-to-surface missile as herein described.

4. Feasibility of Development:

The development of the close-support guided missile system having the characteristics herein described is considered feasible and practicable. If during the development phase it appears to the design agency 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 serve as a detriment to the military value of the item such matters will be brought to the immediate attention of Department of the Army and Continental Army Command for careful consideration before incorporation in the final design.

5. Configuration:

a. General. The size and weight of all major components of the system shall be the minimum attainable, compatible with their intended employment, characteristics specified, and subject to such limitations as are imposed by:

(1) SR 705-30-10

(2) Loading dimensions contained in Berne International Agreement ("Most Foreign Lines (Berne International) Standard Gauge").

b. Guidance and Control. The equipment required in the forward guidance station shall be as light as possible, and shall be capable of being broken down into man-transportable loads.

6. Performance:

a. Range:

(1) Maximum missile range:

(a) Required. Not less than 30,000 meters.
(b) Desired. Not less than 35,000 meters.

(2) Minimum missile range:

(a) Required. Not more than 8,000 meters.
(b) Desired. Not more than 4,000 meters.

(3) Maximum guidance range (using target survey unit data).

(a) Required. Not less than 5,000 meters.
(b) Desired. Not less than 8,000 meters.

(4) Maximum guidance range (using external data) (see subparagraph g. below).

(a) Required. Not less than 20,000 meters.
(b) Desired. Not less than 35,000 meters.

(5) Minimum guidance range:

(a) Required. Not more than 250 meters.
(b) Desired. As short as possible consistent with other considerations of the system.

b. Midcourse guidance. Provision will be made to guide the missile by inertial means between launch and acquisition by terminal guidance equipment.

c. Accuracy. The degree of accuracy which can be achieved by the system has a very important effect on the flexibility of employment of the system. An extremely high degree of accuracy will permit efficient and effective close support fire by the system; hence, accuracy is a determining factor in the usefulness of the system. It is anticipated that certain elements of a forward guidance station will normally be emplaced so that they are masked from the target by terrain in order to minimize hostile countermeasures. This usage of the system shall not cause degradation of the missile accuracy. The accuracy of the system shall be a function of the forward guidance station to target range. Under all conditions specified in this and in paragraph 1 above, the system shall have the following accuracy:

(1) Using integral equipment data at range as specified in subparagraph 6.a.(3) above.

(a) Required. CPE not to exceed five (5) meters.
(b) Desired. CPE not to exceed two (2) meters.

(2) Using data from external sources at ranges as specified in subparagraph 6.a.(4), the accuracies herein specified are those required of the system exclusive of target location accuracy.

(a) Required. CPE not to exceed 40 meters.
(b) Desired. CPE not to exceed 30 meters.

d. Lethality:

(1) Lethality with shaped charge warhead. Assuming a direct hit on a hard target, the missile warhead should have sufficient

lethality to destroy fortifications of the type normally encountered in a deliberately prepared defensive position. A capability of penetrating a minimum of six feet of reinforced concrete at 60° obliquity or 12 feet at zero degrees obliquity is required. In addition, warhead design shall be such as to produce beyond-penetration effects rendering inoperative personnel occupying the defeated fortification.

(2) Lethality with controlled fragmentation warhead. The lethality of the warhead shall be as high and uniform as practicable within a given maximum effects radius, and as low as possible outside this radius, and shall be such that the system accuracy and the lethality of the warhead shall produce an efficient and economical method of achieving the desired casualty effect.

e. Speed. In order to reduce the vulnerability of the missile to small arms and antiaircraft artillery and atomic weapons fire, the speed of the missile shall be the maximum commensurate with the maneuverability and control required to accomplish the accuracy specified in subparagraph c. above.

f. Propulsion. A solid propellant rocket motor is required and shall be integral to the missile.

g. Guidance and Control. Any system of guidance which will accomplish the accuracy requirement stated herein throughout the required range will be acceptable. The following characteristics are desired of the guidance system:

(1) The system shall permit engagement of targets within a 360 degree sector around the forward guidance station.

(2) Line of sight will not be required between launcher and ground guidance equipment.

(3) Suitable antijamming features shall be designed into the missile and into the ground guidance equipment to minimize the effect of enemy electronic countermeasures and effectively reduce interference from friendly control stations or other electronic devices. It shall be possible to operate simultaneously four guidance stations, each controlling a missile, in the same vicinity without mutual interference.

(4) Any launcher shall be capable of operating with any forward guidance station, and any forward guidance station shall be capable of operating with any launcher, with no more than minor adjustments in the system.

(5) It is required that the guidance system be capable of successfully attacking targets not observable from the forward guidance station because of darkness, inclement weather, or terrain masking; or targets beyond the range of the target location equipment. For this reason, the ground guidance equipment must be capable of

accepting firing data obtained from outside sources such as map or survey data, or target location data previously determined by the target location equipment. It is realized that the system accuracy will be degraded at extended guidance ranges when using data external to the system. It is required that the equipment accept such data for targets as far as 20,000 meters from the ground guidance quipment, but it is highly desirable that this capability be extended to at least 35,000 meters.

h. Rate of Fire:

(1) The maximum rate of fire shall be not less than four (4) missiles per launcher for one hour provided the launcher is loaded in its firing position.

(2) A single guidance station shall be capable of handling 8 missiles per hour where each missile is guided to a different target.

i. Launcher. Because of the smoke and dust stirred up by the exhaust gas of a rocket motor and the cone of flame emanating from a burning rocket motor, guided missile launching positions are highly susceptible to location by hostile observation facilities. Furthermore, a missile launcher with a missile in place prepared for launching is highly susceptible to detection by hostile aerial observation. Those conditions dictate that the missile launcher for a relatively short range guided missile system will probably have to be moved frequently and must have high mobility to permit this movement in as short a time as possible.

(1) A self-propelled launcher is required for support of sustained ground combat. If the self-propelled launcher cannot be helicopter transported, an additional special purpose helicopter transportable launcher is required.

(2) The self-propelled missile launcher shall be capable of transporting an assembled missile cross-country from an assembly area to the firing position.

(3) If a separate helicopter transportable launcher is required, the launcher shall be capable of being towed by a standard, light automotive vehicle. Ground mobility is required of the launcher and ancillary equipment to accomplish displacement necessary for the continuous support of ground operations in a moving situation.

(4) Being in close vicinity to a prepared launching site and loaded with a previously checked out missile, in traveling position, no more than 15 minutes shall be required to emplace the launcher(s), orient in azimuth and elevation, make final missile check, and fire.

(5) The missile launcher(s) shall be capable of going "out of action" and into traveling position in not more than five minutes.

(6) The missile launcher(s) shall be equipped with the necessary sighting, traversing, leveling, and elevating mechanisms to permit rapid positioning of the missile for launching. The launcher(s) and/or its on-carriage fire control system shall compensate for cants up to 10° and forward or reverse slopes up to 10°. Standard field artillery sighting and laying equipment are desirable for laying in azimuth and elevation. Provision for manual elevating, traversing, and leveling is required. Power assist is desirable.

(7) The missile launcher(s) shall provide for traversing the launching rails at least 10° (15° desirable) either side of center without moving the launcher mount and without the use of outrigger stabilizing jacks. The missile launcher(s) shall be capable of being repositioned rapidly through 360° to a new center when azimuth shifts greater than the capability of the on-carriage traverse are required. It is desired that this repositioning be accomplished in less than two minutes.

j. Missile:

(1) Safety to crew members and ease of handling shall be stressed in the missile design.

(2) The missile shall be so designed that it may be removed from its container and assembled with the expenditure of not more than one man hour of labor.

(3) The missile shall be so designed that rapid functional tests can be performed with the expenditure of not over one man hour of labor.

(4) The missile shall be designed so that a "go-no-go" check can be made immediately prior to firing in an elapsed time of not more than five minutes.

(5) Warheads:

(a) Types of warheads in order of priority are:

1. Atomic for use against personnel, installations, and any other appropriate tactical targets.

2. Controlled fragmentation for use against personnel and materiel.

3. Shaped charge or other penetration type with lethality as specified in subparagraph 6.d.(1).

4. Practice Warhead. This warhead should be the most economical construction that will permit normal performance of the missile, and will provide fuze setting knobs, response-type receptacles, and compartment openings similar to the atomic warhead

section. No airburst or impact fuze is desired. If, when developed, the fuzing system for the optimum fragmentation warhead proves to be sufficiently economical to permit use in a practice warhead, an airburst capability utilizing this fuze is desired.

5. Chemical for use against appropriate targets.

6. Incendiary for use against appropriate targets.

(b) The atomic warhead and adaption kit features for the atomic warhead section are described in appropriate military and technical characteristics.

(c) Provisions shall be included in the missile to permit detonation of the warheads at heights compatible with warhead and fuzing requirements.

(d) Fuzing and Arming:

1. The warhead fuze shall be armed by command while the missile is in flight except fuze arming for the atomic and controlled fragmentation warheads may be accomplished.

a. By variable arming time which can be set prior to launch.

b. By arming at a minimum fixed time prior to detonation.

c. At a fixed point on the trajectory.

d. By command.

Choice of arming system for the atomic and controlled fragmentation warheads should be based on the arming system which provides a maximum combination of reliability and safety.

2. The warhead and fuze system shall be designed so as to prevent undesired detonation, or at least high-order detonation, of an atomic warhead on impact.

3. The fuze systems required with the warheads, listed in subparagraph (5)(a) above, shall be designed so as to maximize standardization of components.

7. Durability and Reliability:

a. Ruggedness. All elements of the system, including the missiles, must be sufficiently rugged to withstand without damage those conditions of transportability and environment as required in paragraph 8 and 10 below.

b. Reliability. The reliability of the missile system should

be such that:

(1) At least 90% of the missiles removed from six months storage (depot or field) must pass all prefiring checkout tests with only minor adjustments or component replacement by battalion or battery personnel.

(2) Of the missiles which pass the prefiring checkout tests, not more than 5% may fail to launch at the designated time due to system malfunction throughout a 72 hour period following checkout.

(3) In the absence of effective countermeasures, those missiles which launch must have an in-flight reliability of 95%. This is the degree of assurance that, after launch, the missile will not abort due to failure of missile or ground components, but will deliver its payload to the specified target within the normal dispersion limits associated with the required accuracies.

c. Simplicity. Insofar as possible the missile and its associated equipment shall be designed so that all operations from removal from storage to firing can be accomplished with the minimum of personnel. It shall be possible to train operating and maintenance personnel quickly and easily. Checks and tests shall be accomplished by simple test equipment, preferably of the "go-no-go" type, usable by semiskilled personnel.

d. Readiness:

(1) Total preparation required at the launcher shall be held to a minimum.

(2) The missile shall be capable of standing on the launcher in a "ready" condition for at least 24 hours. The reliability requirement stated in subparagraph 7.b.(2) above, applies if the missile is fired at any time during the period of readiness.

(3) Missiles shall be capable of being removed from "ready-to-launch" condition and returned to storage.

(4) Electrical components which have a significant delay after being turned on, due to warm-up before operation, should be capable of being kept in a "ready-to-launch" state for extended periods.

e. Safety. Maximum safety precautions shall be incorporated to reduce hazards to using troops, friendly personnel, and installations.

(1) The atomic warhead, with associated fuzing and arming components, and the missile system shall include safety features required to give the highest possible assurance that a nuclear explosion will not occur at unsafe altitudes over friendly troops. In any case, the probability of such an explosion shall be less than one in 10,000. These safety features shall also be effective for missiles which burn

on the launcher or impact in friendly territory. The missile system shall be capable of providing a self-destruct signal to the atomic warhead installation in case of loss of missile control over friendly troops.

(2) The controlled fragmentation warhead, with associated fuzing and arming components, and the missile system shall include safety features required to give an over-all probability of the warhead functioning prior to the intended point of detonation in space, including tolerances, of less than one in 10,000.

8. Transportability. It is required that the complete system be highly mobile and all elements of the system including missiles be capable of being transported without damage by:

a. Organic transportation over unimproved roads and field terrain. It shall be at least as mobile as medium field artillery. Specially designed transport, if any, should employ standard chassis to the maximum extent possible. If practicable, standard Army trailers will be used.

b. Air:

(1) In Phase I airborne operation (SR 705-30-10) delivery of complete battalion by assault landing aircraft is required. Delivery by parachute is desired.

(2) Delivery of a lightweight system, to include the missile and test, checkout, handling, loading, and launching equipment by helicopter transport is required (subparagraph 6.i.(1)).

c. Rail.

d. Ship.

e. Landing craft. In amphibious operation (SR 705-125-10).

9. Associated Equipment:

a. Checkout and test equipment.

(1) General. All test and checkout equipment shall be as simple, reliable, compact and rugged as possible, and shall be designed to:

(a) Permit functional type tests which will, in themselves, indicate whether the item being tested is operating properly.

(b) Utilize multi-wafer or "gang" switches, labeled functionally.

(c) Trouble shoot, calibrate, and prepare all individual major elements of the system for operation except during

final checkout when test equipment will indicate "go-no-go".

(2) Missile test equipment. This test equipment shall be designed so that:

(a) Rapid functional tests on the missile can be performed.

(b) Major missile components which are non-functioning or operating beyond tolerance limits are immediately indicated.

(c) Any defective plug-in type components can be rapidly isolated except during final checkout when test equipment will indicate "go-no-go".

b. Training equipment and manuals. Concurrently with the development of the missile system it is required that training aids necessary for the conduct of troop training and Army School Training be developed. These include:

(1) Manuals For all equipment not standard to the Army on:

(a) Theory of operation.

(b) Maintenance and repair.

(c) Operators instructions.

(2) Wall charts and slides.

(3) Mock-ups and breadboards.

(4) Practice warheads.

(5) Operator Handling Trainer. A rugged replica of the missile for field handling which can accept test equipment for checkout training.

(6) Flight simulator.

c. Tools and parts lists. Concurrently with the development of the missile system it is required that there be developed:

(1) Standard and special tool lists.

(2) Spare parts lists.

d. Packaging. The missile system shall be so packaged as to withstand transport by rail, ship, or aircraft, by motor vehicle over rough roads and cross country, landings through surf and across beaches, and the normal hazards of loading, unloading, and handling incident to transport and storage.

10. Environmental Conditions:

a. General. The missile system shall be capable of operation and storage under environmental conditions as set forth in SR 705-70-5 and MIL-STD-210, 1 June 1953.

b. Special Requirements:

(1) Operability:

(a) The equipment is required to have the inherent capability of acceptable performance within an air temperature extending from 125°F (minimum exposure of 4 hours with full impact of solar radiation (360 BTU/sq ft/hr)) down to -40°F (minimum exposure of 3 days without benefit of solar radiation).

(b) If it can be accomplished with relatively small increase in cost and without material increase in size and weight, it is desirable that the design provide acceptable performance in air temperature down to -65°F.

(2) Storage and transport:

(a) The equipment is required to be capable of safe storage and transportation without impairment of its capabilities from the effects of temperature from -40°F (for periods of at least 3 days duration) to 140°F (for periods as long as 4 hours per day).

(b) If it can be accomplished with relatively small increase in cost and without material increase in size and weight, it is desirable that the equipment be susceptible to safe storage and transportation without impairment of its capabilities from the effects of temperatures from -80°F (duration of 24 hours, preceded and followed by equilibrium at -40°F) to 160°F (for periods as long as 4 hours per day)

(3) Barometric pressure:

(a) It is required that the equipment shall be designed to permit launching at atmospheric pressures encountered from sea level to 10,000 feet altitude above sea level.

(b) It is required that the equipment shall be designed to withstand, without damage, pressure encountered at 25,000 feet altitude while being air transported.

(4) Humidity. It is required that the system perform its intended function at all relative humidities up to 100% at all temperatures below 90°F and in those temperatures above 90°F at all relative humidities up to the maximum obtainable (not in excess of that corresponding to a vapor pressure of 36 inches of mercury if necessary)

(5) Wind. The system is required to withstand, without damage, surface gusts up to 75 miles per hour, and be capable of design

performance in gusts up to 50 miles per hour and steady surface winds up to 40 miles per hour.

(6) Other Conditions. The system is required to withstand without damage and be capable of acceptable performance when subjected to:

(a) Wind blown objects such as snow, sand and dust.

(b) Extreme precipitation in form of rain, snow, sleet, hail and freezing rain.

(c) Salt spray as encountered in a beach location.

(d) Swarms of insects.

(e) Fungus.

11. Kit Requirements:

a. Low Temperature Operations. The development of kits that may be necessary to permit an operating range down to -65°F shall not delay the system.

b. Fordability. Waterproofing kits as may be required by SR 705-125-10 to meet the fordability characteristics required for combat and tactical operations.

12. Other Requirements:

a. Over-all System. This shall be an integrated system of equipment which will provide for handling, servicing, launching, guidance of the missile to the target, and destruction of the target. Necessary tools, checkout equipment, spare parts, training aids, instruction manuscripts, SNL's and TM's shall be included.

b. Blackout. The system shall be capable of performing its mission effectively under all conditions of weather and visibility both day and night where the position of the target can be accurately fixed by visual or other means. The system shall be designed for operation under conditions of complete blackout.

c. Arctic Clothing. All elements of the equipment must be operable by personnel dressed in heavy arctic clothing.

d. Minimum Operating Personnel. Consistent with other requirements of the system, it should be so designed to require the minimum of personnel both for operation and maintenance.

e. Interchangeability. Where practicable, due consideration should be given to the use of standard items and/or components which would permit interchangeability with similar components of other

standard systems or equipment.

f. Storage. The missile system must be capable of dead storage for periods of three or more years and storage under field conditions for at least one year with only minor maintenance and preparation for active use.

g. Alternate Employment. Studies should be made concerning the feasibility, both from a technical and tactical viewpoint concerning all possible combination of launching from ground, ship or army aircraft (including helicopters) and guiding from ground, ship, or air (including helicopters) with changes in equipment being minimized.

13. Order of Priority. In the case of competing characteristics, for the system less warheads, the developing agency will give priority in the following order of absolute essentiallity:

a. Accuracy.

b. Reliability.

c. Immunity to countermeasures.

d. Safety.

e. Simplicity.

f. Range of effective guidance.

g. Minimum size and weight.

Complete concurrence to this report has been received from all members of the Ordnance Technical Committee, including the specific Subcommittee members listed on the report.

/s/ E. DERICKSON
Executive Secretary

APPROVED
/s/ GLENN E. NIDA
Col, Ord Corps
Chairman Pro Tem

APPROVED BY ORDNANCE TECHNICAL COMMITTEE
13 JUN 57
/s/ JOHN G. REDMON
Lt Col, Ord Corps
Secretary

APPROVED BY ORDER OF
THE SECRETARY OF THE ARMY

/s/ NICHOLSON PARKER, Major, GS
For the Chief of Res. and Dev., OCS

DOCUMENT 9

PILOT MONITORED AIRPLANE FLIGHT TESTS OF THE LACROSSE STEER GUIDANCE SYSTEM

SOURCE: CAL Report No. BE-745-T-105, subject as above, January 1953, pp. 29-32. (Work performed under Contract DA-30-115-ORD-47. Report prepared by S.P. Cook, LACROSSE Project Staff, CAL Aero-Mechanics Dept.)

	FLIGHT #1	FLIGHT #2	FLIGHT #3
Date	9 August 1951	29 August 1951	10 September 1951
Test Locale	Wilson,NY, on Lake Ontario	Near Buffalo Airport	Wilson,NY, on Lake Ontario
Duration	2:15 hours	1:40 hours	2:00 hours
Object	Airplane shakedown & operational check on Command Link & recording equipment.	Shakedown on HICO DME and Command Link Equipment.	Additional functional checks on HICO DME and check out of vertical control channel.
HICO DME	Not checked.	Incomplete check.	Checked.
Command Link	Fuse holder defective.	Signal strength low.	Operating.
Vertical Control	Not checked.	Not checked.	Sensitivity increased.
Horizontal Control	Not Checked.	Not checked.	Not checked.
Pilot's Comments	General functional check of the airplane made enroute to Wilson. Aircraft in good condition. Slight leak on static side of airspeed system. Several straight and level passes flown.	Three straight and level runs flown directly over Transit Road from south to north. Several passes then made over airport runways. Ground station advised on passing check points.	A series of straight and level runs flown to adjust the HICO DME. After this some runs made in which the pilot attempted to fly the vertical control channel. He found this rather difficult.
Engineer's Comments	Visual and radio contact established with ground station at Wilson. Fuse holder on the Command Link receiver defective. It proved impractical to hold the fuse in by hand.	HICO DME and Command Link equipment warmed up prior to flight. Command Link carrier signal strength low; it was recorded for each check point on Transit Road. Circuit breakers in airplane cut out. This caused termination of the tests of this flight.	HICO DME checks made; the check point was not always visible in the drift sight. The sensitivity of the vertical channel adjusted during the flight.

