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DEMONSTRATION OF THE FEASIBILITY
OF A HYPERVELOCITY CLUSTER WARHEAD (U)

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ABSTRACT: This report describes a field experiment conducted to study the feasibility of using only inertial and aerodynamic forces to deploy a cluster of dense, inert, low-drag submissiles into a narrow conical pattern subsequent to burnout of a high-acceleration rocket which has accelerated the warhead to a velocity in the low hypersonic region.

Items discussed include:

Choice of warhead operating concept and design; selection of test vehicle, site and method; and conduct and results of preliminary and system tests.

Five-inch cluster warheads containing 162 one-ounce submissiles were accelerated to approximately Mach 6 in an air-dropped CHEROKEE-rocket test vehicle. Submissile patterns indicated by ground impact demonstrated the feasibility of the warhead triggering concept and of aerodynamic dispersal, although a majority of the submissiles were not deployed cleanly and attempted photographic coverage of the experiment was not fruitful.

U. S. NAVAL ORDNANCE LABORATORY
White Oak, Maryland

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19 August 1964

Demonstration of the Feasibility of a Hypervelocity
Cluster Warhead

The technical program reported herein represents one phase of the determination of the feasibility of the hypervelocity cluster warhead concept for use against a wide spectrum of tactical targets in a limited-war context. Another report covers concurrent terminal ballistic experiments demonstrating the lethality of dense, inert hypervelocity submissiles against various targets.

This work was performed under Bureau of Naval Weapons Task Assignments RMMO-42-040/212-1/F008-08-06 (Hypervelocity Cluster Warhead Research) and R360 FR 105/RO11 01 01 (Foundational Research).

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*Internal NOL(WO) TN's and memos are included in this reference list for completeness. They are not available for external distribution.

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INTRODUCTION

1. In November 1961 the Naval Ordnance Laboratory (NOL(WO)) reported on the feasibility of a hypervelocity air to surface weapon (reference (a)). In brief, the concept envisions a solid-propellant rocket weapon, carried by conventional aircraft, and aimed by conventional aircraft gunsight techniques. The motor accelerates the warhead consisting of a cluster of dense, inert, low-drag submissiles to a velocity of approximately 8,000 ft/sec in approximately one second. Cessation of acceleration at motor burnout triggers warhead separation, allowing aerodynamic forces to disperse the submissiles in a conical pattern. The high ballistic density allows the submissiles to retain sufficient kinetic energy, over a considerable distance of travel, to defeat hard targets (See Figure 1).
2. Subsequent support from the Bureau of Naval Weapons (BUWEPS) has allowed the Laboratory to demonstrate that hypervelocity impact of high density submissiles is an effective mechanism for defeating armor. For specific illustrations see Table 1.
3. A unique part of this warhead concept is the utilization of the aerodynamic environment to cause warhead separation and dispersion. Much consideration has been given to reproducing or simulating these environmental conditions in the Laboratory without success. As a result a research test vehicle employing a "CHEROKEE" rocket motor and a scaled warhead was designed that would nearly produce the desired aerodynamic environments and would be suitable for field testing.
4. A field test program was planned with the objective of demonstrating that the warhead would separate and disperse the submissiles as a result of the aerodynamic environment. It was realized at the outset that the collection of detail data on separation of the warhead would be difficult due to the high velocities and the uncertainties in being able to predict the exact point in space where separation would occur. However, the collection of terminal dispersion patterns was considered adequate to demonstrate that the warhead did separate and disperse the submissiles.

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PREPARATION FOR TESTS

SITE SELECTION

5. During the first quarter of FY 64 NOL(WO) personnel visited four possible locations for firing the first operable feasibility study vehicles. Two launching methods were under consideration, i.e., from a fixed launcher on a site overlooking a suitable impact area or from a helicopter directly above the impact area. Selection of the launch method was somewhat dependent on the selection of a test site because of differences in cost, instrumentation, time scale, and manpower requirements at various test stations. Safety considerations indicated that a large amount of real estate would be required such as that found on the western test ranges. The four test sites visited were the Williams Bombing Range in Arizona; the Dugway Proving Ground, Dugway, Utah; the Naval Ordnance Test Station (NOTS), China Lake, California; and the White Sands Missile Range (WSMR), New Mexico. WSMR was selected as the site primarily because of the low cost. The total amount of project funds actually required by WSMR was less than \$1000. Appendix A reports on the results of a test site survey made prior to selecting WSMR.