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	FLIGHT #4	FLIGHT #5	FLIGHT #6
Date	12 September 1951	14 September 1951	16 October 1951
Test Locale	Wilson, on Lake Ontario	Wilson, on Lake Ontario	Wilson, on Lake Ontario
Duration	2:30 hours	2:10 hours	2:25 hours
Object	Check out of vertical control channel and theodolite operation.	Check out of vertical control system and theodolite operation.	Operational flight on both the vertical and horizontal channels.
HICO DME	Checked.	Checked.	Checked. Malfunctioning.
Command Link	Signal strength low.	Checked.	No time signals received.
Vertical Control	Not functioning properly.	Too sensitive for pilot.	Not checked.
Horizontal Control	Not checked.	Not checked.	Not checked.
Pilot's Comments	A series of straight and level flights on E-W heading 2500 feet offshore made to adjust instrumentation. Then pilot attempted to fly the vertical channel. He was unable to do so.	Several deviations from the flight plan were made at the request of the ground station. The vertical crosspointer was too sensitive for the first recorded pass. Its sensitivity was decreased.	A series of flight runs was performed to check operation of the HICO DME. Since this equipment was not functioning properly the remainder of the test was canceled.
Engineer's Comments	After the HICO DME checks, and after one dry run to check the timing, five record runs were made. During flight the engineer was unable to trouble shoot the vertical control channel. The cross-pointers were off scale.	This was a repeat of Flight #4. The flash bulb failed to fire every time. Four Command Link record passes were made. Exclusive of the flash bulb circuit, everything appeared to be operating properly.	HICO DME checks made per flight plan. No time pulse or flash bulb signals were received on any of these runs. No flight records were taken. The HICO DME range indicator on the ground was not operating properly.

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	FLIGHT #7	FLIGHT #8	FLIGHT #9
Date	18 October	1 November 1951	11 November 1951
Test Locale	Wilson, on Lake Ontario	Wilson, on Lake Ontario	Wilson, on Lake Ontario
Duration	3:45 hours	3:15 hours	1:20 hours
Object	Operational flight on both the vertical and horizontal channels. A continuation of Flight #6.	Checkout flight on both the vertical and horizontal channels.	Demonstration flight on both the vertical and horizontal channels.
HICO DME	Checked.	Checked.	Flight canceled.
Command Link	Checked.	Checked.	Flight canceled.
Vertical Control	Not operating properly.	Sense of indication inverted.	Flight canceled.
Horizontal Control	Too sensitive.	Checked.	Flight canceled.
Pilot's Comments	After HICO DME checks, vertical & horizontal runs made. At zero count the pointers would be at one of two extremes. After a large correction the pointers would go the other extreme.	The pilot managed to zero the two cross pointers. Both cross pointers were very sensitive and required constant attention to hold at or near zero.	After the flight began it was discovered that one of the HICO DME antennas was missing from the airplane. Flight canceled. Weather conditions unsatisfactory also. (Snow squals, etc.)
Engineer's Comments	No time pulse or flash bulb signal was received, at first; trouble was found and repaired in ground equipment. Pilot found it impossible to fly so that the cross pointers were zeroed.	A number of runs were recorded. The sense of the vertical cross pointer was inverted. A secondary horizontal indicator was used to help the pilot to locate the guide beam. Last two runs best to date.	Flight canceled. No runs made or records kept.

[redacted]

	FLIGHT #10	FLIGHT #11
Date	9 November 1951	19 November 1951
Test Locale	Wilson, on Lake Ontario	Buffalo airport
Duration	2:30 hours	1:10 hours
Object	Demonstration flight on both vertical and horizontal control channels.	Maintenance flight check on airplane.
HICO DME	Checked.	No check.
Command Link	Checked.	No check.
Vertical Control	Checked.	No check.
Horizontal Control	Checked.	No check.
Pilot's Comments	On this flight a wire recorder was used to record the pilot's comments after each run. The pilot attempted to zero and hold at zero both cross pointers. Run 2 was regarded as the best.	The purpose of this flight was a general functional check of the aircraft and pilot proficiency. No crab items were noted and the flight was completely successful.
Engineer's Comments	It is necessary for the sensitivity adjustment to be very low in order for the pilot to zero the cross pointers. A number of runs were made with recording equipment connected. Among these are probably the best runs to date.	No comment.

[redacted]

DOCUMENT 10

FLIGHT TESTS OF AIR-LAUNCHED
LACROSSE RV-A-22 (GROUP 0) MISSILES*

S/N and Test Date	Radial M/D**	Remarks
S/N-1 24 Apr 53	141.5 yds.	Vehicle fell free for a 2-sec. period and was roll-stabilized about 3 secs after release as planned. The FW computer properly showed that the vehicle was far above the control line. At 5.5 secs after release, the control line should have been rotated thru the proper 30° angle and the pitch-down signal reduced to bring the missile within reasonable distance of control line. However, the control line did not erect to the required 30° angle and the full pitch-down signal persisted until the vehicle approached close to the control line at about 7 secs after release. Upon removal of erroneous signal, vehicle pulled hard up throughout the remainder of flight. Erroneous persistence of pitch-down signal, together with a lower vehicle velocity at release than preflight calculations had assumed, caused the vehicle to impact 2052 ft short and 372 ft south of the target.
S/N-2 10 Jun 53	9 yds.	An erroneous setting of the angle for release guide beam caused the vehicle release signal to be generated and transmitted from ground station about 2.25 secs. later than intended, this introducing a large initial error. Vehicle separated cleanly from airplane; fell free for 2 secs.; and was roll stabilized about 3 secs. after release, as planned. The AW guidance equipment proceeded to compute position of vehicle with respect to the control line and to generate and transmit corrective signals to vehicle. System performance was sufficiently good to remove the large initial error and to guide vehicle into the near vicinity of target.

* Source: CAL Report Nos.: BE-745-T-109 (S/N-1); BE-745-T-110 (S/N-2); and BE-745-T-122 (S/N-3 thru 8).

** Miss Distance. (Accuracy Specification: CPE 5 yards.)

S/N & Date	M/D	Remarks
S/N-3 17 Jun 53	--	This test, using Fair Weather (FW) guidance system, was unsuccessful. An inadvertent reversal of 180° in phasing of the pitch and yaw servos resulted in a divergent control system. This caused the test vehicle to turn sharply and dive, impacting far short and to the left of the target.
S/N-4 10 Aug 53	412 yds.	A highly successful demonstration of FW control system accuracy was achieved in this test. During controlled portion of flight, the RMS distance from desired path closely approached the ultimate objective of 5 meters. However, at 16.7 secs after launch, a sudden failure in the roll servo system caused the vehicle to go out of control and it impacted about 1200 feet short and 300 feet to the left of the target.
S/N-5 21 Sep 53	47.8 yds.	Although the AW system performed well in a qualitative sense, poor accuracy was achieved and a miss distance of 47.8 yds. resulted. Two operational difficulties were discovered. Spurious oscillations of ± 30 ft. amplitude were observed in both the pitch and yaw control signals. In addition, a serious curvature was discovered in the vertical projection of the control line. After appropriate corrective measures were taken, field tests showed that both of these effects had been eliminated.
S/N-6 19 Oct 53	--	A combination of excessive rolling of the missile between release and roll stabilization, and below normal tracking sensitivity, caused the AW tracker to lose the missile about one-half second after release. As a result there was no closed-loop control during this flight.
S/N-8 19 Jan 54	6.5 yds.	Feasibility of the AW system was clearly demonstrated in this test under conditions more severe than intended. A four-second delay in launch due to malfunction of the release mechanism caused the test vehicle to overshoot the control line by about 600 feet. However, the control system was able to recover completely with five seconds of flight time remaining, resulting in a close miss distance.
S/N-7 21 Jan 54	6.8 yds.	This test, using the AW system, was a complete success. Each component performed properly, as did the over-all closed loop system.

LACROSSE GROUP A FLIGHT TEST PROGRAM (U)

SOURCE:

CAL Report No. BE-745-T-137 (pp 26, 38-41)

Prepared by: R. Sacher Date: October 15, 1957

Approved by: R. Reinnagel
LACROSSE Project Engineer

W. E. Crowell
Head, Weapons System Design Dept.

LACROSSE GROUP A FLIGHT TEST PROGRAM

MSL S/N	LAUNCH DATE	FGS-TO-TGT RGE* (Meters)	TEST OBJECTIVES	OFF BEAM M/D (Meters) YAW	PITCH	REMARKS
1	8/17/54	935	Demonstrate system performance.	--	--	All components performed properly except tracker which failed to acquire in fine mode. Msl remained on internal m/c guidance, impacting 14 miles uprange from target.
2	10/18/54	935	Same as S/N-1.	2.4	-2.2	Excellent demonstration of system accuracy without integral control.
3	--	--	Not flown - Used for lab tests.	--	--	
4	12/9/54	2770	Check performance at longer range.	--	--	Power supply relay failure after launch led to msl maneuver at high speed, causing structural failure.
5	1/18/55	2770	Determine effect of integral control on terminal trajectory.	156.8	3.3	Comd link thermal relay in yaw channel failed to close automatically. Manual closure occurred too late for correction of large yaw error. Pitch guidance functioned properly.
6	1/28/55	2770	Same as S/N-4.	7.5	21.4	Tracker unlocked for 5.4 sec after pitch down resulting in off-beam errors too large to be removed before impact.
7	3/3/55	2770	Examine angle tracker performance more closely.	-0.1	-4.3	DME range flutter at 4 CPS. (Newly designed transponder installed for subsequent firings.)
8	4/26/55	2770	Check performance at steeper dive angle & higher m/c altitude.	--	--	Tracker failed to acquire. Msl remained on m/c guidance, impacting 10 miles uprange from target.
9	6/10/55	1950	Check performance of body-mounted pitot-static tube.	-29.9	-27.8	Faulty grounding of computer cable caused large shift in guide beam, accounting for most of M/D. (Pitot-static tube redrilled to reduce sensitivity to angle of attack changes.)

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10	7/22/55	1950	Same as S/N-9.	-1.9	0.7	EXCELLENT DEMONSTRATION OF SYSTEM ACCURACY WITH INTEGRAL CONTROL.
11	8/19/55	2770	Test live warhead performance.	--	--	DME failed to acquire due to component failure in msl transponder which gave weak signals. Msl impacted 3100 ft from target. Safety features in FGS prevented warhead arming & detonation at impact did not take place.
12	10/14/55	2770	Check early roll stabilization.	12.6	5.0	Early roll stabilization successful. Oscillation in yaw prior to impact traced to DME cyclic error. Source of error found & removed before firing of S/N-14.
13	9/13/55	2770	Demonstrate LACROSSE operation to visiting Army personnel.	-11.9	-5.1	Due to tight scheduling a defective booster amplifier was replaced by 2d unit containing defective capacitor. Resultant guide beam shift accounted for large part of M/D.
14	11/10/55	1580	Test live warhead performance against log-earth bunker.	2.3	-4.4	Missile went through bunker door. Bunker completely destroyed.
15	11/29/55	2770	Check terminal guidance performance at low msl velocities. Test live warhead performance.	-9.8	5.6	Midcourse altitude set at 7500 ft above ground to obtain reduced msl velocities. Control appeared adequate at these velocities. Warhead arming system functioned properly.
16	12/13/55	2490	Check terminal guidance performance at high msl velocities & short launcher-to-tgt range (9000 meters).	1.8	5.2	Early roll stabilization and control at high velocity was satisfactory.

* Launcher-to-FGS Range - 13,000 meters for all missiles except S/N-16.

ABBREVIATIONS:

Comd---- Command
CPS----- Cycles Per Second
DME----- Distance Measuring Equipment
FGS----- Forward Guidance Station
Ft------ Feet
Lab----- Laboratory
m/c----- Midcourse
M/D----- Miss Distance
Msl----- Missile
Rge----- Range
Sec----- Second(s)
S/N----- Serial Number
Tgt----- Target

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SUMMARY OF SYSTEM IMPROVEMENTS

During the course of the fifteen Group A missile firings, several important changes in the system were accomplished. Each change was the result of experience in missile or concurrent flight tests. The major technical modifications follow:

A. ANGLE TRACKER

Early aircraft flight testing and S/N-1 missile firing disclosed the existence of tracking noise introduced by ground reflections which prevented the switch from horn to dish which is the normal acquisition process. A ground plane was installed such as to reduce low angle coverage of the horn thus eliminating the difficulty.

S/N-5 and S/N-6 missiles showed momentary tracking failure at a coincidental aspect with respect to the ground station. Analysis and experiment revealed the cause to be amplitude modulation induced on the received pulse by missile and wing motions. Susceptibility to this modulation was reduced by a band pass filter centered at the scan nutation frequency added before the null detector which switches the tracker from the horn to dish mode. The AGC assist voltage was also increased by 100% to insure against loss of signal during the switch from fine to coarse tracking.

Some difficulty was encountered in the automatic frequency search circuit (AFS) with the search servo pausing at the unstable image frequency. This condition was corrected by increasing the ratio of the anti-stop-to-stop signal.

B. DME TRANSPONDER

During the flight of S/N-1 the operation of the DME transponder was marginal. Igniter shock during launch was suspected as the cause. A ruggedized, higher "G", model was designed having a slightly higher output and was used for missile flights S/N-2 through S/N-7. At the same time, development was started on a transponder incorporating a crystal controlled oscillator to replace the reactance tube oscillator originally used. Flight of S/N-7 was accompanied by a flutter in range measurement of about 4 cps and 25 feet peak-to-peak amplitude. Investigation disclosed the source of this error to be associated with a beat frequency between the airborne and ground 400 cycle supplies. This difficulty was eliminated in subsequent flights by using the transponder with crystal controlled oscillator mentioned above.

C. GROUND DME

Several missile firings showed errors in range cyclically related to the 1000 feet per revoluation rate of the highest modulation frequency. S/N-12 missile impacted about 40 feet in error, and the source was traced directly to DME cyclic error. This impact error was confirmed by REAC studies and resulted from a system resonance excited by the range cyclic error of about 12.5 feet half amplitude. By the addition of filters to remove the 400 cycle servo modulating frequency from the 500 kc DC error channel and by replacing a faulty tube the

cyclic error was reduced to about 3.5 feet half amplitude.

D. BEACON

Aircraft flight tests at WSPG indicated that arcing occurred in the pulse forming network at altitudes above 7500 feet, resulting in beacon failure. By replacing the open network with a hermetically sealed unit and making further modifications to reduce corona discharge, satisfactory performance was achieved at altitudes of 15,000 feet.

E. COMPUTER

S/N-9 and S/N-13 missile firings were subject to impact errors traced to computer zero drifts. In the first instance, a ground current caused by a defective cable-to-panel connector mating was blamed. The second deficiency was traced to drifts within a booster amplifier. The specific cause of drift in the computer amplifier (supplied as a unit) was a defective subminiature capacitor. Because of tracker deacquisition in the fine tracking mode during the flights of missiles S/N-5 and S/N-6 the computer was modified to permit guidance by command during coarse (horn) tracking as well as during fine (dish) tracking.

To reduce oscillations in the flight path during terminal guidance the damping in the shaping network was increased by replacing the 1.9 mfd capacitor with a 2.2 mfd capacitor in both the pitch and yaw circuits. This modification resulted in a transfer function identical to that now used in the Group B and the LACROSSE I computer.

The insertion point of integral control originally set at $\pm$ 100 feet was decreased to $\pm$ 60 feet after the firing of missile S/N-10. The original circuit employing electronic tubes was replaced by a relay directly across the pitch off-beam error channel that inserted integral control as a function of signal level.

F. GROUND POWER SUPPLY UNIT

When the target distance was increased from 3000 feet to 9090 feet it was found that frequency variations in the government furnished primary power unit (PU-107) introduced a noise level in the computer of approximately 8 feet in the yaw channel and 3 feet in the pitch channel. By replacing the hydraulic governor with an electronic frequency regulator the noise level in the yaw channel was reduced to 4 feet.

G. MISSILE

The original missile carried the pitot tube on a boom protruding from the nose. However, this mounting was not desirable on missiles carrying live warheads, and a side arm mount was developed. This was used for the first time on missile S/N-9. During this flight it was found that the horizontally oriented static sensing holes were unduly sensitive to pitch errors. REAC studies indicated that this orientation would produce a self-induced 1.3 cycle oscillation in the missile flight path. The holes were then redrilled 90° from their original position and in this location were found to be satisfactory.

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Review of Group A flight records confirms the cause of major errors to be in guidance equipment. Mechanical design of missile, launcher, and ground station was found to be satisfactory. Accomplishment of the technical objectives of the program was in a large measure credited to energetic efforts of skilled operators. To reduce requirements for operator skills, substantial improvement in electronic design toward simplification and reliability will be required in future equipments.

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DOCUMENT 12

LACROSSE GROUP B FLIGHT TEST PROGRAM (U)

SOURCE:

CAL Report No. BE-745-T-144 (pp. 29,99-100)

Prepared by: R. Sacher

Date: April 28, 1959

Approved by:
R. E. Reinnagel
LACROSSE Project Engineer

W. E. Crowell
Head, Weapon System Design
Department

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LACROSSE GROUP B FLIGHT TEST PROGRAM

MSL S/N	LAUNCH DATE	FGS-TO-TGT RGE (Meters)	TEST OBJECTIVES	OFF BEAM M/D (Meters)		REMARKS
				YAW	PITCH	
19	3/29/56	927	1st test of Gp B Guidance equipment.	-5.25	-1.9	All components performed satisfactorily. M/D was primarily due to errors in zeroing DME transponder.
18	4/5/56	927	Further check on operational accuracy of Gp B Guidance equipment	-2.45	0.7	All components performed properly, resulting in an excellent flight.
20	5/24/56	6,662	Check terminal guidance perf at low velocities & large F.O.-Tgt-Ranges	+1.0	-9.2	Excellent demonstration of long range guidance.
21	6/29/56	3,691	Evaluate system perf at minimum launcher-target range (8000 meters)	+2.6	-37.7	Low command link gain and excessive climb angle at P.D. Resulted in pitch oscillations on the terminal beam.
22	7/8/56	13,229	Check system perf using reduced system gains & extended FGS-Tgt-Range	-2253	-20	Relay failure in the computer prevented yaw signals from being transmitted to the missile.
17	9/21/56	588	Demonstrate LACROSSE operation to the Industrial College of the Armed Forces at APG	-1670	-35	Component failure in the yaw proportional channel resulted in no yaw control.

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SYSTEM MODIFICATIONS

During the course of the Group B program it was found necessary to make important technical changes in the guidance equipment. Each change was the result of experience in missile or aircraft flight tests. The major technical modifications follow:

Angle Tracker

Early flight tests indicated that the horn-to-dish switch-over performance was very poor. The poor performance was attributed to insufficient time to null the tracker while on the horn before the null detector operated to switch the tracker to the dish. By increasing the time delay in the operation of the null detector by a factor of 2, this difficulty was eliminated.

DME/Command Link

During early flight tests a cyclic error of 7 meters peak-to-peak was discovered in the ground station. This error was reduced to 1.5 meters peak-to-peak by coupling an out-of-phase signal to cancel the error.

Slippage of the range pot driving gear caused erroneous signals to be sent to the computer from the DME. A new limit stop was designed and installed to eliminate this slippage. An oscillation in the command section of the transponder was found and eliminated by a design change.

Computer

Although no difficulty was encountered during flight tests, additional relays were added in the pitch and yaw channels to insure completion of the hard-over missile maneuver during the transition from mid-course to terminal guidance in the event that ground control of the missile was lost. Interaction of the DME/command link, angle tracker, and computer thru the three-phase 400-cycle primary power resulted in transient noise appearing in the output signal of the computer. Some of this difficulty was alleviated by changing the sequence of the power distribution. Additional improvement was achieved by grounding all units in the computer. A filter network added in the reference phase considerably reduced the interaction between the tracker and the computer.

In addition to the above modifications, a considerable number of changes were recommended for consideration in the design of the tactical guidance equipment. The major portions of these changes were of a mechanical nature or involved the instrumentation of the system and thus have not been reported here.

DOCUMENT 13

LACROSSE TASK II FLIGHT TEST PROGRAM (U)

Conducted by The Martin Company;
Results Reviewed & Evaluated by CAL

SOURCE:

CAL Report No. BE-745-T-26 (p. 38)

Prepared by: W. J. Szabo 15 July 1957
G. Spangler

Approved by: W. E. Crowell, Head Weapon Systems Design Dept.
R. E. Reinnagel, LACROSSE Project Engineer

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LACROSSE TASK II FLIGHT TEST PROGRAM

MSL S/N*	LAUNCH DATE	FGS-TO-TGT RGE (Meters)	TEST OBJECTIVES	OFF BEAM M/D(Meters) YAW	PITCH	REMARKS
203 2000	1/22/57	1,944	Demonstrate successful performance of LX-1 msl under nominal conditions	+120	-2835	Loss of hydraulic pressure caused missile to impact 2,835 meters short of target.
204 2001	2/21/57	1,059	Evaluate performance near upper limit of a standard trajectory	+5.9	-1.4	Pitch oscillations during midcourse caused by orientation of static holes in pitot tube. Successful test.
206 2003	4/18/57	12,800	Demonstrate increased guidance range	+54.6	-14.8	Occurrence of right turn with missile already to right of beam caused most of yaw error at impact.
208 2005	4/25/57	1,944	Obtain additional hydraulic data	-3.7	-4.1	Successful test.
209 2006	5/14/57	3,050	System performance in short range flight	-14.3	-8.7	Successful but outside CPE.
210 2007	5/23/57	1,699	Demonstrate successful performance using 18° yaw turn w/a left pass	+1937	-4448	Unsuccessful due to erroneous guide beam set into computer.
212 2009	5/29/57	1,016	Evaluate performance in a short range flight	-4.0	-1.8	Successful test.
211 2008	6/13/57	1,699	Demonstrate successful performance using the 18° yaw turn w/a left hand pass	+1.0	+2.4	Successful test.

* Each Task II Missile assigned two serial numbers:
3-digit numbers by Martin; 4-digit numbers by Ordnance.

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DOCUMENT 14

LACROSSE TASK III FLIGHT TEST PROGRAM (U)

Conducted by The Martin Company
Results Reviewed & Evaluated by CAL

SOURCE:

CAL Report No. BE-745-T-29 (p. 33)

Prepared by: G. Spangler 15 July 1958

Approved by: W. E. Crowell, Head Weapon Systems Design Dept.
R. E. Reinnagel, LACROSSE Project Engineer

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LACROSSE TASK III FLIGHT TEST PROGRAM

MSL S/N	LAUNCH DATE	MISSILE RANGE (Meters)	FGS-TGT RANGE (Meters)	MISS DISTANCE (Meters) PITCH	YAW	REMARKS
2052	6/20/57	14,238	1,944	-5.8	-13.1	Successful flight but outside CPE.
2053	7/3/57	13,361	5,976	+6.9	-5.1	Successful test.
2010	7/18/57	9,011	2,393	+5.8	+8.0	Successful test.
2011	7/23/57	14,364	2,764	-5.5	-2.3	Successful test.
2018	8/6/57	14,238	9,689	-45.3	-126	Failure of yaw guidance command.
2016	8/13/57	17,953	12,439	-985	+1101	Beacon system failure prevented tracking.
2015	8/28/57	17,400	6,377	-8.7	-5.1	Successful test
2020	9/19/57	9,594	1,618	--	--	Demonstration - No data available.
2013	10/2/57	14,238	1,944	+39.2	-105.4	Investigate tracker masking on the missile.
2019	10/2/57	14,238	1,944	-4571	+425	Roll reference lost.
2012	11/12/57	2,764	2,764	-1387	+180	Roll reference lost.
2021	12/12/57	17,953	1.287	-3.83	-1.65	Successful test.
2017	12/13/57	Unguided Missile Flight --			--	No assigned target. Lightweight Launcher Test
2022	1/9/58	23,850	2,952	+15	-3	Computer functioning proper.
2025	1/23/58	10,060	7,846	Not Available		FGS Command sporadic.
2023	2/6/58	10,060	11,116	-24	-15	DME signal below threshold level.
2027	2/21/58	Unguided Missile Flight --			--	No assigned target. Lightweight Launcher Test
2014	2/28/58	No Data Available		--	--	Military flight test.
2026	3/19/58	17,953	11,699	-37	-5	Missile could not regain guide beam.
2024	3/26/58	24,850	12,800	-44	-2	Unable to regain terminal control line.
2028	5/8/58	Unguided Missile Flight--			--	No assigned target. Lightweight Launcher Test

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DOCUMENT 15

LACROSSE TASK IV FLIGHT TEST PROGRAM (U)

(Conducted Under the AOMC Composite Test Plan)

SOURCE:

Martin Company Report OR 1294

22 November 1960

(Prepared as part of Contract DA-01-009-ORD-811)

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FLIGHT PERFORMANCE TABLES

Tables I and II contain results of the 59 flight tests conducted by Martin Company crews and the 55 tests by Ordnance Mission System Test Division (STD-OM) crews, respectively. Table III presents a brief summary of the 67 flight tests conducted by Artillery Board and Army crews. A description of those parameters appearing on the tables which need clarification is given below.

PURPOSE

For simplicity of identification, the primary test objectives are broken down into 15 divisions, as follows:

1. GENERAL EVALUATION TEST (GET) - Any missile not flown under one of the other primary objective titles is listed under this objective; however, any of the missiles could be placed under this general heading.

2. GENERAL ELECTRIC/SANDIA (GE/S) - Test of the GE/S XM13 Warhead.

3. MINNEAPOLIS-HONEYWELL (MH) - Test of the MH T52 Warhead.

4. PICATINNY ARSENAL (PA) - Test of the PA T34 Warhead.

5. ON TARGET COMMAND (OTC) - Test of the OTC functions.

6. NOISE FIX (NF) - Test of adequacy of the Noise Fix.

7. LATE ACQUISITION (LAC) - Test of late acquisition capability.

8. DUAL ANTENNA (DA) - Test of performance with airborne Dual DME Antenna System.

9. ROLL ERECTION (RE) - Test of Roll Erection Mechanism.

10. PROGRAM PITCH (PP) - Test of Program Pitch Midcourse Controller.

11. INDUCED ROLL FIX (IRF) - Test adequacy of Induced Roll Fix.

12. LIGHTWEIGHT LAUNCHER (LWL) - Test of the CAL Lightweight Launcher. (The launcher used in other tests was the truck launcher.)

13. PICKLE BARREL (PB) - Missiles flown during "Operation Pickle Barrel" to isolate problem areas and establish fixes.

14. DEMONSTRATION (DEM) - Missiles flown for demonstration purposes.

15. TRAINING (T) - Troop Training flights.

ACCURACY

The missile distances were determined by actual survey and are measured in the horizontal plane. The accuracy in CPE is determined by dividing the radial miss distance by the allowable CPE, the latter being based on the guidance range. A cause of miss is given only if the miss distance exceeded 2.0 CPE.

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TABLE I - MARTIN FIRINGS

Date Fired.....	3/10/58	3/19/58	4/15/58	4/24/58	5/5/58	5/13/58	6/3/58
Ordnance Number...	2030	2029	2033	2037	4037	2045	2047
Martin Number.....	403	402	406	410	459	418	420
Purpose.....	GET	GET	GET	GET	GE/S	GET	PP
Warhead.....	T50E1	T50E1	T50E1	T50E1	XM13	T50E1	T50E1
Range (Meters)							
Laun-to-Tgt.....	17,400	13,000	17,400	13,000	14,219	8,994	24,850
MGC-to-Tgt.....	11,766	7,998	11,766	7,998	548	10,059	2,952
MGC-to-Laun.....	17,239	16,821	17,239	16,821	14,253	14,593	27,525
Accuracy (Meters)							
Miss in Pitch....	2028.0	-1830.0	-57.5	-1.5	0.6	-51.3	1.4
Miss in Yaw.....	2.0	141.0	6.4	391.7	-2.2	2.5	2.0
Radial Miss Dist.	2028	1836	57.8	391.7	2.2	51.4	2.5
Allowable CPE....	18.5	13.7	18.5	13.7	5.0	16.3	7.4
Accuracy in CPE..	Abort	Abort	3.1	Abort	0.4	3.2	0.3
Cause of Miss....	Did not acquire; Broken Wave-guide.	Battery Failure at X +3 seconds.	Noise	Noise	---	Noise	---

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TABLE I (Cont)

Date Fired.....	6/10/58	6/12/58	7/1/58	7/8/58	7/14/58	8/28/58	9/4/58	9/9/58
Ordnance Number...	4045	2048	2034	4004	4025	4033	4034	4055
Martin Number.....	467	421	407	445	447	455	456	477
Purpose.....	GE/S	PP	DEM	GE/S	GE/S	GE/S	MH	GET
Warhead.....	XM13	T50E1	T50	XM13	XM13	XM13	T52	T50E1
Range (Meters)								
Laun-to-Tgt.....	8,257	29,819	16,176	16,844	27,529	17,934	22,683	29,837
MGC-to-Tgt.....	5,872	6,279	2,764	517	6,159	1,287	6,953	2,197
MGC-to-Laun.....	12,909	24,941	14,059	17,222	22,203	16,803	17,239	28,733
Accuracy (Meters)								
Miss in Pitch....	28.5	-6.6	-0.5	-1265.0	-1023	2.6	--	2350
Miss in Yaw.....	5.9	-10.4	1.1	-291.0	265	-1.9	--	--
Radial Miss Dist.	29.1	12.3	1.2	1298	1057	3.2	--	--
Allowable CPE....	11.1	11.6	7.2	5.0	11.4	5.4	--	6.5
Accuracy in CPE..	2.6	1.1	0.2	Abort	Abort	0.6	Abort	Abort
Cause of Miss....	DME failure & noise	---	---	Induced roll	Induced roll	---	Beacon power failure	DME Ranging Error

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TABLE I (Cont)

Date Fired.....	9/24/58	10/7/58	11/28/58	12/3/58	12/5/58	12/5/58	12/8/58
Ordnance Number...	4024	4039	4162	4138	4111	4163	4150
Martin Number.....	446	461	584	560	533	585	572
Purpose.....	GE/S	MH	PB	PB	PB	PB	PB
Warhead.....	XM13	T52	T50E1	T50E1	T50E1	T50E1	T50E1
Range (Meters)							
Laun-to-Tgt.....	22,683	22,683	17,952	14,154	24,850	24,850	17,952
MGC-to-Tgt.....	2,007	6,953	1,287	1,963	1,688	1,688	1,287
MGC-to-Laun.....	21,186	17,239	16,821	12,922	23,666	23,666	16,821
Accuracy (Meters)							
Miss in Pitch....	-2.9	--	7.4	-261.0	-130.0	9.7	-11,625
Miss in Yaw.....	-30.6	--	-3.2	-64.0	-400.0	7.7	-2298
Radial Miss Dist.	30.7	--	8.1	269	420	12.4	--
Allowable CPE....	6.2	--	5.4	6.2	5.9	5.9	5.4
Accuracy in CPE..	5.0	Abort	1.5	Abort	Abort	2.1	Abort
Cause of Miss....	Displaced Guide Beam & Noise	Trans-ponder failure	---	Trans-ponder failure	Failure in yaw command circuit	Highly oscilla-tory at initiation of integral control	Broken solder joint on valve

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TABLE I (Cont)

Date Fired.....	12/8/58	12/10/58	12/10/58	12/11/58	12/12/58	2/27/59	2/27/59	3/2/59
Ordnance Number...	4159	4155	4157	4142	4164	4070	4035	4165
Martin Number.....	581	577	579	564	586	492	457	587
Purpose.....	PB	PB	PB	PB	PB	NF	MH NF OTC	MH NF
Warhead.....	T50E1	T50E1	T50E1	T50E1	T50E1	T50E1	T52	T52
Range (Meters)								
Laun-to-Tgt.....	17,952	14,154	14,154	17,952	14,154	22,676	19,982	24,300
MGC-to-Tgt.....	1,295	1,963	1,963	1,295	1,963	18,134	15,665	5,669
MGC-to-Laun.....	16,814	12,922	12,922	16,814	12,927	14,608	13,145	18,664
Accuracy (Meters)								
Miss in Pitch....	1.7	0.8	-2.7	-0.2	1.4	3.3	--	2588.0
Miss in Yaw.....	0.9	4.9	9.5	1.3	0.3	0.4	--	9599.0
Radial Miss Dist.	1.9	4.9	9.8	1.3	1.4	3.4	--	--
Allowable CPE....	5.4	6.2	6.2	5.4	6.2	26.4	--	--
Accuracy in CPE..	0.4	0.8	1.6	0.3	0.2	0.1	--	Abort
Cause of Miss....	---	---	---	--	--	--	Successful Airburst	Transponder failure

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TABLE I (Cont)

Date Fired.....	3/10/59	3/16/59	3/30/59	3/30/59	4/1/59	4/10/59	4/10/59	4/14/59
Ordnance Number...	4160	4068	4085	4094	4064	4038	4026	4072
Martin Number.....	582	490	507	516	486	460	448	494
Purpose.....	GE/S LWL	DA	GE/S	GE/S OTC RE LWL	LAC NF	GE/S OTC RE	LWL GE/S OTC RE	LAC
Warhead.....	XM13	T50E1	XM13	XM13	T50E1	XM13	XM13	T50E1
Range (Meters)								
Laun-to-Tgt.....	17,378	12,994	12,959	27,583	19,993	20,075	13,199	18,209
MGC-to-Tgt.....	1,023	10,360	15,623	3,961	15,665	3,793	4,384	4,615
MGC-to-Laun.....	17,315	23,354	14,608	27,278	13,144	17,195	13,958	15,521
Accuracy (Meters)								
Miss in Pitch....	2.9	5.6	-42.8	-21,926	-11.6	-6.4	1,642	-7,820
Miss in Yaw.....	3.2	-5.5	-4.3	-228	-3.1	-1.4	11,509	721.0
Radial Miss Dist.	4.3	7.9	43.0	8,500	12.0	6.5	--	--
Allowable CPE....	5.0	16.7	23.3	8.7	23.3	8.5	26.7	9.5
Accuracy in CPE..	0.9	0.5	1.8	Abort	0.5	0.8	Abort	Abort
Cause of Miss....	---	---	---	Failure Roll Erection Circuit	---	---	Failure Roll Erection Circuit	Induced Roll Combined Pitch & Yaw Maneuvers

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TABLE I (Cont)

Date Fired.....	4/24/59	4/27/59	5/6/59	5/12/59	5/26/59	6/10/59	6/11/59	6/16/59
Ordnance Number...	4071	4172	4040	4079	4046	4041	4050	4122
Martin Number.....	493	594	462	501	468	463	472	544
Purpose.....	DA	T	GE/S OTC LWL	GE/S	LWL GE/S OTC	GE/S OTC LWL	MH OTC	GE/S
Warhead.....	T50E1	T50	XM13	XM13	XM13	XM13	T52	XM13
Range (Meters)								
Laun-to-Tgt.....	12,944	28,560	19,108	16,857	8,005	14,342	19,919	23,407
MGC-to-Tgt.....	15,408	2,956	17,650	11,375	17,644	6,404	9,995	17,786
MGC-to-Laun.....	2,610	2,954	10,375	13,758	17,750	14,721	14,732	13,133
Accuracy (Meters)								
Miss in Pitch....	-17.0	No Coverage	-14.2	14.1	20.0	-4.8	--	-53.2
Miss in Yaw.....	-2.3		70.7	15.2	-145	-5.6	--	-34.7
Radial Miss Dist.	17.1		72.1	20.7	147.0	7.4	--	63.5
Allowable CPE....	23.0	7.6	25.8	18.0	25.8	11.8	--	26.0
Accuracy in CPE..	0.7	Abort	2.8	1.2	5.7	0.6	--	2.4
Cause of Miss....	---	Suspect clogged pitot tube	Error in FGS set up	---	Failure DME Ranging	---	Successful Airburst	Extended Guidance Range

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TABLE I (Cont)

Date Fired.....	7/7/59	7/7/59	7/17/59	7/24/59	7/28/59	7/28/59	8/4/59	8/7/59
Ordnance Number...	4130	4100	4065	4134	4144	4121	4003	4128
Martin Number.....	552	522	487	556	566	543	425	550
Purpose.....	MH	MH LWL	IRF	GE/S	GE/S LWL	GE/S	PP	MH
Warhead.....	T52	T52	T50E1	XM13	XM13	XM13	T50E1	T52
Range (Meters)								
Laun-to-Tgt.....	16,116	8,330	16,636	9,007	29,646	29,830	29,837	12,131
MGC-to-Tgt.....	15,701	18,092	6,285	7,431	19,887	17,110	19,097	17,050
MGC-to-Laun.....	14,118	17,343	10,791	7,889	13,136	12,913	11,710	12,798
Accuracy (Meters)								
Miss in Pitch....	--	--	-4.4	30.5	-18.2	-64.4	-273.0	--
Miss in Yaw.....	--	--	6.6	0.6	-65.5	-20.3	3616	--
Radial Miss Dist.	--	--	7.9	30.6	68	67.5	3626	--
Allowable CPE....	--	--	11.6	13.0	28.6	25.1	27.6	--
Accuracy in CPE..	--	--	0.7	2.4	2.4	2.7	Abort	--
Cause of Miss....	Successful Airburst	Successful Airburst	---	Guidance cutoff & misplaced target	Auto-pilot errors	Guidance cutoff due to mask	Dis-placed Guide Beam & Induced Roll	Success-ful Air-burst

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TABLE I (Cont)

Date Fired.....	8/18/59	8/24/59	8/27/59	9/4/59	9/11/59
Ordnance Number...	4066	4131	4149	4073	4067
Martin Number.....	488	553	571	495	489
Purpose.....	IRF	MH	MH	LAC	IRF
Warhead.....	T50E1	T52	T52	T50E1	T50E1
Range (Meters)					
Laun-to-Tgt.....	23,012	10,502	29,636	20,090	16,636
MGC-to-Tgt.....	7,178	7,413	11,368	7,722	6,285
MGC-to-Laun.....	15,955	7,889	18,711	17,239	10,791
Accuracy (Meters)					
Miss in Pitch....	-6.2	-67.2	--	--	-17.6
Miss in Yaw.....	5.1	1.4	--	--	-0.4
Radial Miss Dist.	8.0	67.2	--	9000	17.6
Allowable CPE....	12.7	13.0	--	13.4	11.6
Accuracy in CPE..	0.6	5.2	--	Abort	1.5
Cause of Miss....	--	Missile oscillated about guide line & failed to go through OTC	Successful Airburst	Induced Roll	--

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TABLE II - STD-OM FIRINGS

Date Fired.....	9/2/58	9/15/58	9/19/58	10/9/58	10/17/58	10/22/58	11/25/58
Ordnance Number...	2042	2040	2041	4001	2049	4015	4002
Martin Number.....	415	413	414	423	422	437	424
Purpose.....	GET	GET	GET	GET	GET	GET	GET
Warhead.....	T50E1	T50E1	T50E1	T50E1	T50E1	T50E1	T50E1
Range (Meters)							
Laun-to-Tgt.....	29,111	29,644	7,904	29,838	7,904	29,644	14,924
MGC-to-Tgt.....	9,198	9,150	4,814	18,646	10,789	502	4,999
MGC-to-Laun.....	21,734	24,071	12,082	16,275	18,192	29,904	18,792
Accuracy (Meters)							
Miss in Pitch....	-112.4	-86.1	-937.0	-95.5	3.1	2.6	-9.75
Miss in Yaw.....	-125.9	-164.0	-25.0	49.4	13.2	-0.7	17.3
Radial Miss Dist.	168.7	185.2	937	107.5	13.6	2.6	19.8
Allowable CPE....	15.2	15.2	9.8	27.0	17.2	5.0	10.0
Accuracy in CPE..	11.1	Abort	Abort	Abort	0.8	0.5	2.0
Cause of Miss....	DME Noisy; Pitch Bias	DME Malfunction	DME-Antenna Pattern Mask	Radio Interference	---	---	---

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TABLE II (Cont)

Date Fired.....	11/25/58	3/3/59	3/5/59	3/12/59	3/18/59	4/23/59	4/23/59	4/24/59
Ordnance Number...	4016	4143	4166	4168	4167	4018	4170	4057
Martin Number.....	438	565	588	590	589	440	592	479
Purpose.....	GET	GET	MH	MH	PA	GET	MH	GET
Warhead.....	T50E1	T34E2	T52	T52	T34E2	T50E1	T52	T50E1
Range (Meters)								
Laun-to-Tgt.....	14,924	14,364	7,904	22,683	14,364	15,027	12,969	14,897
MGC-to-Tgt.....	4,348	5,260	5,874	10,178	525	10,231	6,389	3,965
MGC-to-Laun.....	19,270	14,369	5,162	12,922	14,369	11,751	7,809	11,536
Accuracy (Meters)								
Miss in Pitch....	-3.7	7.1	-18.8	--	-6.6	-10.6	--	4.4
Miss in Yaw.....	2.4	-4.1	-77.8	--	-5.9	9.1	--	2.2
Radial Miss Dist.	4.4	8.2	80	--	8.8	14.0	--	4.9
Allowable CPE....	9.2	5.0	11.1	--	5.0	16.5	--	8.7
Accuracy in CPE..	0.5	1.6	7.2	--	1.8	0.8	--	0.6
Cause of Miss....	---	---	Mis-placed aiming stake	Success-ful Air-burst	---	---	Success-ful Air-burst	---

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TABLE II (Cont)

Date Fired.....	5/1/59	5/7/59	5/13/59	5/14/59	5/16/59	5/29/59	5/29/59	5/29/59
Ordnance Number...	4058	4019	4169	4032	4082	4017	4020	4021
Martin Number.....	480	441	591	454	504	439	442	443
Purpose.....	GET	GET	PA	MH	DEM	GET	GET	GET
Warhead.....	T50E1	T50E1	T34E2	T52	T50	T50E1	T50E1	T50E1
Range (Meters)								
Laun-to-Tgt.....	14,228	14,924	14,364	27,546	15,334	20,082	20,082	20,082
MGC-to-Tgt.....	12,402	10,094	1,171	14,429	1,367	10,678	10,678	5,080
MGC-to-Laun.....	16,277	11,356	13,774	16,274	14,741	16,275	16,275	17,239
Accuracy (Meters)								
Miss in Pitch....	-43.4	-14.8	-5.0	--	-750	-7.7	5008	80.0
Miss in Yaw.....	-26.4	-7.1	-2.0	--	400	-84.9	1933	41.0
Radial Miss Dist.	50.8	16.4	5.4	--	850	85.3	--	90
Allowable CPE....	19.2	16.4	5.2	--	5.4	17.1	17.1	10.1
Accuracy in CPE..	2.6	1.0	1.0	--	Abort	5.0	Abort	8.9
Cause of Miss....	---	---	---	Successful Airburst	Beacon malfunction	Saturated Yaw Commands	Beacon malfunction	Saturated Yaw Commands