6. At the time NOL(WO) set up the tests, the WSMR standard work request followed a specific format called a Request for Work and Resources (RWWAR). A copy of the final form accepted at WSMR appears as reference (b). This is of historic value only, since there is now a standard form in use for work requests to be submitted to any of the three national missile ranges.

ROCKET MOTOR QUALIFICATION

7. One of the first steps in preparing for field tests of the research vehicle was to fire two CHEROKEE rockets from a rail launcher at the NASA Wallops Station on 16 October 1963 (reference (c)). The purpose of these rounds was to check the ability of the CHEROKEE rocket motor to operate properly under high accelerations. (The CHEROKEE had never experienced such high accelerations before.) Figure 2 shows the CHEROKEE High Acceleration Rocket (CHAR) assembled on a rail launcher as was used at Wallops Station. Data was obtained to show that the flights followed the predicted trajectory closely as shown in Figure 3. Velocity measurements were obtained by radar tracking late in flight, and through extrapolation the rocket's peak velocity was estimated to have been in the neighborhood of 6100 ft/sec. High

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speed motion picture films of the launch area showed good ignition and smooth motion off of the launcher. The two observed trajectories were essentially identical which would not be expected if there had been any rocket malfunction or major aerodynamic instability. It was not possible to estimate the maximum yaw or yaw period from the data, but the observed smooth straight exhaust trail indicated no appreciable yaw during burning.

8. A rocket motor static test was conducted at the Naval Weapons Laboratory, Dahlgren, Virginia to determine whether an NOL designed Ignition Safety Device (ISD), which was attached with clamps inside the rocket engine's nozzle, would be ejected from the nozzle by pressure from the exhaust gas at ignition without creating any motor malfunction, and if any of the ejected parts would be expelled in a manner that would be hazardous to the launching aircraft. A force in excess of 15 lbs would be needed to cause the clamps to release the ISD. To confirm that this would not adversely affect the rocket, a CHEROKEE rocket engine was static tested at NWL, Dahlgren, Va. in March 1964. A pressure-time trace indicated no apparent pressure build-up in the motor chamber resulting from the ISD obstruction in the nozzle. Satisfactory ignition occurred, and the ISD was blown free from the nozzle. Movie film indicated debris from the one static firing rose over 100 feet above the test pad, and exhaust flame shot out about 30 feet and remained constant throughout the static test. These data indicate that no critical complications will occur during motor ignition when an ISD is used in subsequent rocket motor operations as planned (when the rocket is 1500 feet away from the launching A/C).

LAUNCHING TECHNIQUE

9. In order to be able to conduct the field tests a launching technique had to be devised. After considerable thought it was decided that the most desirable condition would be to have a stationary platform relative to the ground from which a round could be dropped or fired so that its trajectory would be nearly perpendicular to the surface of the earth. In this manner terminal impacts on the earth coupled with other data would provide information on the submissile dispersion.

10. Since such a stationary platform was not feasible, it was decided that dropping from a hovering helicopter would approximate the desired condition. Therefore a system was devised to drop-test test vehicles from a helicopter. This system provides for the mechanical interfacing to the aircraft and provides for a safe separation distance of the test

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vehicle from the aircraft before rocket motor ignition. (See the wiring schematic in Figure 4.) A safe separation distance was defined as 1.5 times the distance that a fragment would be projected if the rocket should detonate upon ignition. The dropping system uses an Aero 15C-1 Bomb Rack and adapter that allows the rack to be hung on the aircraft. An auxiliary electrical cable is run from the rack to a special control box inside the aircraft. The control box is wired as shown in Figure 5. An engineer flies in the aircraft on each test and operates the control box. With the control box intent switch closed and the pickle switch depressed the release hook solenoid is energized and the release hooks open. The rack interlock switch is mechanically shifted as the hooks open so that the center conductor and the outer braided conductor are unshorted and the circuit is completed to the bomb arming unit. The three conductor cable leading from the bomb arming unit to the pull-away connector and wafer switch reels out of the rack housing, rotating an actuator cam as the test vehicle falls away. The first one inch of fall of the test vehicle pulls out the wafer switch arming tab and completes the center conductor circuit. After two inches of fall, the center conductor switch in the bomb arming unit makes the final connection from the battery in the control box to the ISD. This starts the eight second delay explosive switch and initiates the thermal battery. After five inches of fall the conductor cable reaches its pull-out limit, and the test vehicle connector pulls away from the wafer switch. After eight inches of fall an arming wire pull-out releases the test vehicle connector tie-down band, and after 12 inches of fall an arming wire pull-out starts the mechanical timer. While the battery is fully activated (up to voltage) in approximately 1/4 second, it is not connected across the igniter until the explosive switch contacts close at eight seconds and the mechanical timer contacts close at nine seconds. If either timer is pre-failed or run down, the thermal battery match circuits are interrupted, rendering the entire device inoperative.

11. Several mock-ups utilizing the special control box, the Aero 15C-1 Bomb Rack, and the ISD were constructed and tested at the Laboratory to verify the timing of the various functions. Other test vehicle mock-ups were fitted up to a SH-3A helicopter and dropped at NATC Patuxent River. These units fired flash bulbs, demonstrated that the system worked, and confirmed the times of events under realistic conditions.

12. Even though it was expected that the field tests would be conducted in a low RADHAZ (electromagnetic radiation hazard) environment reasonable precautions were taken to

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protect against electromagnetic radiation. A test device with shielding simulating a live round, was prepared and exposed to severe radiation while carried on a helicopter at NATC Patuxent River. The unit successfully completed this go-no-go type of test. Further RADHAZ checks were successfully completed at WSMR, New Mexico using the planned test aircraft and all known sources of radiation.

BALLISTIC PREDICTIONS

13. Ballistic predictions were prepared as follows: A drag function for the rocket assembly was estimated prior to the CHAR test at Wallops Island as shown in Figure 6. Trajectory computations using this function agreed reasonably well with observed results. This function was then used in computing inert and live drop trajectories. The initial portions of the drops were fitted to get agreement with results obtained from two rounds dropped from a SH-3A helicopter at the photo-theodolite range, NATC Patuxent in December 1963. Based upon the photo results at NATC Patuxent, the missile's carrier should have a forward velocity relative to the wind, so that upon release of the missile, the missile's oscillations during free fall would be minimized or dampened so as to have the best probability of hitting a fixed ground target.

14. The trajectories were computed for several conditions of ground speed and wind as tabulated (Table 2). It was assumed that all releases would be directly into the wind, from a horizontal carrying position, and that wind velocity would vary linearly from that specified at the launch altitude of 10,500 ft to 1/10 that value at sea level. The computation was carried out on the IBM 7090 using the 6° of freedom program of reference (d). Additional physical data required for the computations are included in Table 3.

15. The results were used to make plots of offset vs ground speed for the conditions expected at WSMR with a target elevation of 4000 feet above mean sea level assumed, and the various specified wind speeds added to ground speed to give true air speed for each curve drawn (Figure 7).

16. Figures 8 and 9 are plots of the computed inert and live trajectories respectively for 60, 75 and 90 knots air speed and 60 knots ground speed which are the computed cases nearest to most of the test conditions actually used.

17. In addition to positions along the trajectory as functions of time, angular orientation was also computed.

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However, the full 6° system was not simulated - there was no estimate of magnus coefficients or other spin effects - hence, the calculated angular motion is essentially an oscillation in plane of the trajectory only. This appeared to be adequate for the intended purposes. The predicted trajectories were apparently at least as accurate as other measurements in the system such as the radar position indication.

MATERIAL PREPARATION

18. Material preparation included ancillary hardware (nozzle, fins, straps). The type nozzle attached to the CHEROKEE rocket engine for WSMR tests was in accordance with Thiokol's 6:1 expansion ratio design such that the exit diameter was equal to the body diameter. It was a divergent design with a 15° half angle and was screwed into the motor case. The nozzles were fabricated from AISI 4130 steel. It was 7.060 inches long and its external exit diameter was 5.250 inches.