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TABLE II (Cont)

Date Fired.....	6/2/59	6/4/59	6/4/59	6/4/59	6/5/59	6/12/59	6/26/59	7/1/59
Ordnance Number...	4063	4195	4054	4175	4022	4048	4115	4086
Martin Number.....	485	617	476	597	444	470	537	508
Purpose.....	GET	GET	GET	GET	GET	MH	MH	GET
Warhead.....	T50E1	T50	T50E1	T50	T50E1	T52	T52	T34E2
Range (Meters)								
Laun-to-Tgt.....	16,636	20,082	21,684	20,082	21,684	15,024	7,904	14,364
MGC-to-Tgt.....	7,400	10,678	18,549	10,678	14,724	2,379	9,205	1,186
MGC-to-Laun.....	9,363	16,275	4,690	16,275	15,226	14,261	9,479	13,758
Accuracy (Meters)								
Miss in Pitch....	-8.7	-27.5	-37.2	-35.8	45.1	--	--	1.5
Miss in Yaw.....	12.6	-10.1	-9.8	-14.5	-194.4	--	--	-2.5
Radial Miss Dist.	15.3	29.3	38.4	38.6	199.5	--	--	2.9
Allowable CPE....	13.0	17.1	26.9	17.1	22.2	--	--	5.2
Accuracy in CPE..	1.2	1.7	1.4	2.3	9.0	Abort	--	0.6
Cause of Miss....	---	---	---	---	Possible Ranging Malfunction	Gyro Failure	Successful Airburst	---

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TABLE II (Cont)

Date Fired.....	7/14/59	7/23/59	7/31/59	8/12/59	8/20/59	8/28/59	9/24/59	9/30/59
Ordnance Number...	4069	4139	4110	4158	4044	4181	4171	4119
Martin Number.....	491	561	532	580	466	603	593	541
Purpose.....	GET	MH	MH	MH	GET	GET	PA	MH
Warhead.....	T50E1	T52	T52	T52	T34E2	T34E2	T34E2	T52
Range (Meters)								
Laun-to-Tgt.....	17,940	16,636	16,636	29,830	14,364	21,684	14,357	13,000
MGC-to-Tgt.....	12,189	5,594	10,483	6,299	1,185	18,548	1,181	5,920
MGC-to-Laun.....	21,563	12,160	13,758	24,953	13,758	4,690	13,758	7,294
Accuracy (Meters)								
Miss in Pitch....	-38.6	--	--	-20,553	1.7	-3.7	0.7	-43.1
Miss in Yaw.....	-15.2	--	--	-1,618	-0.4	-20.0	1.9	-36.3
Radial Miss Dist.	41.4	--	--	--	1.7	20.3	2.0	56.4
Allowable CPE....	19.0	--	--	--	5.2	26.9	5.2	11.2
Accuracy in CPE..	2.2	--	--	Abort	0.3	0.8	0.4	5.0
Cause of Miss....	---	Successful Airburst	Successful Airburst	Clogged Pitot Tube	---	---	---	---

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TABLE II (Cont)

Date Fired.....	10/8/59	10/15/59	10/27/59	11/10/59	11/16/59	11/18/59	11/19/59	11/24/59
Ordnance Number...	4152	4074	4088	4148	4047	4341	4052	4083
Martin Number.....	574	496	510	570	469	763	474	405
Purpose.....	MH	MH	MH	MH LWL	MH LWL	PA	MH	MH
Warhead.....	T52	T52	T52	T52	T52	T34E2	T52	T52
Range (Meters)								
Laun-to-Tgt.....	16,640	23,206	20,115	13,004	12,984	14,357	27,546	20,082
MGC-to-Tgt.....	6,781	3,817	17,276	5,920	13,143	1,181	16,414	13,194
MGC-to-Laun.....	10,598	21,361	--	7,299	13,373	13,758	17,322	8,175
Accuracy (Meters)								
Miss in Pitch....	--	--	--	--	--	0.1	--	--
Miss in Yaw.....	--	--	--	--	--	-8.1	--	--
Radial Miss Dist.	--	--	--	--	--	811	--	--
Allowable CPE....	--	--	--	--	--	5.2	--	--
Accuracy in CPE..	--	--	--	--	--	1.6	Air-burst	--
Cause of Miss....	Successful Airburst	Successful Airburst	Successful Airburst	Successful Airburst	Successful Airburst	Unknown	Abort Side-Lobe Acquisition	Abort Transponder malfunction

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TABLE II (Cont)

Date Fired.....	1/12/60	1/14/60	1/20/60	1/29/60	2/2/60	2/16/60	3/23/60	3/25/60
Ordnance Number...	4352	4116	4113	4076	4392	4376	4077	4156
Martin Number.....	774	538	535	498	814	798	499	578
Purpose.....	PA	LWL	MH LWL	MH LWL	GET	MH LWL	GE/S	GE/S LWL
Warhead.....	T34E2	T50	T52	T52	T341N	T52	XM13	XM13
Range (Meters)								
Laun-to-Tgt.....	14,356	16,645	24,834	20,101	27,546	24,169	7,910	18,721
MGC-to-Tgt.....	1,181	6,781	12,575	13,196	3,600	7,099	11,183	5,000
MGC-to-Laun.....	13,758	10,605	17,253	8,206	27,631	17,226	10,391	14,447
Accuracy (Meters)								
Miss in Pitch....	-1500	3.5	-34.4	1.6	4.0	--	23.3	-315.0
Miss in Yaw.....	200	10.5	-6.3	-20.6	0.0	--	-41.4	-103.0
Radial Miss Dist.	--	11.0	35	20.7	4.0	--	47.6	331.0
Allowable CPE....	5.2	12.23	19.47	20.25	8.2	--	17.73	10.0
Accuracy in CPE..	Abort	0.9	1.8	1.07	0.48	--	2.68	Abort
Cause of Miss....	Unknown	---	---	---	---	Successful Airburst	---	Side Lobe Acquisition

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TABLE III - ARTILLERY BOARD AND ARMY FIRINGS

Missile S/N			Calculated CPE	Miss CPE
Ordnance	Martin	Date Fired	(Meters)	(Meters)
2035	408	3/23/58	27.9	Abort
4075	497	8/12/58	5.2	Abort
4098	520	8/22/58	9.5	3.5
4099	521	9/4/58	28.7	1.2
4105	527	9/11/58	5.0	Abort
4107	529	10/1/58	28.0	2.0
4103	525	10/17/58	5.0	Abort
4108	530	10/17/58	9.3	Abort
4140	562	10/23/58	28.7	Abort
4109	531	10/28/58	28.7	Abort
4136	558	10/28/58	28.7	1.7
4133	555	10/31/58	17.0	1.9
4146	568	11/10/58	4.5	Abort
4127*	549*	12/16/58	5.4	Abort
4129*	551*	12/17/58	6.2	0.9
4191	613	6/26/59	8.6	0.9
4182	604	6/27/59	5.7	0.7
4184	606	6/29/59	13.8	0.7
4186	608	6/29/59	19.1	2.1
4188	610	6/29/59	12.6	1.6
4194	616	6/29/59	5.0	1.6
4190	612	7/6/59	13.2	Abort
4192	614	7/9/59	13.2	0.5
4189	611	7/11/59	7.8	1.0
4185	607	7/15/59	26.3	0.2
4187	609	7/15/59	31.3	1.1
4248	670	7/21/59	5.0	Abort
4249	671	7/23/59	14.7	Abort
4250	672	7/23/59	5.0	1.3
4193	615	7/27/59	7.1	Abort
4303	725	11/18/59	7.1	1.0
4305	727	11/18/59	--	Abort
4304	726	11/19/59	5.2	3.5
4298	720	1/19/60	8.3	0.8
4292	714	1/22/60	5.0	Abort
4293	715	1/25/60	17.0	Abort
4294	716	1/26/60	10.0	0.6
4449	871	1/29/60	10.1	2.3
4296	718	2/7/60	8.3	2.44
4299	721	2/9/60	10.0	Abort
4450	872	2/11/60	21.3	Abort
4295	717	2/17/60	25.6	Abort
4297	719	2/17/60	22.8	Abort
4239	661	3/29/60	--	Abort

* Fired as part of "Operation Pickle Barrel."

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TABLE III (Cont)

Army Firings*

Missile S/N			Calculated CPE	Miss CPE
Ordnance	Martin	Date Fired	(Meters)	(Meters)
4205	627	1/29/60	10.5	No Data
4208	630	1/29/60	6.4	0
4210	632	1/29/60	6.4	Abort
4213	635	1/29/60	10.1	Abort
4209	631	1/31/60	6.4	0.54
4211	633	1/31/60	9.8	Abort
4246	668	1/31/60	9.8	2.55
4206	628	2/1/60	9.8	Abort
4264	686	2/1/60	6.4	4.68
4272	694	2/1/60	10.4	Abort
4217	639	3/3/60	6.4	Abort
4220	642	3/3/60	6.4	Abort
4257	679	3/3/60	15.3	Abort
4222	644	3/5/60	--	Abort
4255	677	3/5/60	--	Abort
4267	689	3/5/60	4.0	Abort
4291	713	3/5/60	--	Abort
4229	651	4/7/60	2.6	Abort
4265	687	4/7/60	7.54	0.4
4259	681	4/9/60	--	Abort
4262	684	4/9/60	0.58	0
4326	748	4/9/60	12.4	Abort
4334	756	4/9/60	3.3	Abort

* First 44 firings (listed above) were conducted by the Artillery Board.

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DOCUMENT 16

HEADQUARTERS
U. S. ARMY ORDNANCE MISSILE COMMAND
Redstone Arsenal, Alabama

ORDXM-X 18 Dec 59

Lieutenant General J. H. Hinrichs
Chief of Ordnance
Washington 25, D. C.

Dear Jack:

(U) I have just had a look at the Artillery Board report titled "Service Test of the LACROSSE Missile System." A copy of this 16 November report has been furnished to ORDTX. It is significant that the major shortcomings in LACROSSE, as pointed up by the report, approximate those which we have long known. Our proposals for correction have not been supported by DA staff and so we are left with serious defects in the system such as its ECM vulnerability.

(U) You may recall that early in May 1959 I furnished you in detail a plan for LACROSSE improvements which would have brought it in line with User requirements. In our meeting of 11 May, you approved that plan and accepted it as the official Ordnance position. We have held to that position as a valid and reasonable means of getting the bugs out of the system. Army staff would not buy it and in August directed termination of our main effort for an improved LACROSSE. As General Shinkle pointed out in his briefing to you on 11 November, LACROSSE is not now a solid, dependable system - and it will not be until we get the approval and funds to make it so.

(U) I strongly urge that you again focus the attention of Staff on this problem and try once more to prod them into action.

Sincerely yours,

s/t J. B. MEDARIS
Major General, USA
Commanding

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DOCUMENT 17

Cost Center
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Priority

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CG, USAOMC, Redstone Arsenal, Alabama

COFORD, DA, WASHINGTON, DC

In reply refer to ORDXR-CR-503-Signed (Barclay)

1. (U) Reference the following:

a. USCINCEUR Msg EC 9-6304 of 8 Dec 59 to DA which requested information concerning LACROSSE System.

b. OCO TT Msg #002 of 11 Dec 59 which quoted Reference 1.a. above and requested AOMC provide information involved.

c. OCO TT Msg #011 of 18 Dec 59 which provided guidance for AOMC response to queries contained in Reference 1.a. above.

2. (U) In response to the information requested in paragraph 3.b. of Ref 1.a. above, the limitations of the current LACROSSE System, in terms of the Military Characteristics as contained in OTCM 36527 approved 13 June 57, are as follows:

a. Refer to Paragraph 6.a of OTCM 36527 - In Missile range performance, the present system does provide the required minimum and maximum ranges. However, a limitation arises if 30,000 meters is to be

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7 Jan 60

ORDXR-CR s/t JOHN A. BARCLAY

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achieved with all types of warheads, under other than standard NACA day conditions, and with air burst and target altitude requirements included. Present system can fire to 30,000 meters at 20° terminal dive only, under only standard NACA day conditions, with only a ground burst, and with no altitude differential between launcher and target. Introducing only the 45° dive angle, which is desirable in the use of atomic warheads for safety purposes, the maximum range is reduced to approximately 24,600 meters. A new requirement has arisen which calls for engagement of targets as much as 5000 feet above or below the launcher, with heights of burst up to 3,000 feet above such targets. While this new requirement infers acceptance of whatever range degradation occurs, the effect on horizontal range of any insistence on this requirement will be considerable. Lower initial missile velocity, or thrust termination, would be necessary to achieve the desired minimum range of 4,000 meters. Neither of those approaches is considered feasible with the present rocket motor.

In maximum guidance range performance where target location data is obtained by use of the Target Ranging Set, a limitation arises in that the range of the present TRS, against targets of low reflectivity and under varying ambient light conditions, is considered to be not greater than 3,000 meters. There is evidence that the present TRS will range to almost 5,000 meters if the target is of sufficient reflectivity, but the existence of such a type target in a tactical environment is questionable.

Where maximum guidance range performance involves target location data obtained from external sources, the present guidance system does provide the required range of 20,000 meters.

The minimum required guidance range of 250 meters is not met by the present system. Consistent with other characteristics of the system, such as antenna patterns and tracking rate capabilities, the present system cannot tolerate any portion of the missile flight trajectory being closer than 400 meters from the guidance central tracker.

b. Refer to Paragraph 6.c. of OTCM 36527 - In accuracy a CPE of 5 meters is required when target location data is obtained by use of the Target Ranging Set. The present system meets this requirement only at a guidance central-to-target ranges of 1,000 meters or less. The CPE increases approximately 1 meter per additional 1,000 meters of range at ranges from 1,000 meters to the maximum usable range of the Target Ranging Set. Accordingly, the achieved CPE is 6 meters instead of 5 at 2,000 meters guidance range, 7 meters instead of 5 at 3,000 meters, and so on to approximately a 9 - 10 meter CPE at 5,000 meters, assuming the TRS can range to 5,000 meters. This limitation is not attributable to ranging inaccuracy of the TRS, but merely to the fact that a 1 mil tracking system is involved.

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When using target location data obtained from external sources, such as reconnaissance aircraft, and exclusive of the accuracy of the map or photo data involved, the system is required to provide a CPE of 40 meters, with 30 meters desired. The desired CPE of 30 meters is met by the present guidance system out to the required guidance range of 20,000 meters.

The Military Characteristics anticipate that a guidance station will be masked from the target by terrain, and state that in such cases the accuracy shall not be degraded but remain a function of the guidance central-to-target range. LACROSSE accuracy is a function of that range, but is fully realized only when the missile can be tracked into the target. Hence terrain masking does degrade the accuracy achieved, with the degradation being a function of the height and slant distance from the target at which tracking and ranging is lost. Continual reconnaissance and pre-selection of optimum guidance central locations is at present the only solution to minimizing the effects of terrain masking on system accuracy.

c. Refer to Paragraph 6.d. (2) of OTCM 36527 - the recent directive to terminate the T-52 warhead development has been partially modified to permit the completion of combined R&D - Engineering flight tests. Present plans call for placing the T-52 in a shelf-item status by mid-1960, without live testing by user agencies. A warhead of this general type should be provided, since lack of same somewhat negates efficient use of the accuracy of LACROSSE, its outstanding feature when compared with other delivery systems.

d. Refer to Paragraph 6.g. of OTCM 36527 - The present system meets the 360 degree requirement for the guidance central only if launchers can be properly deployed in support of that central. The system is restricted in that overhead tracking is impossible, and missile approaches to target must be selected so as to assure that the guidance central location is included in the missile antenna radiation pattern at all times.

The FM-CW ranging and control link of the present system, operating at 420 mc and 450 mc, is considered virtually non-resistant to jamming by small, low-powered, and inexpensive jamming signal devices.

Present LACROSSE guidance systems cannot operate freely and simultaneously, without mutual interference, unless separated by a distance of 30 miles or more. Mutual interference can only be avoided by multiple system operation on a time-sharing basis.

Development of the MOD I all-pulse Ka band guidance system, which was intended to provide the level of anti-jamming and anti-interference features desired, has been terminated.

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e. Refer to Paragraph 6.h. of OTCM 36527 - The present system can meet the intent of the rate of fire requirement insofar as launching and handling requirements are concerned. A possible limitation arises in the form of the time required at the LACROSSE FDC to process and disseminate fire control data in certain guidance modes of operation. The FADAC computer will be evaluated for LACROSSE purposes by mid-1960. Subject to the final results of the evaluation and a positive decision to employ same, LACROSSE FADAC units could be made available to LACROSSE units by mid-1961.

f. Refer to Paragraph 6.i. of OTCM 36527 - The present self-propelled launching and handling system is definitely not helicopter transportable. Four (4) sets of helicopter transportable launching and handling equipment are currently being tested and evaluated by ordnance and user agencies. It is anticipated that testing will be completed and a production configuration will be firmed by July 1960. Subject to DA procurement desires as yet unstated, it is anticipated that complete HT L&H system can be made available to LACROSSE units by the spring of 1961.

g. Refer to Paragraph 6.j. of OTCM 36527 - Prior comments concerning the T-52 warhead are again applicable. Suitable practice and training warheads are being provided; however, development of a chemical or an incendiary warhead for LACROSSE has not been required to date. The On Target Command System, in conjunction with present fuze designs, for arming and detonation of both ground and air bursts, is considered to fulfill the fuzing requirements imposed by the military characteristics.

h. Refer to Paragraph 7 of OTCM 36527.

Ruggedness has not been attained throughout the complete system, particularly in the test and maintenance equipment. The majority of test equipment chassis have been manufactured to "best commercial practices" due to limitations on time and funds. Studies are now in process for the complete militarization of system equipment. Redesign of test equipment appears to be mandatory to improve ruggedness and reliability and increase the confidence level of the troops employing such equipment.

Reliability requirements obviously embrace other requirements such as ruggedness, simplicity and readiness. The degree of satisfaction of the requirement for 90 per cent reliability in missiles removed from six months storage cannot be assessed until considerably more missiles are produced, stored, and checked upon removal from storage. Using missiles directly from the production line, with no six months storage, the 90 per cent prefiring checkout reliability has not been achieved. This area of reliability is presently estimated at between

45 and 60 per cent. The planned incorporation of an improved autopilot, with concurrent redesign of the 2nd echelon Guided Missile Test Set and related 3rd Echelon test items, is expected to improve this area of reliability by approximately 20 per cent. Improvements in the reliability of the missile beacon, missile transponder, and ground guidance equipments are being sought through a concerted reliability program, which to date has revealed the need for improved quality and durability of key components rather than major assembly redesigns. While considerable difficulty has been experienced with the PPU of the MGC in the past, recent performance of improved models of this power unit has been encouraging. The design of the PPU is marginal; however, there is no known power supply of comparable cost, weight and size which is capable of adequately replacing it.

The present system inflight reliability is approximately 75 per cent, as opposed to the 95 per cent requirement. The requirement involves the degree of assurance that after launch, the missile will not abort due to failure of missile or ground components, but will deliver its payload to the specified target within the normal dispersion limits associated with required accuracies. Excluding pre-flight checkout and preparation, the missile guidance central has proven to be inherently more reliable than the missile during actual flight operations. Very few flights have aborted as a result of MGC failure. The missile - 2nd Echelon Missile Test Set combination is the problem, and the major problem components are the autopilot, transponder and beacon.

Simplicity has been achieved in required operations from removal from storage to actual firing, in that a minimum of personnel are needed. System operation is possible by semi-skilled personnel, however, present test and maintenance operations at 3rd and 4th and 5th Echelon require skilled ordnance personnel who have completed formal training and have considerable on-the-job experience. This is caused by the abundance of starred value and critically matched components throughout the system.

i. Refer to Paragraph 8 of OTCM 36527 - Excepting the 3rd Echelon Test and Maintenance Vans, the present system has the degree of mobility desired. The non-militarized 3rd Echelon equipment is not considered sufficiently rugged to withstand cross-country operations. Every component and individual of the LACROSSE battalion is transported by organic wheeled vehicles ranging in capacity from 1/4-Ton to 5 Ton. All components of the missile guidance central are man-transportable with limitations. The target Ranging Set consists of an 80 pound head and a 30 pound tripod. The MGC tracker consists of two 60 pound units, with the tracker head being difficult to carry without the special frame. The guidance central primary power supply consists of two 62 pound packages, with the volume of the housing unit being somewhat undesirable

from a man-carrying standpoint. Helicopter transportability has been discussed in preceding paragraphs. The present M-108 loading crane weighs 19,785 pounds and is thereby not usable in assault landing aircraft for Phase I airborne operations wherein the upper weight limit is 16,000 pounds. A lightweight crane weighing 14,000 pounds, which includes the 10,700 pound curb weight of the M45 21/2 Ton Truck, is now being tested.

j. Refer to Paragraph 9 of OTCM 36527.

Compactness in test equipment has not been achieved. The test equipment consists of five (5) M-109 vans with five (5) trailer-mounted power units at 3rd Echelon and four (4) M-109 vans with four (4) trailer-mounted power units at 4th Echelon.