19. It was determined by reference (e) that a satisfactory configuration for providing adequate static stability to the CHEROKEE would be a cruciform fin arrangement with a minimum static margin of 1.5 calibers. To decrease dispersion a fin cant angle of one degree was used. The design allows each fin to be capable of withstanding a 4500 in.-lb bending moment, which is the maximum load resulting from aerodynamic forces if the missile assumes a maximum of 10° angle of attack at the predicted burnout velocity. The fins were fabricated from AISI 4130 steel and welded directly to the nozzle.

20. Two metal straps equidistant from the rocket motor's cg were used for attaching the CHEROKEE to a 15C-1 bomb rack. (The 15C-1 bomb rack with an adapter was rigidly fastened to the aircraft.) The straps had protruding points on their inner surface which made positive contact with the rocket engine case. This allowed the CHEROKEE to be electrically grounded at all times while attached onto the aircraft. The straps were fabricated from high carbon spring steel, so that upon release they would immediately spring away and not become entangled with the rocket body or fin system. The straps were adjustable and could be tightened when in place.

WARHEAD

21. The experimental warhead was officially designated Warhead, Rocket, WOX-9A. It was selected from a number of preliminary designs studied for possible use in rocket energy employment systems. Some of the design concepts considered were a group of designs in which the darts were

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loaded in tubes, and another group employing metallic structural framing to hold the darts on tiers. The WOX-9A design was selected for the initial feasibility tests because it seemed to have fewer problems in detailed design and manufacture. The predicted deployment sequence seemed to have a reasonable chance of success, relying on a combination of inertial and aerodynamic forces to release and remove the nose fairing at rocket burnout, permitting the darts to proceed with relatively low retardation.

22. A brief description of the WOX-9A warhead is as follows:

The darts were positioned on a slotted base plate and were confined to their respective positions by a bulkhead, which prevented forward movement, and foam plastic, which fit within the aft section of the fairing, circumferentially encasing them. During rocket motor acceleration a sliding "Q" weight shears a pin, which restrained it until the inertial force of the weight reached 90 to 95 gravities. After shearing the pin the weight moves back compressing a spring. The spring is used to overcome friction in the system when the warhead's nose is loaded as in flight. The "Q" weight moves forward under the action of the spring plus inertia as soon as the rocket burns out and drag forces exceed motor thrust. This releases the detents, which hold the nose assembly in place, and high stagnation pressure on the spherical nose pushes the nose back into the fairing cavity along a guide rod. The pressure builds up inside the warhead cavity, ruptures the fairing and displaces the bulkhead, thus removing all constraints on the darts.

23. The basic feature by which this design differed from most of its predecessors was in the use of a cylindrical instead of conical dart, with three fins per dart which could nest together and permit the bodies to fit in a close packed hexagonal array. This made it feasible to exceed the design goal of 160 darts when packaged in a single tier.

24. The detailed designs were completed in the spring of 1963 and a contract was placed with Toolcraft Inc. of Baltimore, Maryland to make six heads complete with darts plus two with lead ballast. For a complete description of the warhead and its intended method of operation see Appendix B.

25. The warheads were received in November 1963. They were thoroughly inspected and the assembly completed at NOL. One head successfully withstood a vibration test intended to simulate helicopter carry and an external pressure test simulating the external pressure rise on the cone during

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flight. The heads were disassembled and shipped to Holloman AFB, White Sands, New Mexico, in March 1964, where they were reassembled just before the flight tests in April.

OPERATIONS

26. Coordination between NOL personnel and operating facilities at Holloman AFB were handled through CDR McGaha, Naval Liaison Officer (NLO) at Holloman AFB, who processed the RFWAR covering the NOL test series through the proper channels.

27. The explosive assembly work was performed in the west area of the Holloman AFB with some assistance by an AF rocket systems group. After the igniter leads were slightly modified and the igniters were checked for electrical continuity, the igniters were inserted into the rocket motor by means of a special tool furnished by the motor manufacturer with the base of the igniter 41.75 inches from the nozzle exit. The ignition safety device (ISD) was checked for electrical continuity. The ISD was inserted into the rocket's nozzle and attached to the nozzle exit with clamps (Figure 10). A pull-away connector, which was attached to the ISD with a shielded cable was clamped onto the motor case 3.5 inches forward of the missile CG. This is the approximate position where an electrical socket from the 15C-1 bomb rack can make contact with the missile when assembled to the aircraft. The two metal straps for attaching the missile to the bomb rack were assembled 14 inches apart and equidistant from the rocket's CG. Figure 11 shows the parts to be assembled on the live round and Figure 12 is the missile ready for aircraft loading. During the complete assembly operation and storage time, all rocket engines were electrically grounded. Personnel working in the area took necessary precautions to also ground themselves and avoid other safety hazards.