Although final go-no-go checkout of major assemblies is considered satisfactory, the subchassis go-no-go tests, trouble shooting, and calibration of system equipment presents many difficulties. Many of the chassis are not standardized and extreme difficulty is experienced in testing a subchassis with the go-no-go tester designed for that purpose. On a few subchassis, such as an intermediate frequency amplifier, it is possible to use the provided go-no-go tester but the tester does not have the capability of isolating a malfunction, nor does field maintenance have a repair and alignment capability.

k. Refer to Paragraph 10 of OTCM 36527.

Minor deficiencies discovered in recent cold chamber tests are now in the process of being corrected by modification work orders. The complete LACROSSE System will be Arctic tested at Fort Churchill beginning in January 1960.

l. Refer to Paragraph 12 of OTCM 36527.

Interchangability is a major problem in the LACROSSE system. Although this problem is prevalent in many of the major assemblies, the Missile Guidance Central and the DME test set are principal offenders. Engineering has been completed and manufacturing started on a non-militarized Dynamic Range and Computer Simulator to replace the DME Test Set. It was recently determined that only 13 of the 25 MGC chassis were interchangeable. Of the remaining 12 chassis, the effort required to assure interchangeability varies from a relatively minor modification to 6 chassis, more serious modification to 2 chassis, and a complete redesign of 4 chassis. Such modifications and redesign are now under advisement. The decision will be based on the extent of the changes required, as well as the time and funds to be involved.

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No serious attempts have been made to incorporate alternate employment in the system. Launching from a moving or stationary ship, to a fixed guidance point ashore, is considered feasible for naval post-landing ship-to-shore bombardment. The air-dropping or launching of LACROSSE missiles from high speed aircraft, to the control of guidance centrals aground, is considered feasible. It is not planned to pursue either the ship-launching or air-craft-launching method for LACROSSE at the present time.

m. The comments above are from an Ordnance view and are broad in nature. For a more detailed reply, the using troops should be contacted.

3. (U) In response to the information requested in paragraph 3.c. of Reference 1b and paragraph 2.c. of Reference 1.c. above, the costs of MAP program are based on the following assumptions:

a. Requirement for MAP is as reflected in Five Year Materiel Program received at this agency November 1959.

b. Equipment for MAP will be delivered after Army requirement has been satisfied, as reflected in Five Year Materiel.

c. Since there will be an Army procurement of missiles in FY 61, no additional indirect costs will be required to support MAP in the missile area.

d. Since there will not be an Army procurement of ground or test equipment in FY 61, funds will be required to support engineering for the MAP requirement in this area.

e. A minimum of 15 percent concurrent repair parts will be required.

f. Since the Army requirement will have been satisfied prior to delivery of MAP requirements, no funding for Engineering Orders will be applicable specifically to MAP.

4. ~~(S)~~ (U) Costs for MAP FY 60 Procurement are as follows:

Item	Quantity	Unit Cost	Total
Missile	120	$ 57,508	$6,901,000
Current Autopilot			
New Autopilot	120	56,963	6,736,000

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CG, USAOMC, Redstone Arsenal, Alabama

Item	Quantity	Unit Cost	Total
Ground Equipment			
Current Autopilot	3	$1,667,666	$5,003,000
New Autopilot	3	1,637,666	4,913,000
Type IV Test Equipment			
Old Autopilot	3	954,300	2,863,000
New Autopilot	3	917,300	2,751,900
T34E2 Warhead	120	3,912	469,400

The cost figures given above for the new autopilot are only estimates and have not been confirmed by the contractor.

5. ~~(8)~~ 4 The availability of an all pulse Ka band guidance system would be contingent upon the Army R&D effort continuing on the quantities of equipment desired. Since these factors are unknown at the present time, cost information on a Ka band system can not be furnished within the time frame allowed.

DOCUMENT 18

HEADQUARTERS
DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON 25, D. C.

In Reply
Refer To 00/60S 340

22 JAN 1960

Major General J. B. Medaris
Commanding General
Army Ordnance Missile Command
Redstone Arsenal, Alabama

Dear Bruce:

(U) I have carefully reviewed your letter of 18 December 1959 on LACROSSE and have been briefed on the Artillery Board Service Test as well as the ARGMA TWX which told of action taken to correct deficiencies listed by the Board.

(U) As I look at this program I am astounded at the similarity between LACROSSE and DART. You remember how the improvements on the latter were always "just around the corner." To me, the fundamental difference is that LACROSSE is basically a good system. The difficulty is that the corrections for the known deficiencies which have appeared in the equipment to date are marginal.

(U) Our action at this time should be concentrated on getting sound corrections for the deficiencies indicated by Engineering and User Test into existing materiel. When we have these under our belt, it will be time to consider the further improvements incorporated in our 29 May proposal.

(U) Under the provision that it does not dilute or delay getting effective corrections into the basic system, I do not object to a very limited effort with existing funds to better prepare us to reclama the August D/A Staff position. (The scope of the LACROSSE Program could increase or you may discover a means for making a major reduction in the cost and risk of the May proposal).

(U) I realize that this is taking advantage of a D/A Staff decision. However, they are stuck with it and I am inclined to hold them to it at this time. Staff's refusal of our May 1959 proposal was predicated primarily on budgetary limitations and, possible, an ACSI evaluation that the ECM limitations would not be actively exploited by the enemy. (I believe ACSI was naive). The FY 1961 RDT&E budget is going to be tight. The total Surface-to-Surface missile portion, excluding PERSHING, is only

C O P Y

Major General J. B. Medaris

about 11.8 million. The kiss of death is on any request now for fund increases in the LACROSSE program to provide substantial ECM improvement.

(U) I expect your Command to actively pursue means of improving the LACROSSE to the extent permitted by available funds. I am inclosing some actions suggested by my Staff. Do you have any better ones?

Sincerely yours,

1 Incl
Suggested AOMC
Actions.
(C)

s/t J. H. HINRICHS
Lieutenant General, USA
Chief of Ordnance

SUGGESTED ACTIONS ON LACROSSE

1. ~~(c)~~ 4 High priority AOMC actions to receive concentrated effort.

a. Establish an especially qualified technical team, (utilizing Ordnance-wide and Industrial sources) to conduct an extended review of the progress being made in eliminating the current LACROSSE problems as revealed by R&D, Engineer and User Tests. The output of this team should be a list of deficiencies, along with:

(1) An analysis of the extent of the current deficiency.

(2) A technical evaluation of the proposed solution through the appropriate engineering calculations required to indicate that it is fundamentally sound.

(3) The time scale involved at arriving at a solution.

(4) A cost estimate to accomplish the technical task.

(5) The submission of concrete proposals and tasks to be supported.

b. A review similar to that of paragraph 1 directed at the test equipment problem. The output of this team should be:

(1) An analysis of the impact of supporting LACROSSE with its existing 3rd and 4th Echelon Test Equipment.

(2) The practicality of hardening portions of the test equipment only (e.g. harden contact team test equipment).

(3) Discussion of other alternates available. (Similar to paragraph 1.b.(2).)

(4) Application of UTE. A development and five-year material plan should be included as well as an estimate of the risk involved in obtaining reliable, tactical type equipment in an appropriate time scale.

(5) A concrete proposal on the work to be done in the test equipment area.

Incl 1

C O P Y

SUGGESTED ACTIONS ON LACROSSE (Cont'd)

c. Carefully review all system limitations previously furnished to the User to insure that they are actually required with the current equipment being furnished (this is to include firing parameter limitations furnished to the User). Results of this review should be made available to OCO as soon as available.

2. (U) Low priority AOMC actions to receive very limited effort. These are to be undertaken only if they do not dilute or delay effective corrections to the basic system:

a. Give moral support to the Martin Company in the demonstration of the work they have done (understood to be at their expense) on the improved guidance system. Martin should not be misled into believing that support for the extension of this program is imminent.

b. Establish the costs and time scale of bringing one complete set of improved guidance LACROSSE with supporting test equipment to a tactical prototype stage - that is, essentially a shelf R&D item. This would include approximately 25 - 30 flight tests. (E/U Testing should not be included, but complete integration of White Sands Missile Range and User personnel in the program is suggested). When available, this program should be submitted to OCO.

c. A review of the AOMC 19 May 1959 plan for improved guidance and, separately, the improved motor program. The output of this review would be a program, reviewed if necessary, which has fully considered previous adequacy of technical performance, as well as past experience of program time slippages and increased costs, so as to limit risks to a reasonable level. When available, this program should be submitted to OCO.

3. (U) OCO Actions:

a. Follow corrective actions closely - particularly for evidence of elimination of deficiencies by sound, proven fixes.

b. Be alert to further expansion of the LACROSSE program and possible reclama of the D/A Staff August decision if this should occur.

c. Review carefully the programs submitted under paragraphs 2.b. and 2.c. above and advise the Chief of Ordnance whether either of them (in conjunction with progress being made on fixes of the current system) justify a reclama.

COPY

DOCUMENT 19

THE MARTIN COMPANY
Orlando, Florida

25 March 1960

Refer to: 60-1107
Mail No.: MP-17

Brig. General J. G. Shinkle
Army Ordnance Missile Command
Army Rocket & Guided Missile Agency
Redstone Arsenal, Alabama

Subj: Projected Overrun of Contract Funds Required to Complete Industrial Contract DA-36-034-ORD-2524

Dear General Shinkle:

As we approach the completion of contract DA-36-034-ORD-2524, which we have previously referred to as the Fiscal '57 Industrial Buy, our latest estimate to complete indicates that we will not need $75,000 currently in the definitive contract. Since all the hardware to be furnished under this contract has been delivered and we are in the process of tying up loose ends contractually, we feel it appropriate at this time to indicate to you that this amount of funds may be deobligated at your earliest convenience.

Further, you will recall that on contract DA-01-009-ORD-614 an overrun requirement of $2,245,588 was negotiated last fall as a result of the extreme emergencies and efforts required during the period prior to activation last July; we have now likewise completed all major end item deliveries of hardware under this contract, and are pleased to report that we will not need $180,000 of that total amount which had not been funded through this date.

We have been able to meet or beat our contract schedule requirements every month since last November, including the ground and test equipment currently being delivered for the activation of the four reduced strength battalions. We were able to deliver last month's battalion and 3rd echelon equipment complete by the 23rd of the month as against a requirement of the 30th of the month. We have delivered the second battalion on the 17th of March against a requirement of the 31st of March, and we are similarly hopeful of completing the remaining two battalion complements of hardware prior to our contract requirements. You may be assured that the equipment which we are delivering to meet this year's activation requirement has been built and tested under a calm and thorough quality and test environment, and has in fact been marriage tested to the satisfaction of your quality representatives as well as those in our organization.

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We feel that we are passing through a major milepost on Lacrosse and believe that the future looks even brighter. In our meeting with representatives of the Artillery and Ordnance, held last week, I must admit that we had some anxious moments at the start of the meeting. However, Messrs. Gonsalves, Hightower and Kelley were able to rapidly bring the meeting back on an even keel and to a successful completion. We at Martin are thoroughly convinced that the highest priority program problem today is the clean-up of those items which serve as an irritant today to the Artillery and to Ordnance, as noted in the minutes of the meeting. You may rest assured that we will bend every effort to expedite resolution of these problems, and are vigorously working with your key Lacrosse managerial people to implement this corrective action in the field throughout the weapon system.

We received a most unusual reaction from the Artillery in response to our proposal to solve their deficiency item called ECM (namely, the implementation of the improved guidance program), as I am sure has been reported to you by Colonel Lehtonen and others who were present. We are convinced that the Artillery is overwhelmingly concerned with the present, and at the moment not too concerned with long term solution of the fundamental system problem. However, we are equally convinced that they will not be satisfied with Lacrosse after we have cleaned up the deficiencies which disturb them now, and that they will then have no other weapon system available in the field for several years which can live in the electronic environment anticipated.

We feel that as an urgent but secondary priority endeavor, we must and should continue with our efforts on the improved guidance program to whatever level available funding will permit, since we will be unable to solve the ECM problem in a short time span similar to that which will be required to solve the other deficiencies that were noted in the meeting last week. We recommend that every effort be made to provide some means to keep this program alive until significant funding can be made available to pursue it on a sound and conservative basis to remove the stigma of the past from Lacrosse, which has accrued due to our rushing to the field prematurely with unproven hardware. Our representatives are this week meeting with R&D personnel to develop a joint program plan for such implementation. Should any assistance be required in making these presentations at higher levels, please do not hesitate to call upon us.

It has been a relatively rare occasion in the past when we have been able to report good news to your office, and we are pleased to submit the foregoing.

Sincerely,

THE MARTIN COMPANY

H. R. STAUDT
Lacrosse Project Director

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DOCUMENT 20
HEADQUARTERS
U. S. Army Ordnance Missile Command
Redstone Arsenal, Alabama

ORDXR-FML 27 Apr 60

SUBJECT: LACROSSE Weapons System (U)

TO: Chief of Ordnance
Department of the Army
Washington 25, D. C.

1. (U) Reference is made to Chief of Ordnance letter of 22 January 1960 to Commanding General, U. S. Army Ordnance Missile Command, subject: "LACROSSE Missile System."

2. (U) Inclosure #1 to this letter spells out the specific deficiencies of the current LACROSSE System as jointly defined by CONARC and this Command, and provides proposed solutions and costs. The deficiencies do not include those that may be correctable from the current R&D improved autopilot program, nor any future improved guidance or improved motor programs. A total of $14,030,000, including engineering funds, and a time period of approximately two years, are required to correct those deficiencies considered and to incorporate the involved fixes in field equipment. Deduction of $4,189,000 of engineering funds already committed toward the FY 60 LACROSSE Program results in a requirement for $9,841,000 of additional funds to remedy only those deficiencies considered in the inclosure.

3. (~~C~~ U) This Command considers it illogical to propose an improvement program which does not include incorporation of the advantages planned to accrue from the R&D improved autopilot program. A successful improved autopilot program will result in reliability, cost, technical performance, tactical performance, and test equipment advantages which are not possible in a program limited to the extent outlined in Paragraph 2. above. It is estimated that industrial procurement and incorporation of the autopilot program hardware will involve an additional cost of approximately $7,600,000 and a total time period of approximately three years. In short, significant improvement of the existing LACROSSE System is considered to involve a total of approximately $17,441,000 (9,841,000 plus $7,600,000) and a total time period of three years.

4. (~~S~~ U) Prior to any commitment of a sum of money in the order of $17,441,000 to fund a three-year program to improve LACROSSE within its present system limitations, it is considered mandatory that a firm decision be made as to the future of LACROSSE beyond that three-year period. Specifically, a decision is required as to whether a second

C O P Y

generation LACROSSE System will or will not become a reality. The following factors must be considered:

a. Simultaneous provision of an improved guidance system and an improved motor is in order.

b. Development of the improved guidance system has been continued on a minimum effort basis and has a current posture which lends itself to immediate implementation within this fiscal year.

c. An improved motor (probably a dual thrust packaged liquid design) can be developed, tested, and qualified within the time frame of provision of the improved guidance system, and at a reasonable cost.

d. The improved autopilot system will be developed and tested in the next four months, and can be incorporated well within the possible phasing of the improved guidance system. It should be noted that the improved autopilot system is in reality an out-crop of the original MOD I autopilot effort.

e. The improved guidance system (MOD I), in combination with the improved autopilot system and an improved propulsion system, will provide the following features in the LACROSSE System which are not attainable in a mere correction of the existing system as outlined in Paragraph 2:

(1) High anti-ECM capability (improved guidance).

(2) High resistance to cross-battery interference, so as to permit multiple firings in the same local area (improved guidance).

(3) High resistance to random electronic communication interference (improved guidance).

(4) Increase of guidance range from 20,000 to 40,000 meters (improved guidance).

(5) Induced roll stability during combined pitch and yaw maneuvers, which will permit later acquisition and multiple yaw approaches to target (improved autopilot).

(6) A clamping altimeter system which will provide a more efficient pitch plane trajectory which will prevent losses of range in the order of 2,000 meters (improved autopilot).

(7) A more producible and less expensive autopilot (improved autopilot).

ORDXR-FML
SUBJECT: LACROSSE Weapons System (U) 27 Apr 60

(8) A modularized Guided Missile Test Set at 1st and 2nd Echelons which is more reliable, easier to maintain, and possesses desirable self-verification features (improved guidance and autopilot).

(9) Modularized 3rd and 4th Echelon test equipment which is more reliable, militarized, easier to operate and maintain, better packaged in the van configuration, and eligible for use in the event multiple purpose test equipment is not available in the time frame involved.

(10) Reduction of minimum launching range from 8,000 to 4,000 meters (improved motor).

(11) Increase of maximum launching range from 24,600 meters at 45° dive and 30,000 meters at 20° dive to approximately 40,000 meters at a 45° dive under normal conditions. This will open up the system to firing at least 30,000 meters (the military requirement) at a 45° dive (desirable for atomic deliveries) under most any conditions of air burst, meteorological and target elevation requirements (improved motor).

(12) Increased missile midcourse velocity which provides a more responsive missile all the way to target, decreases the flight time, increases possible firing rate, and reduces period of time the missile is subject to electronic and physical countermeasures (improved motor).

(13) Eliminate excessive smoke upon launch by substitution of a less amount of steam which dissipates more rapidly (improved motor).

(14) Higher overall system reliability.

5. (U) Inclosure #2 shows in chart form the correction program outlined in Paragraphs 2. and 3. above together with corresponding timing and costs of an improvement program as outlined in paragraph 4. Hereafter follows pertinent remarks relative to funding an improvement effort.

a. The use of $15,441,000 of the $17,441,000 (see Paragraph 3) on a second generation LACROSSE, reserving $2,000,000 for minimum clean-up of the existing system, would fund 52% of the effort required to bring the improved system to a flight test stage and point of possible release to industrial procurement. An additional $13,800,000 could be realized in FY 60 by an appropriate reduction of Army Materiel Objectives. The total of $29,241,000 that could be realized by the diversion of $15,441,000 and $13,800,000 from the present system requirements would practically fund the entire Phase I and II Programs as shown on Inclosure 2. Such an approach would put the LACROSSE System in a more enhanced

C O P Y

position than could be accomplished by expenditure of the same amount of money in an equivalent period of time on the present system.

b. Since the funding figures shown on Inclosure 2 are preliminary estimates, it is possible that the Phase III would require an additional $10,000,000; thereby, increasing the price differential by the same amount.

c. Since Phase I and II of the improved LACROSSE Program as shown on Inclosure 2 can be considered as product improvement with the possible exception of the motor and test equipment, it is recommended that PEMA monies be utilized.

6. (U) Based on the foregoing factors and a complete analysis of the current LACROSSE situation, this Command recommends the following course of action:

a. An immediate reclama be made to the mid-1959 DA Staff decision on a second generation LACROSSE System. The reclama should involve a request for consideration of reduction of the FY 60 LACROSSE buy by 14 sets of ground equipment, 3 sets of general support test equipment, and 200 missiles to realize the $13,800,000 mentioned in Paragraph 5.a. above.

b. That upon receipt of detailed plans for the second generation system from this Command in the first week of May, 1960, a final DA Staff decision with regard to such a system be obtained by no later than 20 May 1960.

7. (U) This Command strongly recommends immediate diversion of funds toward provision of a second generation LACROSSE System within three years in lieu of mere improvement of the existing system over the same time span. Mere improvement of the existing system will not render LACROSSE more palatable to users other than the U. S. Army, and will not foster nor prolong the useful life of the system in the field.

2 Incl
*1. LACROSSE Wpn Sys Evaluation Report (U) dtd Apr 60, SECRET
*2. Photo, LACROSSE Present Sys vs Improved Sys CONF

s/t AUGUST SCHOMBURG
Major General, USA
Commanding

*Not reproduced.

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DOCUMENT 21

HEADQUARTERS
DEPARTMENT OF THE ARMY
Office of the Chief of Ordnance
Washington 25, D. C.

00/60S 3645 22 July 1960

ORDTX

SUBJECT: LACROSSE Program (U)

TO: Commanding General
U. S. Army Ordnance Missile Command
Redstone Arsenal, Alabama

REFERENCE: Letter from Commanding General, U. S. Army Missile Command, Subject: "LACROSSE Weapons System," file ORDXR-FML, dated 27 April 1960.

1. (U) Referenced letter has been carefully reviewed by the Chief of Ordnance. This review has resulted in a decision not to reclama to D/A Staff the improved guidance system - (Coded Ka band). The primary reasons are:

a. Time scale and costs involved and this office's assessment of the practicality of obtaining such funding.

b. Such a course would require disruption of the troop activation plan.

c. In view of the limited firing tests and the fact that the multipurpose test equipment upon which your plan depends is not funded, it is a high risk program.

d. The Army Staff has re-affirmed their position relative to ECM limitations (see paragraph 3.c. of Inclosure 1).

2. (U) It is requested that you cease all work on the "improved guidance" LACROSSE (Ka band) except for such other components as are required to improve the effectiveness, reliability or maintainability of the basic LACROSSE now in the field.

3. (U) The remarks contained in Inclosure 1 to reference letter relative to 50% down time and possibility of requiring additional maintenance personnel are disturbing. This is particularly true in view of informal information from User personnel that the down-time estimate

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ORDTX
SUBJECT: LACROSSE Program (U) 22 Jul 60

is conservative. Also, it is noted that the time scale to apply fixes to alleviate this situation is beyond the time scale of the current production buy. Information is requested as to your plan for improvement of system reliability and your proposed steps to obtain the maximum emphasis from Martin in applying necessary fixes in the event that production is completed prior to finalization and retrofit of the necessary fixes.

4. (S) In view of paragraph 2 and 3 above, Ordnance is considering recommending to the D/A Staff that plans for LACROSSE be held at the current eight battalion procurement commitment. Also, that PADA LITTLEJOHN or Missile A be considered for any additional troop requirements in this area. PADA LITTLEJOHN appears the most practical if early time frame requirement exists. Your comments on this matter would be appreciated.

5. (U) The Inclosure 1 to this letter requests information which we are unable to extract from the data incorporated in referenced letter. By separate correspondence we are asking your Command to supply this data and to up-date and identify the funding information contained therein. Upon receipt of this answer we will formalize our requests to D/A Staff for funds. In the meantime we are forwarding general information on basic LACROSSE fixes to D/A Staff for their planning purposes.

1 Incl
*Thermofax cy of ltr fm Hq., USCONARC, dtd 29 Feb 60 with 1st Ind thereto fm C/R&D to OCO dtd 27 June 60. (S)

s/t C. W. CLARK
Brigadier General, USA
Chief, Research and Development Division

*Not reproduced.

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DOCUMENT 22

HEADQUARTERS
DEPARTMENT OF THE ARMY
Office of the Chief of Ordnance
Washington 25, D. C.

In Reply Refer to: 7704 10 October 1960

ORDGX

Major General August Schomburg
Commanding General
U.S. Army Ordnance Missile Command
Redstone Arsenal, Alabama

Dear Augie:

I wish to reemphasize my very deep concern over the operability of the LACROSSE System. I am not satisfied that sufficient effort is being placed on LACROSSE to assure that a reliable system will be delivered to the field.

Last February when General Colglazier and I appeared before the House Appropriations Committee, we heard the LACROSSE System alternately referred to as "a pile of junk," "a highly questionable weapon," and "half a weapon." I wonder how close to the truth such statements would be today? Frankly, I had to admit to Congress that we had reliability difficulties. I stated, however, that we had made considerable progress toward improving the system's performance. Was I justified, really, in that statement? It will soon be a year since my appearance before the Appropriations Committee. When the next hearings are conducted, will we be able to demonstrate any appreciable improvement in the system? Progress must continue with a strong sense of urgency. No relaxation of effort will be tolerated simply because the program is in a buy-out position. Or should we cancel the program now?

In this connection, it would be to our interest to prepare a detailed review showing the problems confronting us a year ago, the actions taken to resolve them, and the improvement which has been or will be made, together with remaining problems and what is being done or can be done to solve them. I need this so that I can take the offensive and be able to relate to one and all the strides we have taken to make LACROSSE a dependable, workable system. Your review must cover all facets of the system - R&D through field operations and support.

My real concern is whether we are producing the most reliable system possible within the limitations placed upon us. I recently received your AOS-5's requesting an additional $7 million for the

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UNCLASSIFIED

Major General August Schomburg 10 October 1960

LACROSSE System. I presume that aside from the autopilot, these funds will enable you to correct all known deficiencies in the present system. If this is not the case, I will expect you to give me the details of any further requirements in connection with the review mentioned above. I want you to pursue the review on the present system, not a second generation system. It seems to me that much of the difficulty we have now may be cured by improved inspections and quality control, and good manufacturing practices.

The question of a second generation, or LACROSSE II, is separate. It must be considered in the light of the spectrum of weapons now in being, or shortly to be fielded, which will accomplish the job assigned to LACROSSE, the probable dollars to be available, and the time frame in which such a second generation LACROSSE could be fielded and supported. I doubt seriously that we could justify going for it.

I want to repeat that I am certain that LACROSSE is going to be under fire again during this budget cycle. It is important that we have a complete and objective review from which, or on which to build our case. I do not want to have to weave a fabric of fairy tales to "get it by". I want some really solid results and a really solid and detailed review. I want you and your people and the Martin people to read the published Hearings before The House Appropriations Subcommittee that cover this subject. It starts on page 118 of Part 5, Procurement, and runs through page 125. While the "off-the-record" part is omitted, it was equally juicy.

Get hot!

Sincerely,

s/t J. H. HINRICHS
Lieutenant General, USA
Chief of Ordnance

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DOCUMENT 23
HEADQUARTERS
U. S. Army Ordnance Missile Command
Redstone Arsenal, Alabama

ORDXM-I 1 Nov 60

Lieutenant General J. H. Hinrichs
Chief of Ordnance
Department of the Army
Washington 25, D. C.

Dear Jack:

(U) Reference is made to your "get hot" letter of 10 October 1960 in which you express your desire for a detailed review of the LACROSSE Missile System; such review to show the problems confronting us a year ago, the improvements which have been made or will be made to correct them, and a run-down of the remaining problems and what is being done to solve them.

(U) Since receipt of your letter there have been several significant events regarding the LACROSSE Program which I feel have overtaken the requirements of your letter and which have provided you with information to give you the major status of the LACROSSE Program.

(~~S~~ U) As I pointed out in my discussion with you on 24 October, and as noted in the copy of my talking papers which I left with you, the seven million dollars which we have requested as additional funds in FY-61 and FY-62 will complete the effort necessary to eliminate the 133 deficiencies of the LACROSSE System which are presently defined. I would like to point out that these funds will not permit the incorporation of the new autopilot nor will they provide any improvement in the area of vulnerability to friendly interference, including interference between batteries or enemy electronic countermeasures. With regard to these areas I feel that the User will just have to live with the present situation for the period of time in which the LACROSSE is intended to be utilized in the field.

(U) I feel that everything that can be done to give you a status review has been done. Unless you signify otherwise, I consider that the latest LACROSSE exercises have met the requirements of referenced letter. With respect to the importance of the subject, you may rest assured that for some time I have considered this one of our "hot" programs.

Sincerely,

s/t AUGUST SCHOMBURG
Major General, USA
Commanding

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23-1

DOCUMENT 24

HEADQUARTERS
U. S. Army Ordnance Missile Command
Redstone Arsenal, Alabama

2 November 1960

Lieutenant General J. H. Hinrichs
Chief of Ordnance
Department of the Army
Washington 25, D. C.

Dear Jack:

Reference is made to the verbal request of your staff on 31 October 1960 to this Command to answer questions concerning six possible courses of action with respect to the LACROSSE Program. It is my understanding that the answers to these questions are required by your office and DCSLOG to support a DA Staff recommendation on the LACROSSE Program to the Secretary of the Army.

On the night of 31 October 1960, Mr. Bruce Smith from your office handcarried approximately 36 pages of handwritten questions to personnel of this Command. We were advised that these questions were prepared by several segments of DCSLOG. In review, it appears they were apparently not coordinated and were not given serious consideration prior to their submittal. In addition, some of these questions were poorly worded leaving considerable room for interpretation. Therefore, in answering some of the questions, we had to use certain assumptions. We have been hampered by the manner in which the information reached us, but have done the best we can under the time limits and prevailing circumstances.

Inclosed are twenty copies of a brochure containing the specific questions which were asked us and the applicable answers for each course of action. I'd like to point out that some of these answers are a "best guess" on the part of this Command. Time did not permit a thorough evaluation and review of all the ramifications and conditions surrounding these courses of action, especially since we were instructed that we were not to consult districts or contractors.

To the best of our knowledge and ability, under these adverse conditions, the facts presented in the inclosed brochures are valid.

Sincerely yours,

/s/ August Schomburg
AUGUST SCHOMBURG
Major General, USA
Commanding

1 Incl
Brochure (20 cys)
(Inclosures handcarried to OCO by Mr. Onifrio)

LACROSSE POSSIBLE COURSES
OF ACTIONS AND EVALUATION (U)
2 November 1960
ARGMA

INTRODUCTION

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INTRODUCTION

The purpose of this brochure is to answer questions regarding the LACROSSE system and encompasses the possible following six courses of action. DCSLOG requested the subsequent question for additional background and guidance. References used in the preparation of this data are: teletype from OCORD, Number 013, dated Oct 31, 1960, to AOMC; and working papers handcarried by OCO representative to Industrial Operations, ARGMA, on 1 November 1960.

(1) The first course of action pertains to undertaking the Improved Guidance Program at a cost of at least $66.1 million.

(2) The second course of action is to terminate the LACROSSE program immediately and inactivate all units.

(3) The third consideration is to keep the current eight battalions through FY 66 at reduced strength in personnel but full strength in equipment.

(4) The fourth course is to bring four battalions to full strength and maintain through FY 66. Remaining battalions to be inactivated immediately.

(5) Course five considers termination with FY 61 buy and correction of those deficiencies currently planned to be corrected.

(6) The sixth course of action considers terminating Martin Company participation in the LACROSSE program and contracting elsewhere for current requirements.

SECTION A
COURSE OF ACTION I

Undertake the "Improved Guidance" Program at a cost of at least $66 million in PEMA.

1. Eight (8) full strength battalion through FY 66.
2. Annual service practice consumption of 96 missiles.
3. Objectives of 120 missiles per battation.

QUESTION:

1. Will it be necessary to stop current production to implement this course of action?

ANSWER: Common missile items under procurement currently scheduled for completion in September 1961, will be stretched out through February 1963, to maintain manufacturing capability. LACROSSE I missile center sections currently under procurement will be terminated. MOD I center sections will be produced from March 1962 through December 1963. LACROSSE I ground and test equipment (less common items) will be terminated. MOD I ground and test equipment will be produced from April 1962 through December 1963.

2. If production is stopped, what will be the slippage in deliveries?

ANSWER: Even though a complete stoppage in production will not occur, delivery of usable tactical missiles will stop December 1960, and will not resume until November 1961. A loss will result in assets position from a total of 762 missiles to a total of 458 missiles, June 1961; from a total of 988 missiles to a total of 441 missiles December 1961. Equipment to Augment 8 LACROSSE I R/S battations to 8 F/S battalions would not be delivered, and 4 sets of LACROSSE I fourth echelon test equipment would not be delivered.

3. Will it be necessary to alter production schedules under the new program? If so, How?

ANSWER: If the improved guidance program is implemented, a change in production schedules will be required. Missile production will be changed from anticipated delivery of complete missiles at the rate of approximately 60 per month January 1961 through October 1961, to a delivery of missile airframes at a rate of approximately 20 per month January 1961 through February 1963. In addition, an auxiliary schedule for new beacons, transponders, and autopilots will be added in order to maintain developed skills for these items, as well as provide additional complete missiles in the event of a national emergency. Schedules for production of equipment for augmentation of R/S battations to form F/S battalions will be deleted, except for the production of launchers, PPU's, and target ranging sets which will remain as presently scheduled. Production schedules for Type IV test equipment will be deleted, except for one set of fifth echelon test equipment which will remain as now scheduled.

4. How much will it cost to suspend production until a new program is ready to be implemented?

ANSWER: To suspend the program for the month of November, it is estimated that the cost would be $2,000,000.00; however, there is no suspension anticipated under present plan.

5. What will be the new lead times under the Improvement program?

ANSWER: From receipt of program approval until delivery of tactical missiles, lead time will be 22 months; until equipment is available for conversion of tactical battalions, 27 months; until equipment is available for conversion of maintenance support detachments, 29 months. Thereafter, reorder lead time for each item is 15 months (12 production and 3 administrative).

6. Furnish projected 142 report on each item. (Superseded: agreement with OCO to furnish unit price of missiles, ground equipment, and test equipment.)

ANSWER: A. Missile program unit cost including improved motor and repair parts: $136,000 (estimated).

B. Ground equipment unit cost including repair parts F/S battalions: $1,829,000 (estimated).

C. Improved system Ordnance test equipment including repair parts, excluding salvage value of vans, etc., average battalion support cost: $2,287,000 (estimated).

7. If the LACROSSE "Improved Guidance Program" is implemented, what would be the dollar impact on present and future buys?

ANSWER: A. Parts procurement

PEMA	O&M,A	(Millions of Dollars)	
FY 61 - 63	FY 64	FY 65	FY 66
$9.0	$4.0	$4.5	$4.5

B. Overhaul

		O&M,A	(Millions of Dollars)		
FY 61	62	63	64	65	66
.6	1.08	1.5	1.5	1.5	1.5

C. Modification

		O&M,A	(Millions of Dollars)		
FY 61	62	63	64	65	66
.52	.714	.15	.15	.15	.15

D. Technical Representatives

		O&M,A	(Millions of Dollars)		
FY 61	62	63	64	65	66
.343	.343	.343	.181	.181	.181

E. Manuals

		O&M,A	(Millions of Dollars)		
FY 61	62	63	64	65	66
.2	.2	1.2	.15	.08	.08

(NO Add-On Costs)

8. Would the "Improved Guidance Program" affect the present support plan as to the numbers of direct support and general support units presently deployed? Are they capable of supporting within existing TO&E's? If not, what would they require?

ANSWER: The present LACROSSE system has (8) direct support detachments and (2) general support detachments. Under the "Improved Guidance" concept a total of 5 field maintenance detachments will fulfill the support role. They will be assigned on an area basis with a contact team added for each additional battalion supported. The present TO&E's will not suffice and the following is the recommended table of organization:

				C/T
Detachment Commander	4801	Capt	1	
Operation Officer	4801	Lt	1	
Maintenance Officer	4815	WO	1	
Operations Sgt	248.60	E8	1	
SR. External Guid, Repm	248.60	E6	1	1
External Guid, Repm	248.10	E5	2	1
Ass't Ext Repm	248.10	E4	1	

Sect Chief Internal Repm	247.60	E6	1	
Internal Guid Repm	247.10	E5	2	1
Ass't Internal Repm	247.10	E4	1	
ORD Supply Spec	763.60	E6	1	
ORD Supply Spec	763.10	E4 & E5	6	
Wrecker Operator	631.10	E4	1	
Pwr Gen Spec	624.10	E4	1	
Clerk Typist	711.10	E4	1	
Electro Mech Repm	434.60	E6	1	
Electro Mech Repm	434.10	E4		1
				23/4

Equipment list will be developed at a later date if this program is approved.

9. Assuming the MAC's would have to be revised, what would be the estimated cost of this program?

ANSWER: $57,600 O&M,A (estimate).

10. What are OGMS requirements in support of this program?

ANSWER: 2 sets of ground equipment
2 sets of Type IV test equipment
9 modification kits for missiles
2 sets of training spares
Except for training spares all are in the $66 million program.

11. Does MOD I require additional test equipment? If so, what is the dollar amount? Is this included in the $66 million buy?

ANSWER: Yes, the MOD I program will require additional test equipment. The cost of this equipment is $6.0 million FY 61, $6.0 million FY 62, and $3.6 million FY 63 and this cost is included in the $66 million program. This additional test equipment replaces the present test equipment.

12. Is any of the $66 million applicable to O&M,A?

ANSWER: No.

13. Deleted.

14. What will be the cost for:

A. Engineering the modification and/or redesign of existing missiles?

ANSWER: $4,750,000 (estimate).

B. Engineering the modification and/or redesign of existing ground handling equipment?

ANSWER: $6,250,000 (including missile guidance central) (estimate)

C. Engineering the modification and/or redesign of training equipment?

ANSWER: $200,000 (estimate).

15. What are the costs of developing inspection procedures (quality assurance)?

ANSWER: $1,500,000 (estimate).

16. What added costs will be incurred for materiel consumed, facilities, and services utilized in proof and acceptance testing?

ANSWER: $690,000 (estimate) total. Of this $550,000 is for material and $140,000 is for services.

17. What is the added cost of in-house engineering to establish requirements to be performed by the contractor and to insure adequate contractor performance of engineering services?

ANSWER: None (engineering personnel are not oriented by system).

18. What are the costs for amending and revising specifications, drawings, and standards to up-date the procurement package?

ANSWER: $4,300,000 (estimate) (includes $1,500,000 cited in question 15 under this action).

NOTE: The funds cited in answers to questions 14, 15, 16, 17 & 18 are included in the $66.1 million improved guidance program.

19. Would additional facilities be required?

ANSWER: No additional facilities will be required for the MOD I program.

20. If additional facilities are required, what would be their cost and how would they be financed under the present 4200 budget?

ANSWER: None required.

21. How long would it take to acquire additional facilities, if needed?

ANSWER: None required.

22. What amount of PEMA 4231 would be required? By fiscal years?

ANSWER: None.

23. Transportation costs returning missiles, warheads, guidance and launching equipment (breakout separately and show totals)?

ANSWER: $40,000.

24. Storage (order of magnitude and costs)?

ANSWER: N/A

25. Should oversea demilitarization be considered? (Give cost - oversea vs. CONUS).

ANSWER: Demilitarization of obsolescent equipment should be accomplished overseas. Estimated cost $150,000 for demilitarization Type IV, ground equipment and missile components.

26. Recommend applications for alternate utilization of peculiar equipment?

ANSWER: N/A

27. Financial implications of repair parts support required?

ANSWER: Same as 7 A.

SECTION B
COURSE OF ACTION II

Terminate the LACROSSE program immediately and inactivate all units.

1. Stop all procurement immediately and recoup maximum funds estimated at $20 million after termination cost.

QUESTION:

1. How much money will be recouped by the Army? By MAP?

ANSWER: An estimated 20 million dollars by Army after termination cost. Not applicable for MAP since no MAP funds have been obligated.

2. Will there be any serious impact on civilian communities as a result of the termination of the LACROSSE program? If so, where and how much?

ANSWER: A. Orlando, Florida: The Martin Company, prime contractor for LACROSSE, is located in Orlando, Florida, and employs approximately 8,100 people. Of this number approximately 2,500 work on the LACROSSE. A sudden unemployment of 2,500 people in a city the size of Orlando would definitely cause a serious impact. Local merchants, banks and investment institutions would immediately feel a decline in business. In addition, local government and schools would be penalized in loss of revenue at a time when their yearly budget is already in operation.

B. Due to contracts of a smaller nature and subcontractors, an impact of a lesser degree will result in the following communities:

Springfield, Mo. - Trailmobile, Inc. - missile container
Nutley, N. J. - ITT Federal - airborne guidance
Elmhurst, N. Y. - Kollsman Inst. Co. - altitude control unit
Santa Monica, California - Summers Gyro - gyroscopes
Burlington, Mass. - Associates, Inc. - magnetron tubes
Marshall, Texas - Longhorn Ordnance Works - motor loading
Burlington, Iowa - Iowa Ordnance Plant - warhead loading

NOTE: The above is not all inclusive but takes into consideration the major suppliers and supporting Government installations.

3. Will the LACROSSE termination result in increased PERSHING G&A cost: If so, how much by percent and by dollars.

ANSWER: Termination of LACROSSE will increase PERSHING overhead approximately 4 to 5 million dollars Martin does not breakout G&A cost.

4. How much committed O&M,A money can be recouped?

ANSWER: $1,350,000 (estimate).

5. How much money spent can be saved in terms of salvage and other requirements?

ANSWER: Estimated $2.2 million. This is in addition to $20 million.

6. What would be the cost to terminate the present contracts?

ANSWER: $7.8 million (estimate).

7. Deleted.

8. What is the time estimated to complete all termination actions?

ANSWER: Army procurement regulations provide 12 months for termination, and that additional time may be allowed upon approval by higher authority. It is estimated that approximately 24 to 36 months will be required to complete all termination actions.

9. What is the estimated value of the termination inventory?

ANSWER: Estimated $15 million.

10. Deleted.

11. What items in the termination have application or can be adapted for other use?

ANSWER: An estimated $3.2 million for the system hardware is given in lieu of the item identification due to the numerous listings involved.

12. What facilities would be laid away and what would be the cost thereof?

ANSWER: $45,000 (estimate). The $455,000 for layaway in the current 5 year materiel plan was based on a future requirement for the LACROSSE system. Under termination of the program, it is assumed that any future requirement would be deleted.

13. Transportation costs returning missiles, warheads, guidance and launching equipment (breakout separately and show totals)?

ANSWER: $557,000 (estimate).

14. Storage (order of magnitude and costs)?

ANSWER: $64,300 (estimate).

15. Should oversea demilitarization be considered? (Give cost - oversea vs. CONUS). (Cost included in items 13 and 14).

ANSWER: N/A

16. Recommend applications for alternate utilization of peculiar equipment?

ANSWER: N/A

17. Financial implications of repair parts support required?

ANSWER: N/A

SECTION C
COURSE OF ACTION III

Keep current 8 battalions through FY 66 and reduce strength in personnel but full strength in equipment.

1. Missile objective of approximately 100 per battalion.

2. Annual service practice consumption of 48 missiles.

3. Correct those deficiencies that are currently planned to be corrected.

4. Terminate all procurement not necessary to support above objectives.

5. No additional procurement of missiles in FY 61.

QUESTION:

1. How much will it cost to correct the deficiencies in subparagraph 3.C. and where do you propose to get the funds?

ANSWER: $7.2 million. If funds cannot be made available by OCO and hardware reduction were a necessity, then all FY 61 hardware procurement, with exception of range safety warheads and warhead containers, would be cancelled. An additional 20 missiles from the FY 60 program would also have to be terminated. With these cancellations and the necessary authorization to utilize available in-house repair parts authorities, the $7.2 million could be realized for correction of deficiencies. Should this course of action be pursued, the basic load of missiles for each full strength battalion must be reduced to 108 each.