28. Control functions for radar tracking, camera directions range timing, aircraft control and missile launching originated at the Range Control Center designated King 1. Automatic plotting boards operating with "C" band radar and beacon in the A/C were used to control the approach to time the launch so that the ground camera system could get pictures. Since the target area was necessarily remote from the radar station, there were errors in the release point, which were difficult to eliminate, and it was found that there was not enough return from the unit for a radar skin track.

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29. The specific target area designated Hyper-Z1, was selected for two reasons: it had a hard, flat, clean surface, which would make impact location easier, and from a safety point of view it was approximately 6 miles from any permanent range installation and 12 miles from the edge of Holloman AFB. A cross with an 80-foot span was used as a target, and the arms were oriented north-south and east-west.

INSTRUMENTATION

30. Both the launch A/C and the missile were tracked by the permanently installed range cinetheodolite and tracking telescope cameras. Other position data were to be obtained from a three station fixed camera array set around the impact point. Each station had two ribbon frame (R.F.) movie cameras oriented for maximum area coverage. Seventy mm and 35 mm cameras, respectively, were oriented for use in obtaining warhead opening and impact data. Since there were missile release point errors, the release point was out of the cameras' field of view, and the missile flight presented a small photographic image. No conclusive data were obtained from this camera setup.

Another array of eight fixed cameras was installed for documentary coverage. There were two 16 mm movie cameras at each station 250 feet from Hyper-Z1 at approximately 045°, 135°, 225°, and 315°. One of each pair was pointed at the estimated motor ignition point and the other covered the target area. A single camera was placed at Hyper-Z1 pointing at the ignition point. It was hoped that these cameras would provide a more detailed look at the firing events. A hand-held 16 mm movie camera was used from a chase A/C. Partial coverage of the third and fourth live units was obtained from the fixed cameras as well as an almost complete trajectory of the third unit from the A/C. It is intended that a documentary film be made from the footage collected during the program.

AIRCRAFT

31. When the test series had begun at Holloman AFB the bomb racks and related equipment were hooked up to an Army H-37 helicopter. Two drop rounds were attached to the 15C-1 bomb racks with the straps that were adjusted and fixed previously on the rounds. After a continuity and clearance check the H-37 took off. However, before the H-37 helicopter reached the target area, engine fire warning lights came on. The results were that the helicopter returned to base and was grounded for a major inspection.

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32. The Army Aviation Branch suggested that we review our launching requirements with them, in the light of existing circumstances, to determine if an alternate method would be acceptable. Our ballistic predictions indicated that a small forward velocity was not only acceptable but was desirable. Further review indicated that we could tolerate a forward velocity relative to the air of approximately 60 to 65 knots. The Army suggested that we look at the L-20 fixed wing airplane to see if we could adapt our hardware to it because they thought that by flying with the flaps partly down and on the verge of a stall they could keep the forward velocity within an acceptable range. This was done and the actual fit-up looked as shown in Figure 13.

33. A RADHAZ check similar to that done on the SH-3A and H-37 was conducted successfully on the L-20. The test missile used for RADHAZ checks is shown hung on the L-20 in Figure 14.

34. Arrangements were made for chase aircraft carrying a photographer to fly above and behind the launching aircraft. The photographer was to attempt to photograph the missile looking along its line of flight. It was felt that this technique provided the photographer with the best chance of keeping the missile in the field of view of the camera.

TEST EVENTS

35. There were five test events for the Hyper Project, each consisting of two elliptical closed-traverse runs, using a L-20 launch aircraft. The rounds dropped at White Sands Missile Range (WSMR) are listed sequentially in Table 4.

36. The L-20 went into the elliptical pattern when it approached the target area and coordinated itself with King 1, ground radar station, for a positive fix. For the first run only an inert drop test was made. At separation a flash bulb actuated signifying the release and the spring steel straps, which supported and held the round on the bomb rack, sprang away. The inert round fell for approximately 20.5 seconds and was found with little difficulty, buried to within eight inches of the base. This was short of the target but approximately in line with the launch aircraft's flight path. Since the release system on the L-20 aircraft appeared satisfactory the live test program was initiated. Each round was typical in its modus operandi. (See Figure 15)

37. The inert rounds were intended to assist radar control in locating the correct point for release to get the live rounds to hit the target. It was discovered that the radar

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was not tracking the inert rounds, but indicated vertical drops after release. It is felt that the radar was tracking the steel straps and lug assemblies which were found in each case on the surface approximately under the release point.

38. Several methods of data collection were used during each test event. Flying in the immediate vicinity of the launch aircraft were chase aircraft, except for the first inert drop test, to record each launch with photo coverage. Both fixed wing and helicopters were used for photo data collection. From the ground, data collection was obtained by using cinetheodolite and tracking telescope cameras.

39. The first WOX-2A missile malfunctioned and fell to earth without firing. It was resolved that the ISD was stripped off the rocket motor soon after the missile was released from the aircraft. Upon ground inspection, the ISD assembly was recovered intact but fired; however, there was no indication that the ignition device system ever actuated the igniter squibs. Upon careful inspection of the results of photographic coverage, it was concluded the other three WOX-2A missiles performed satisfactorily, and no motor instability was noticed.

40. On the remaining powered missile flights the bomb rack released the motor and the spring steel straps flipped away from the missile as intended. The WOX-2A fell for 9.4 seconds. This delay was needed to permit rotation of the weapon from a horizontal to a vertical orientation and to provide a safe separation distance from the aircraft when the rocket motor is ignited. The motor ignited and experienced a 250g peak acceleration while reaching a speed in excess of 6500 ft/sec within one second of burning before burnout. The burnt motor case continued on its course until impact.

RESULTS

41. Summary of impact data from the live rounds is as follows:

Round L-1. - The missile failed to ignite and major portions of the ruptured case were located about five feet from the center of impact with the nozzle relatively intact, fins twisted. Base of the warhead with tails of most darts entrapped in the base plate slots and gypsum sand was found about 20 feet ahead of other major parts. Some dart noses were found scattered around the area among other holes from both the motor parts and darts. It was assumed that all was intact until impact. From the accrued information from reference (f), Figure 16 represents the trajectory the missile fell; Figure 17 is altitude versus time plot; and Figure 18

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depicts the tangential velocity versus time. It may be noted that Figures 16, 17 and 18 also represent the five inert rounds which were dropped since their physical characteristics are essentially the same as the live rounds.

Rounds L-2, L-3, L-4. - Difficulty was encountered when trying to locate the impact areas. Inner cone parts from fairings were found first. Continuation along the flight line led to major impact. The central motor impact hole was an approximately three-foot diameter crater containing clumps of compacted sand darkened by heat and/or carbon. Some good clean dart impact holes about 1/2 inch diameter were located at 60 - 70° from the vertical in line with the trajectory. Other impacts that broke the desert crust were more irregular in shape. Much of the motor fragments apparently were blown out of the hole by action of the following body and tail. There were a number of darts or dart parts that impacted at relatively low velocity. Some apparent holes showed no traceable penetration and were assumed to be left by parts ricocheting from the impact hole, which skipped along, hitting one or more places before coming to rest. Table 5 shows the number and type of penetration after each test event. The flight plots prior to ignition of rounds L-2, L-3 and L-4 were obtained from references (g), (h) and (i), respectively. Figures 19, 20 and 21 for round L-2; Figures 22, 23 and 24 for round L-3; Figures 25, 26 and 27 for L-4 are the trajectories each missile fell, the altitude versus time and tangential velocity versus time, respectively. Figures 28 and 29 denote the comparison of measured versus computed trajectories of the WOX-2A missiles and D-3 drop rounds, respectively.

42. The flight of the launching aircraft was continuously monitored by radar at King 1. Plots were made of the flights on a radar plotting board. Instructions were continuously given to the pilot on bearing and speed by King 1 as each drop was in process. The actual countdown and command to drop were made by King 1. Unfortunately King 1 did not know where the target was located accurately enough to be able to direct the pilot in such a manner as to make a direct hit on the target; however, minor modifications to the technique should improve the accuracy.