2. Will there be any cost increase for the remaining procurement (CA-3D) if so how much? Will there be any slippage in procurement? If so, where and how much?

ANSWER: This answer is based on the assumption that the question applies to 1.D. of "Course of Action III" and the assumption that 1.E. of "Course of Action III" means NO missiles will be procured in FY 61; consequently, there will be no increase in cost and no slippage in procurement.

3. Will there be any serious impact on civilian communities as a result of the termination of the LACROSSE program? If so, where and how much?

ANSWER: No termination under assumptions listed in Question 2; therefore, no impact.

4. What would be the impact on Ordnance specifically in reference to maintenance of this equipment if users were at half-strength?

ANSWER: This approach would enhance the Ordnance position as far as maintenance is concerned. This would allow for turn around major items to the battalion and would reduce the operational down time of the battalion. If a decision to implement this approach is rendered, it is recommended that battalions go to full strength in personnel and

equipment in the firing section, and that the guidance section remain at reduced strength in personnel and 3/4 strength in equipment. Approximately 8 guidance stations could be deleted from procurement by this action. This would save $2.8 million.

5. In connection with Item 5, what would be the addition cost, if any, due to a slow down of production while the engineering change orders to correct deficiencies are being incorporated in the contract?

ANSWER: There is no anticipated slow down of production while the engineering change orders to correct deficiencies are being incorporated in the contract.

6. A. What would be the estimated costs to terminate based on the revised Army and MAP requirements?

ANSWER: In order to support the criteria stated, there would be no termination costs. Instead, it would be necessary to procure in FY 61: 56 missiles for Army; 40 missiles for MAP; 24 range safety warheads for Army; 10 T34E2 HE warheads for MAP; 1 F/S battalion equipment set for MAP; 1 set Type IV test equipment for MAP.

6. B. What is the estimate of deobligated funds in the event of partial termination checkout funds deobligated on a PRORATA basis of Army and MAP requirements?

ANSWER: In view of 6.A., not applicable.

6. C. What would be a fair dollar estimate of the termination inventory? (Breakout separately any items which would have a use on other systems).

ANSWER: In view of 6.A., not applicable.

6. D. Deleted.

7. What will be the cost for:

A. Engineering the modification and/or redesign of existing missiles?

ANSWER: $4,735,000 (estimate).

B. Engineering the modification and/or redesign of existing ground handling equipment?

ANSWER: $8,713,000 (includes test equipment) (estimate).

C. Engineering the modification and/or redesign of training equipment?

ANSWER: $200,000 (estimate).

The above funds include those necessary to provide the engineering to correct the 133 deficiencies of the present system and normal production engineering through FY 66.

8. What are the costs of developing inspection procedures (quality assurance)?

ANSWER: None, these procedures are already being developed.

9. What added costs will be incurred for materiel consumed, facilities and services utilized in proof and acceptance testing?

ANSWER: None.

10. What is the added cost of in-house engineering to establish requirements to be performed by the contractor and to insure adequate contractor performance of engineering services?

ANSWER: None. Engineering personnel are not oriented by system; therefore, this course of action will not result in a change of such personnel.

11. What are the costs for amending and revising specifications, drawings, and standards to up-date the procurement package?

ANSWER: None to up-date present procurement package. Approximately $500,000 per year to keep documentation current and up to date. Costs for up-dating documentation as a result of engineering to correct 133 deficiencies is included in $7.2 million cited in Question 1 of this course of action.

12. A. Would additional facilities be required?

ANSWER: No.

B. What would be the cost?

ANSWER: N/A

C. What amount of PEMA 4231 funds would be required by fiscal year? (Post production engineering funds).

ANSWER: 1.0 million, FY 62 (estimate)
2.0 million, FY 63 (estimate)
2.0 million, FY 64 (estimate)
2.0 million, FY 65 (estimate)
2.0 million, FY 66 (estimate)

13. Would layaway of any facilities be necessary? What would be the cost?

ANSWER: It is anticipated that all facilities would be utilized on other missile programs, and that no layaway would be effected, consequently no cost of layaway incurred.

14. Transportation costs returning missiles, warheads, guidance and launching equipment (breakout separately and show totals)?

ANSWER: N/A

15. Storage (order of magnitude and costs)?

ANSWER: N/A

16. Should oversea demilitarization be considered? (Give cost - oversea vs. CONUS).

ANSWER: N/A

17. Recommended applications for alternate utilization of peculiar equipment?

ANSWER: N/A

18. Financial implications of repair parts support required?

ANSWER: N/A

NOTE: (Questions 14 - 18) no additional costs are to be incurred by implementation of this program. This is a current Army program.

SECTION D
COURSE OF ACTION IV

Bring four (4) battalions to full strength and maintain thru FY 66; remaining battalions to be inactivated immediately.

1. Missile objective of 120 missiles per battalion.

2. Annual service practice consumption of 48 missiles.

3. Correct those deficiencies currently planned to be corrected.

4. Terminate all procurement not necessary to support above objectives.

QUESTION:

1. How much will it cost to correct the deficiencies listed in Course of Action IV C and where will you get the funds?

ANSWER: Cost $6,000,000 estimated.

A total of $4,015,000 will be realized by cancellation of FY 61 missile buy, use of $1,300,000 FY 60 repair parts, authority and termination of 20 missiles from FY 60 buy.

2. What will be the termination charges and how much money will the Army and MAP regain from the termination? Will there be any slippage in the remaining production? If so, how much?

NOTE: Action on FY 61 Army procurement and FY 60 MAP procurement has been suspended by DCSLOG until the decision is made on which course of action to adopt.

ANSWER: It is estimated that termination charges will be $1.4 million. The Army will recoup an estimated $6.5 million from the termination. MAP regain is not applicable since it is not under contract. There will be no slippage in remaining production.

3. Will there be any adverse effects on civilian communities from the termination listed in Course of Action IV D? If so, how much and where?

ANSWER: The termination under IV D would be a partial termination and would result in an impact less severe than that reported under Course of Action II, Question 2. Unable to measure the severness of the

impact at this time.

4. Will there be any increased costs for the items to be procured? If so, how much?

ANSWER: The only item that will be procured under this concept will be range safety warheads. Since this item is only a minute particle of the total production to be at Martin, Orlando, an estimated 20% increase in cost would occur. This amounts to approximately $275,000 cost increase per year for range safety warheads.

5. What savings will be realized under this plan in the following areas:

A. Part procurement O&M,A?

ANSWER:	FY 61	62	63	64	65	66
	.6	2.	2.2	2.2	2.2	2.2

B. Overhaul?

ANSWER:	FY 61	62	63	64	65	66
	.3	.54	.75	.75	.75	.75

C. Modifications O&M,A?

ANSWER:	FY 61	62	63	64	65	66
	.22	.14	.11	.05	.05	.05

D. Technical representatives O&M,A?

ANSWER:	FY 61	62	63	64	65	66
	.12	.12	.12	.12	.12	.12

E. Maintenance engineering?

ANSWER: No savings.

6. In connection with Item C what would be the additional cost if any, due to a slow down of production while the ECO's to correct deficiencies are being incorporated in the contract?

ANSWER: No additional cost is contemplated as result of production slow down because no production slow down would occur.

7. A. Deleted.

B. Deleted.

C. What would be fair dollar estimate of the termination inventory? (Breakout separately and items which would have a use in other systems).

ANSWER: Item 4 applicable to this is, terminate all procurement not necessary to support objectives of Course of Action IV. A fair dollar value of termination inventory is approximately $1,413,500.

D. Deleted.

8. What will be the cost for:

A. Engineering the modification and/or redesign of existing

missiles?

ANSWER: $4,735,500 (estimate).

B. Engineering the modification and/or redesign of ground equipment?

ANSWER: $8,713,000 (includes test equipment) (estimate).

C. Engineering the modification and/or redesign of training equipment?

ANSWER: $200,000 (estimate).

The above funds include those necessary to provide the engineering to correct the 133 deficiencies of the present system and normal production engineering through FY 66.

9. What are the costs of developing inspection procedures (quality assurance)?

ANSWER: No additional costs. These procedures are already being developed.

10. What added costs will be incurred for materiel consumed, facilities, and services utilized in proof and acceptance testing?

ANSWER: None.

11. What is the added cost of in-house engineering to establish requirements to be performed by the contractor and to insure adequate contractor performance of engineering services?

ANSWER: None. Engineering personnel are not oriented by system.

12. What are the costs for amending and revising specifications, drawings and standards to up-date the procurement package?

ANSWER: None to up-date present package. Approximately $500,000 per year to keep documentation current and up to date.

13. Would additional facilities be required? What would be the cost?

ANSWER: No additional facilities required.

14. Would any layaway of facilities be required? What would be the cost?

ANSWER: No layaway required.

15. Transportation costs returning missiles, warheads, guidance and launching equipment (breakout separately and show totals)?

ANSWER: N/A

16. Storage (order of magnitude and costs)?

ANSWER: N/A

17. Should oversea demilitarization be considered? (Give cost - oversea vs. CONUS).

ANSWER: N/A

18. Recommended applications for alternate utilization of peculiar equipment?

ANSWER: N/A

19. Financial implications of repair parts support required?

ANSWER: N/A

NOTE: If an early decision is provided there will be no requirement to ship additional Type IV to USEUR. These equipments (3) DS and (1) GS which are scheduled for early deployment can be diverted to maintenance float, Ordnance Depots for rebuild, and any non-tactical applications which may be required.

SECTION E
COURSE OF ACTION V

Terminate with FY 61 buy and correct those deficiencies currently planned to be corrected.

1. Essentially the program we are currently following.

2. Missile procurement may be cut back to make $7 million available that is required for correction of deficiencies.

3. No FY 62 procurement except training warheads, therefore, test equipment previously scheduled for FY 62 buy must be procured within FY 61 funds.

QUESTION:

1. Will it be necessary to cut back missile production to get the $7 million required for correction of deficiencies? If so, how much of a cutback? If any missiles are to be procured, what are the new estimated costs?

ANSWER: Yes, cancel all hardware procurement in FY 61 with the exception of range safety warheads and warhead containers. An additional 20 missiles from the FY 60 program would also have to be terminated. With these cancellations and the necessary authorization to utilize available in-house repair parts authorities, the 7 million could be realized for correction of deficiencies. Should this course of action be pursued, the basic load of missiles for each full strength battalion must be reduced to 108 each.

2. What are the estimated costs for FY 61 and any subsequent procurement for Army or MAP, separately?

ANSWER: (Estimates)

ARMY	4120.2	$15,647,336	
	4220.2	455,000	Layaway
	4230.1	1,000,000	Ground Equipment Engineering
MAP	4020.2	5,086,728	

3. Will there be any adverse effect on civilian communities? If so, how much and where?

ANSWER: If termination is planned and notice is given six or eight months in advance, then there should be no serious impact on civilian communities. Contractor employees, community merchants, banks, schools, and local government will have ample time to plan and adjust to a decline in the economic growth of their communities.

4. Will there be any break in production for the FY 61 Army buy and the MAP 60 buy if a decision is made by 1 December 1960? If so, how much will the break cost the Army and MAP, separately?

ANSWER: There will be a break in production in that the FY 61 Army buy, originally intended to be placed under contract one month prior to the target date for decision of 1 December 1960, will be delayed until receipt of decision. There will be no break in production in MAP since the receipt of MAP go-ahead was not anticipated until a date after 1 December 1960. The estimated cost of break in production for FY 61 Army buy is $2. million for month of November 1960.

5. How much will it cost to terminate the FY 61 Army buy? The FY 60 MAP buy?

ANSWER: A. No FY 61 Army funds have been contractually obligated; however, $500,000 has been obligated for ARGMA in-house support. Therefore, there will be no contractual termination cost.

B. No FY 60 MAP funds have been obligated; therefore, there will be no termination cost.

6. Would this course of action have an impact on the present program?

ANSWER: No.

7. What will be the cost for:

A. Engineering the modification and/or redesign of existing missiles?

B. Engineering the modification and/or redesign of ground handling equipment?

C. Engineering the modification and/or redesign of training equipment?

ANSWER: (Question 7A).

A. $4,735,000 (estimate).

ANSWER: (Question 7B).

B. $8,713,000 (includes test equipment) (estimate).

ANSWER: (Question 7C).

C. $200,000 (estimate).

The above funds include those necessary to provide the engineering to correct the 133 deficiencies of the present system and

normal production engineering through FY 66.

8. What are the costs of developing inspection procedures (quality assurance)?

ANSWER: No additional costs. These procedures are already being developed.

9. What added costs will be incurred for materiel consumed, facilities and services utilized in proof and acceptance testing?

ANSWER: None.

10. What is the added cost of in-house engineering to establish requirements to be performed by the contractor and to insure adequate contractor performance of engineering services?

ANSWER: None. Engineering personnel are not oriented by system. Approximately $1,000,000 ARGMA in-house support would have to be absorbed by other missile systems.

11. What are the costs for amending and revising specifications, drawings, and standards to up-date the procurement package?

ANSWER: None to up-date present package. Approximately $500,000 per year to keep documentation current and up-to-date.

12. What layaway would be required if termination with the FY 61 buy occurs?

ANSWER: It is anticipated that all facilities would be utilized on other missile programs, and that no layaway would be effected, consequently no cost of layaway incurred. $455,000 (estimate). The $455,000 for layaway in the current 5 year materiel plan was based on a future requirement for the LACROSSE system. Under termination of the program, it is assumed that any future requirement would be deleted.

13. What additional facilities, if any, would be required to correct deficiencies currently planned to be corrected?

ANSWER: No additional facilities are contemplated.

14. What amount of PEMA 4231 funds would be required by fiscal years? (Post production engineering funds).

ANSWER: (Estimated).

1.0 million, FY 62
2.0 million, FY 63
2.0 million, FY 64
2.0 million, FY 65
2.0 million, FY 66

SECTION F
COURSE OF ACTION VI

Terminate Martin Company participation in the LACROSSE program and contract elsewhere for current requirements per missile equipment and engineering support.

1. Time, slippages, costs increase for termination.

2. The new company would have to re-tool - great cost for training new personnel.

QUESTION:

1 How much will it cost to terminate Martin Company participation? How much would the Army recoupe from the termination? MAP?

ANSWER: It is estimated that the cost to terminate Martin Company participation would be approximately 5.7 million dollars. The Army would recoupe an estimated $17.3 million. No recoupe on MAP because no MAP to terminate.

2. Do you consider it feasible to use the present Martin Company subcontractors when the contract is placed elsewhere? If so, will there be a cost increase and how much?

ANSWER: Yes. It is strongly recommended that any new prime contractor utilize LACROSSE existing subcontractors in order to minimize problem areas. Due to increased competition among subcontractors, no direct cost increase could be foreseen. See "Course of Action (contractor)," Question 1, in this section, relative to increased indirect costs.

3. How long would it take to terminate Martin Company participation and to prepare for production using one of the arsenals as a major prime?

ANSWER: As specified in answer to Question 8, Course of Action II, approximately 24 to 36 months would be required to completely terminate the current LACROSSE program. In accordance with BOB Bulletin 60-2, this is considered a new start and would be in direct conflict with this policy; therefore, it is not considered feasible to introduce another arsenal as a major prime.

4. How long would it take to transfer production to another unspecified civilian concern?

ANSWER: Providing the termination directive and authority to contract with another commercial concern are received concurrently, approximately 30 months will lapse prior to initial delivery from the new contractor. These 30 months are required for: selection of contractor, procurement and installation of tooling, training of manufacturing personnel, procurement of necessary materials and equipment from subcontractors, manufacturing and final assembly.

5. How much would it cost for each of the above situations?

ANSWER: The answer to this question in included in Numbers 6 & 7 below.

6. How much would it cost using the arsenal as the major prime?

ANSWER: In accordance with BOB Bulletin 60-2, this is considered a new start and would be in direct conflict with this policy; therefore, it is not considered feasible to introduce another arsenal as a major prime.

7. How much would it cost using another civilian firm as the major prime?

ANSWER: To procure the programmed FY 60 and FY 61 quantities of missiles from another commercial contractor, an estimated total of $63.8 million will be required. This is exclusive of the AK program. This does not include funds to correct 133 deficiencies.

8. What would be the slippage in production in each of the above cases?

ANSWER: Due to the 30 months required prior to initial production and then the approximately 6 months at a relatively low production rate, approximately 3 years slippage in production will occur if recontracting with a commercial concern is instigated.

9. What would be the new lead times for each of the items in the above situations?

ANSWER: The initial lead time for all items with a new contractor will be approximately 30 months as follows: 6 months for selection of contractor and contracting, 24 months for production. Reorder lead time for each item will be 15 months as follows: 3 months administrative, 12 months production.

10. Will the LACROSSE termination result in increased PERSHING G&A cost? If so, how much by percent and by dollars?

ANSWER: Termination of LACROSSE will increase PERSHING overhead approximately 4 to 5 million dollars. Martin does not breakout G&A cost.

11. Will there be any serious impact on civilian communities as the result of termination of Martin Company participation? If so, where and how much?

ANSWER: A. The Martin Company, prime contractor for LACROSSE is located in Orlando, Florida, and employs approximately 8,100 people. Of this number, approximately 2,500 work on the LACROSSE. A sudden unemployment of 2,500 people in a city the size of Orlando would definitely cause a serious impact. Local merchants, banks and investment institutions would immediately feel a decline in business. In addition, local government and schools would be penalized in loss of revenue at a time when their yearly budget is already in operation.

B. Due to contracts of a smaller nature and subcontractors, an impact of a lesser degree will result in the following communities:

Nutley, N. J. - ITT Federal - Airborne Guidance
Elmhurst, N. Y. - Kollsman Inst. Co. - Altitude Control Unit
Santa Monica, Calif. - Summers Gyro - Gyroscopes
Burlington, Mass. - Associates, Inc. - Magnetron Tubes

12. What are the answers to the first 11 questions assuming that Course of Action 5 is adopted instead of Course of Action 1?

ANSWER: Since this is based upon termination at completion of the FY 61 procurement program, only range safety warheads would be involved. Following answers relate to specific Questions 1 through 11 under the Question 12 circumstances:

(1) No termination costs as such due to orderly closeout of program.

(2) No major subcontractors participate in production of the range safety warhead. Documentation will be adequate to support competitive procurement of FY 62 program quantities. Using this method of procurement, an estimated 10% reduction in cost should be realized.

(3) Martin Company termination - not applicable, 10 months would be required from receipt of program authority until delivery of the first item as follows: 3 months administrative, 7 months production.

(4) Under good procurement practices, approximately 11 months.

(5) This question is so answered by Numbers 6 and 7 below.

(6 & 7) It is estimated that by using an arsenal or another commercial contractor as the prime, the range safety warhead should be acquired at a 10% reduction in the Martin Company costs.

(8) No slippage would occur.

(9) As established in answers to Questions 3 and 4 above.

(10) Due to the small amount of workload involved, this orderly phase out should not appreciably affect other contracts at Martin Company.

(11) Under this situation, an orderly close out would be effected; therefore, no serious impact would occur.

13. Furnish any additional information you consider pertinent which is not requested above?

ANSWER: None.

14. Are there enough repair parts, modification kits, etc., in the pipe line to take care of the existing systems during the downtime of selection and production of a new contractor?

ANSWER: The concurrent buy, plus the very small amount of replenishment procurement would be inadequate to support the Martin peculiar items. Vendor and Martin subcontractor items could be replenished from vendors and subcontractors. It would probably be necessary to put some of the factory tooling in depots to fabricate critical items of peculiar equipment.

15. Deleted.

16. Deleted.

17. What is the estimate of the value of the termination inventory?

ANSWER: An estimated $14.5 million.

18. Deleted.

19. Deleted.

COURSE OF ACTION (IN-HOUSE)

1. What will be the cost for:

A. Engineering the modification and/or redesign of existing missiles?

B. Engineering the modification and/or redesign of existing equipment?

C. Engineering the modification and/or redesign of training equipment?

ANSWER: Presently, there is no in-house capability to perform complete engineering support for this system.

2. What are the costs of developing inspection procedures (quality assurance)?

ANSWER: Approximately $400,000 to checkout new manufacturing facility inspection procedure and assure that acceptance criteria of manufacturing facility is compatible with system.

3. What added costs will be incurred for material consumed, facilities, and services utilized in proof and acceptance testing?

ANSWER: Due to increase in quantity of proof test missile required resulting from new manufacturing facility, $1,350,000 (estimate) will be required.

4. What are the costs for amending and revising specifications, drawings and standards to up-date the procurement package?

ANSWER: For documentation maintenance only (no engineering) approximately $1,000,000 first year and $750,000 per year thereafter.

5. Do we have capability for accomplishing design and engineering in-house? If so, what will be the cost?

ANSWER: No.

6. What are the production engineering costs if in-house production is contemplated?

ANSWER: There are no costs quoted because production engineering cannot be accomplished in-house.

7. What would be cost of layaway, if any, for Martin Company? Subcontractors?

ANSWER: No layaway contemplated for Martin Company or subcontractors since it is anticipated that production equipment would be utilized elsewhere.

8. Course of Action VI as to termination and action under Number I. 1 thru 3.

ANSWER: Policy set forth in BOB Bulletin 60-2 prohibits this course of action.

9. Would additional facilities be required? What is the estimated cost?

ANSWER: In-house capability for the production of this system does not exist; therefore, this question is not applicable.

10. Would PEMA 4231 funds be required? If so, what amount? Time required to complete these actions? (Post production engineering funds).

A. Performance in-house by Ordnance?

B. By another private contractor?

ANSWER: A. None, as the capability does not presently exist.

B. FY 62 1.2 million
FY 63 2.4 million
FY 64 2.4 million
FY 65 2.4 million
FY 66 2.4 million

SUB-COURSE OF ACTION - CONTRACTOR

1. What will be the cost for:

A. Engineering the modification and/or redesign of existing missiles?

B. Engineering the modification and/or redesign of existing ground handling equipment?

C. Engineering the modification and/or redesign of training equipment?

ANSWER: FY 61 - $5,000,000 (estimate).
FY 62 - $4,000,000 (estimate).
FY 63 - FY 66 - $375,000 per year (estimate).

These funds are increased over what would be required by Martin Company due to the fact that any other contractor would have to build up and maintain a high order of capability and intelligence which is already available at Martin. In addition to these additional funds required, this course of action would result in a delay of approximately 9-12 months in the Industrial Engineering program.

2. What are the costs of developing inspection procedures (quality assurance)?

ANSWER: Approximately $400,000 to checkout new manufacturing facility inspection procedure and assure that acceptance criteria of manufacturing facility is compatible with system.

3. What added costs will be incurred for material consumed, facilities and services utilized in proof and acceptance testing?

ANSWER: $1,350,000 (estimate). This added cost would be

necessitated by the fact that extensive proof testing would be required in the early phase of any new manufacturer's effort gradually increasing in rates as more confidence was attained.

4. What is the added cost of in-house engineering to establish requirements to be performed by the contractor and to insure adequate contractor performance of engineering services?

ANSWER: $250,000 (estimate) per year. Required for additional personnel to closely monitor and direct contractor engineering effort.

5. What are the costs for amending and revising specifications, drawings, and standards to up-date the procurement package?

ANSWER: Approximately $1,500,000 first year; $1,000,000 per year thereafter. This cost is estimated as that required to train contractor in Ordnance documentation requirements and procedures and to provide the same capability which is now provided by Martin Company with respect to maintenance of documentation. This would be reduced approximately 20% if the contractor had prior experience in documentation effort for ARGMA.

6. Course of Action VI as to termination and under Number V. (1 thru 3)?

ANSWER: The time and costs involved in pursuing this course of action would be prohibitive. Therefore, information of this question is not submitted.

7. Would additional facilities be required? What is the estimated cost?

ANSWER: Amount of facilities cannot be determined until contractor has been selected. However, an undeterminable amount of facilities at Martin Company may be transferred to new contractor.

8. Would PEMA 4231 funds be required? What is estimated cost?

ANSWER: (Estimated) (Post production engineering funds). FY 63 - 2.4 million; FY 64 - 2.4 million; FY 65 - 2.4 million; FY 66 - 2.4 million.

9. Time required to complete these actions:

A. By performance in-house by Ordnance?

B. By another private contractor?

ANSWER: A. N/A
B. FY 62 - 66

10. Per verbal agreement with ORDPX the following is offered in lieu of 142 Report.

ANSWER: Missile program unit cost including improved motor, and repair parts, etc., if it were produced by new contractor; $162,200 (estimate). Ground equipment program unit cost including repair parts, etc., (full strength battalions) if they were produced by new contractor; $2,194,800 (estimate). Test equipment program unit cost of set of Type IV (present concept) if it were produced by new contractor; $1,300,000 (estimate).

DOCUMENT 25

214/04

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PP RUEBZH

DE RUEPC 11K

S 041539Z (Jan 61)

FM COFORD DA

TO RUEBZH/CGUSAOMC HUNTSVILLE

INFO RUEBZC/CGUSARGMA HUNTSVILLE

RUELPT/CO MISMA CHAMBERSBURG

DA GRNC

BT

S E C R E T DA988100 from ORDAA ONOFRIO

1. (S) References:

a. DA987486 dtd 20 Dec 60 (Info cy to AOMC & ARGMA) covering decision to remain at reduced strength LACROSSE bns.

b. ORDXR-IL 1028 dtd 21 Dec 60 requesting decision on procurement of LACROSSE Missiles.

c. ORDXM-IF 12-2-60 dtd 28 Dec 60 requesting definitive guidance on LACROSSE program.

d. ORDIZ-AR 12-255 stating planned FY-61 LACROSSE msl procurement has been cancelled.

2. (S) The translation of the DA Staff decision (Ref 1a) in terms of units, equipment, and inventory objectives (10) follow:

a. 8 reduced strength bns (EUR-3, PAC-1, CONUS-4)

4 sets maintenance float equipment.

1 additional missile guidance control per Bn.

1 additional launcher per Bn.

b. Missile inv obj 95 per Bn by end FY-62.

Missile loss factors are:

FY 61 - 68

FY 62 - 58 (10 of this qty to be held in depot for future alloc.)

C O P Y

FY 63 thru FY 66 - 48 per year.

c. XM-84 inv obj for FY 62 thru FY 64 is reduced to 372. (The feasibility of this reduction should be checked with CGOSWAC).

d. T34 Whd inv obj should be adjusted based on XM84. I.O. plus 28.

e. Practice whd reqmnts should be computed on basis of ASP firings for reduced strength Bns.

f. Type IV test equip. required to support reduced force structure.

g. 4 range safety systems (incl Type IV Test Equip.)

h. 11 missile traj simulators.

i. Assume no MAP procurements.

j. Complete planned modifications on remaining assets.
NOTE: Coordination should be effected with MISMA on specific major end item requirements.

3. (C) Request UR Command:

a. Take immediate termination action to meet stated objectives in a manner most economical to the government.

b. With a view toward a buy—out of required hardware in FY 61, determine items for which additional procurement is required.

c. Furnish this office by 12 Jan 61:

1. Your termination plans including quantities and amount of recoverable PEMA funds. Also furnish changes to AMCP reflecting quantities and dollars to most economically and efficiently complete program.

2. FY 61 O&M,A funds to be recovered and your plans for re-obligation. In addition, your estimated savings to be generated in the FY 62 O&M,A program

04/1539Z

DOCUMENT 26

LIST OF LACROSSE CONTRACTS

Compiled by: Mary T. Cagle

NOTE: The contract information assembled in this document is not considered final or complete. Since time did not permit a complete search of all contract files, it was necessary to limit the information to immediately available sources indicated.

DOCUMENT 26

LIST OF LACROSSE CONTRACTS[a/]

PART I - NAVY CONTRACTS WITH APL/JHU & CAL[b/]

Contract Number	Type	Date	Item or Objective	Contract Value
Unknown	--	1947-50	LACROSSE Feasibility Studies: APL/JHU - FY 48:	$ 60,000
			CAL - FY 49:	100,000
			CAL - FY 50:	250,000
			TOTAL:	$ 410,000

PART II - ARMY CONTRACTS WITH CORNELL AERONAUTICAL LABORATORY, INC.

DA-30-115-ORD-11	CPFF	Jun 50	Research & Development, LACROSSE.....	74,415[b/]
DA-30-115-ORD-47	CPFF	Feb 51	Research & Development, LACROSSE.....	20,278,082
DA-30-115-ORD-908	CPFF	Nov 57	Research & Development, LACROSSE.....	6,231,518
			TOTAL:	$ 26,584,015

PART III - ARMY CONTRACTS WITH THE MARTIN COMPANY

DA-36-034-ORD-1892	CPFF	Apr 55	Research, Development, & Testing.....	26,888,372
DA-36-034-ORD-2000	CPFF	May 55	LACROSSE I Engineering Study.....	7,078,100
DA-36-034-ORD-2013	CPFF	Jun 55	Production of Missile & Ground Equipment.....	42,582,159
DA-36-034-ORD-2216	CPFF	Jan 56	Training Aids.....	135,900
DA-36-034-ORD-2244	FP	Mar 56	Instructor Services.....	143,900
DA-36-034-ORD-2524	CPFF	Jun 57	Production of Missile & Ground Equipment.....	8,889,783
DA-36-034-ORD-2441	COST	Jun 57	Facilities (Capital Equipment Only).....	1,218,467[b/]
DA-01-009-ORD-578	CPFF	Oct 57	Engineering Services & Documentation.....	21,601,879
DA-01-009-ORD-593	CPFF	Dec 57	Instructor Services.....	28,600
DA-01-009-ORD-583	CPFF	Dec 57	Concurrent Repair Parts.....	10,101,985
DA-01-009-ORD-625	CPFF	Mar 58	Instructor Assistance.....	15,800
DA-01-009-ORD-614	CPFF	Mar 58	Production of Missile & Ground Equipment.....	23,653,686
DA-01-009-ORD-626	CPFF	Mar 58	LACROSSE Support/Contractor Maintenance.....	3,256,034
DA-01-009-ORD-668	FP	Jun 58	Training LACROSSE MOD I System.....	489,900

a/ Unless otherwise indicated, contract data taken from List of Active & Closed Out Contracts, published by Industrial Directorate, 1 July 1962.

b/ Data taken from Incl to ARGMA Letter, 15 Jul 60, subj "House Committee on Appropriations - LACROSSE."

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PART III (Cont)

Contract Number	Type	Date	Item or Objective	Contract Value
DA-01-009-ORD-729	CPFF	Feb 59	LACROSSE Missiles and Related Items.....	$ 22,703,840
DA-01-009-ORD-841	CPFF	Feb 59	Msls, Ground Equip, Type IV Test Equip.....	33,179,425
DA-01-021-ORD-5965	FP	Jun 59	Instructor Assistance.....	55,556 b/
DA-01-009-ORD-774	OPEN	Jul 59	LACROSSE FY 60 Blue Streak.....	412,626
DA-01-009-ORD-770	OPEN	Jul 59	LACROSSE FY 60 Replenishment Parts.....	829,468
DA-01-009-ORD-789	FP	Aug 59	Technical Representative Services.....	238,082
DA-01-009-ORD-811	CPFF	Sep 59	FY 60 LACROSSE R&D.....	3,344,882
DA-01-009-ORD-807	CPFF	Nov 59	Recondition LACROSSE Items.....	150,196
DA-01-009-ORD-904	FP	Jun 60	Launcher, XM398E1.....	937,212
DA-01-009-ORD-919	OPEN	Jun 60	Replenishment Spare Parts.....	2,172,166
DA-01-009-ORD-920	OPEN	Jun 60	LACROSSE FY 61 Blue Streak.....	701,640
DA-01-009-ORD-922	FFP	Sep 60	Technical Representative Services.....	374,706
DA-01-009-ORD-927	CPFF	Sep 60	Repair Parts and/or MO.....	3,958,928
DA-01-009-ORD-957	CPFF	Mar 61	FY 61 LACROSSE Engineering Services.....	4,444,912
DA-01-009-ORD-985	OPEN	Jun 61	LACROSSE FY 62 Blue Streak.....	219,535
DA-01-009-ORD-986	OPEN	Jun 61	LACROSSE FY 62 Repair Parts.....	654,872
DA-01-009-ORD-1004	FP	Nov 61	Technical Representative Services.....	288,409
DA-01-009-ORD-1020	CPFF	Jan 62	Repair Parts.....	133,292
DA-01-009-ORD-1021	CPFF	Jan 62	Modification Kits.....	16,257
			TOTAL MARTIN CO. CONTRACTS:	$ 220,900,569

PART IV - OTHER LACROSSE CONTRACTS

Contract Number	Type	Date	Name of Contractor	Item or Objective	Contract Value
DA-01-021-ORD-5092	CPFF	Sep 56	Thiokol Chemical Corp.	R&D, LACROSSE Motor	$ 99,820
DA-01-009-ORD-706	FFP	Oct 58	Univ of Alabama	Translate Documents	4,500
DA-19-020-ORD-4690	CPFF	Jun 58	General Electric Co.	XM84 Adaption Kit	10,403,867
DA-19-020-ORD-5292	CPFF	Jun 60	General Electric Co.	XM84 Adaption Kit FY 60	1,796,841
DA-36-034-ORD-2941	FP	Jun 59	Parrish Pressed Steel	Igniters XM47E1	3,100
DA-36-034-ORD-3253	FFP	Jun 60	Parrish Pressed Steel	Rkt Mtr Metal Pts w/Ign.	375,947
DA-33-019-ORD-3424	FPRE	Jun 60	Goodyear Acft Corp.	Rkt Mtr Metal Pts w/Ign.	595,056
DA-23-072-ORD-1589	FPRE	Jun 60	Intercont. Mfg Co.	Warhead T34E2 Metal Pts	90,033

b/ See note above.

UNCLASSIFIED

UNCLASSIFIED

PART IV (Cont)

Contract Number	Type	Date	Name of Contractor	Item or Objective	Contract Value
DA-04-200-ORD-1079	FFP	Jun 60	Sierra Electronic	Transistor Testors	$ 19,582
DA-04-495-ORD-3105	CPFF	Jun 60	Solar Aircraft Co.	Prototype Gas Turbine	67,000
DA-20-018-ORD-22977	CPFF	Jul 60	Superior Coach	Engineering, Van	107,405
DA-20-018-ORD-22961	CPFF	Unk	Superior Coach	Modify Van Body	24,456 c/
DA-23-072-ORD-1603	FPRE	Aug 60	Trailmobile, Inc.	Msl Container XM374E2	751,576
DA-20-018-ORD-23921	FFP	Nov 61	Maple Lane Die	Stacking Pads	5,199
DA-01-021-ORD-12984	FFP	May 62	Mink-Dayton, Inc.	Stacking Pads	13,740
DA-36-034-ORD-2741	CPFF	Jun 58	York Div Bendix Avia Corp	Fuze T3025E3	1,115,096 b/
DA-36-034-ORD-3330	FP/RDT	Jun 60	York Div Bendix Corp	Fuze T3025E3	660,736 b/
DA-36-034-ORD-2753	FP	Jun 58	Friez Inst Div, Bendix	Baro Switches	684,962 b/
DA-36-034-ORD-2975	FP	Jun 59	Friez Inst Div, Bendix	Baro Switches	305,226 b/
DA-36-034-ORD-3320	FP	Jun 60	Friez Inst Div, Bendix	Baro Switches	214,666 b/
DA-36-037-ORD-3010	CPFF	Jun 59	Westinghouse Elec Corp	Fuze T3025E3	3,506,602 c/
DA-11-022-ORD-2562	Unk	Unk	Magnavox	Base Element Warhead	63,633 c/
DA-28-017-ORD-3176	Unk	Unk	Applied Design Co.	Warhead Containers	388,155 c/
				TOTAL OTHER CONTRACTS:	$ 21,297,198

SUMMARY

Part I - Navy Contracts with APL/JHU & CAL.....	$ 410,000
Part II - Army Contracts with CAL.....	26,584,015
Part III - Army Contracts with Martin Company.....	220,900,569
Part IV - Other LACROSSE Contracts.....	21,297,198
GRAND TOTAL:	$ 269,191,782

b/ See note above.

c/ Data provided by W. B. Stuart, General Support Div, Procurement & Production Directorate, Army Missile Command.

TYPE OF CONTRACT - ABBREVIATIONS

COST..... Cost Contract (ASPR 3-405.2)
CPFF..... Cost Plus Fixed Fee (ASPR 3-405.5)
FFP..... Firm Fixed Price (ASPR 3-404.2)
FP..... Fixed Price
FP/RDT... Fixed Price/Redeterminable
FPRE..... Retroactive Price Redetermination After Completion (ASPR 3-404.7)
OPEN..... Open End Contract

UNCLASSIFIED

(U) GLOSSARY

-A-

ABC----- Airborne Control
ABMA---- Army Ballistic Missile Agency
ACS/G-4- Assistant Chief of Staff for Logistics
AFF----- Army Field Forces
AK------ Adaption Kit
AMC----- Army Materiel Command
AOMC---- Army Ordnance Missile Command
APG----- Aberdeen Proving Ground
APL/JHU- Applied Physics Laboratory, Johns Hopkins University
ARGMA--- Army Rocket and Guided Missile Agency
Arty---- Artillery
ASA----- Assistant Secretary of the Army
Asst---- Assistant
AT------ Antitank
AW------ All Weather

-B-

Bn------ Battalion
BuOrd--- Bureau of Ordnance

-C-

CAL----- Cornell Aeronautical Laboratory, Inc.
CG------ Commanding General
Chap---- Chapter
cm------ centimeter
CO------ Commanding Officer
Co.----- Company
COFORD-- Chief of Ordnance
Compl--- Complete, Completion
CONARC-- Continental Army Command
Cont---- Contract
CONUS--- Continental United States
Coord--- Coordinate, Coordination
Corp---- Corporation
CPE----- Circular Probable Error
CPFF---- Cost Plus Fixed Fee
cps----- cycles per second
CTV----- Control Test Vehicle
CW------ Continuous Wave
CY------ Calendar Year

-D-

DA------ Department of the Army
db------ decibels
DCSLOG-- Deputy Chief of Staff for Logistics
DCSOPS-- Deputy Chief of Staff for Operations
DEM----- Demonstration
Dep----- Deputy
Dev----- Development

(U) GLOSSARY (Cont'd)

-D-

DF--------- Disposition Form
Dir-------- Director
Dist------- Distance
Div-------- Division
DME-------- Distance Measuring Equipment
Doc-------- Document
DOD-------- Department of Defense
DTG-------- Date-Time-Group

-E-

ECCM------- Electronic Counter Countermeasure
ECM-------- Electronic Countermeasure
ECO-------- Engineering Change Order
Engr------- Engineer(ing)
Equip------ Equipment
E-U-------- Engineer-User

-F-

FGS-------- Forward Guidance Station
Fld-------- Field
FOCI------- Farrand Optical Company, Incorporated
fps-------- feet per second
ft--------- feet
FTL-------- Federal Telecommunications Laboratory
FW--------- Fair Weather
FY--------- Fiscal Year

-G-

GE/S------- General Electric/Sandia
GET-------- General Evaluation Test
GFE-------- Government Furnished Equipment
GO--------- General Order
Govt------- Government

-H-

HICO------- Hastings Instrument Company
Hist------- History, Historical
HTS-------- Helicopter Transportable System

-I-

in.-------- inch
Incl------- Inclosure
IRF-------- Induced Roll Fix

-J-

JCS-------- Joint Chiefs of Staff

-K-

kc--------- kilocycle
km--------- kilometer
kw--------- kilowatt

(U) GLOSSARY (Cont'd)

-L-

Lab--------- Laboratory
LAC--------- Late Acquisition
Laun-------- Launcher
lb(s)------- pound(s)
Ltr--------- Letter
LWL--------- Lightweight Launcher

-M-

MC---------- Military Characteristic
mc---------- megacycle
M/D--------- Miss Distance
Memo-------- Memorandum
MGC--------- Missile Guidance Central
MH---------- Minneapolis-Honeywell
MIT--------- Massachusetts Institute of Technology
mm---------- millimeter
MOD--------- Modification
MOS's------- Military Occupational Specialties
Ms---------- Manuscript
Msl--------- Missile
MSP--------- Missile System Plan

-N-

NF---------- Noise Fix
NOrd-------- Navy Ordnance

-O-

OCO--------- Office, Chief of Ordnance
OCRD-------- Office, Chief of Research and Development
OCTI-------- Ordnance Corps Technical Instruction
Ofc--------- Office
Off--------- Officer
OGMS-------- Ordnance Guided Missile School
OML--------- Ordnance Missile Laboratories
ORD--------- Ordnance Readiness Date; also Ordnance
OTC--------- On Target Command
OTCM-------- Ordnance Technical Committee Meeting

-P-

PA---------- Picatinny Arsenal
PEMA/S------ Procurement of Equipment and Missiles, Army/Support
P&P--------- Procurement and Production
PP---------- Program Pitch
PPU--------- Primary Power Unit
Proc-------- Procurement
Prod-------- Production
Proj-------- Project
psi--------- pounds per square inch

(U) GLOSSARY (Cont'd)

-R-

RDA------- Request for Deviation Approval
R&D------- Research and Development
Re-------- Regarding
RE-------- Roll Erection
Rept------ Report
Res------- Research
RF-------- Radio Frequency
RIAS------ Research Institute for Advanced Studies
RROE------ Redstone Resident Ordnance Engineer
RSA------- Redstone Arsenal
RSIC------ Redstone Scientific Information Center

-S-

sec------- second
SM-------- Supply Manual
S/N------- Serial Number
Spec------ Specification
SSM------- Surface-to-Surface Missile
STD-OM---- System Test Division, Ordnance Mission
STEER----- Sight Tracking Electronic Equipment Ranging
Subj------ Subject
Suppl----- Supplement, Supplemental
SXR------- Senior ARGMA Representative

-T-

Tech------ Technical
Tgt------- Target
TM-------- Technical Manual
TP-------- Test Plan
TR-------- Technical Requirement
TSU------- Target Survey Unit
TT-------- Teletype

-V-

VT-------- Variable Time (Fuze)

-W-

WSMR------ White Sands Missile Range

-X-

XSSM-A---- Experimental Surface-to-Surface Missile - Army

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