43. All three warheads appeared to have opened prior to missile impact. The location of the recovered parts indicated the warheads' opening point was somewhere near the expected or probable burnout time. A number of darts, 14 to 20 percent, separated from the warhead intact and continued until impact at a high velocity. A large number of darts were recovered on or near the surface, indicating low energy at impact.

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The assumption is made that the release and dispersion was not clean. To obtain a positive indication of whether the dispersal pattern of the submissiles would be improved and to determine if the fairing was not peeling back properly at motor burnout, the warhead attached to the L-4 missile was pre-split along the grooves of the fairing. Upon ground inspection this modification did not result in a larger number of high energy impacts. It did enlarge the pattern area somewhat.

44. The L-3 round had more fairing parts recovered than any other. One segment was curled outward with the forward lip apparently broken off in the outward direction, and failure continued by folding and peeling in the same direction. There was considerable wrinkling with four fairly sharp bends at increasing intervals. Other segments show major wrinkling and random tearing on rounds L-2 and L-4 but not outward folding. On two recovered segments, there is indication that the front lip folded inward. One lip of a segment was recovered with essentially no distortion. It was ripped off cleanly where the fairing skin was attached, and no conclusive evidence denoted which direction it bent. It could have pulled in tension.

45. There was considerable evidence of heating on the fairings. The thin tip of a nose piece was tempered to a blue with various shades thru light straw (varying from 700 to 400 degrees Fahrenheit) progressing back into the thickened area toward the latch (located at the nose release section) on the recovered segment. There was still some evidence of the paint on this piece. On the thinner fairing parts, there was evidence of heating to a somewhat lesser degree. Up at the radius leading to the 5.25-inch diameter cylinder and along the forward surfaces, most of the paint was gone. The inner parts of the warhead ripped off at the spot welds and brazed joints and gave little or no indication of heating.

46. Many whole darts, noses and tails were recovered. On the L-2 round 26 nose pieces, 12 tail pieces and 9 whole darts with the tails distorted were recovered. The L-3 round had 35 nose pieces, 40 tail pieces and 17 whole darts with distorted tail fins. Recovered on the L-4 were 37 nose pieces, 17 tail pieces and 14 darts, also with their tail assemblies distorted. Many of the whole darts on all of the rounds had partially unscrewed tail assemblies. On all of the rounds excluding L-1 various pieces of each warhead fairing and mechanism were found along the flight path and behind the impact area.

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47. The impact patterns of round L-2, L-3 and L-4 denote an elliptical shape along the flight path and centered around the motor impact point. Figure 30 shows the impact pattern from the L-2 round. The major diameter (axis) of the impact zone resulting from the L-2 round is about 480 feet. The minor axis is 240 feet diameter. The pattern of impacts from round L-3 is shown in Figure 31. Its major axis depicting the dart impact zone is 220 feet, and the minor axis is 150 feet. The pre-split fairing on round L-4 shows a much greater scatter of hits, Figure 32. A relatively fewer number of high velocity hits were discovered, and most were located within a 100-foot diameter about the major impact point. Scattered along the nominal flight path and behind the missile impact point were hits within 500-foot distance.

CONCLUSIONS

48. The warhead packaging was such that the darts were oriented and assembled with their tails in slots on the base plate. These slots evidently prevented the darts from spinning free and moving out from the line of flight; hence, all of the recovered dart tails were twisted, and many were wrung free from the tungsten nose. The bulkhead in the warhead, which restricted the darts from moving forward during handling and rocket motor operation, showed deep impressions from the dart noses. These impressions probably occurred when the fairing was opening and was allowing the darts to commence their escape. The bulkhead was attached to the fairing and was not clear from the flight path of the darts. Upon a close visual inspection of the recovered fairing pieces, there was indication of the fairing's six segments not peeling uniformly back towards the base plate when the release mechanism operated. This result would disrupt the release pattern of the darts and also cause many of them to collide with each other and break. Other darts would continue on their free flight but their bodies were exposed laterally to the line of flight. This condition would cause the fully exposed darts to be subjected to severe bending about the screwed joint connecting the tail to the tungsten nose, thereby also causing many to break. Since such a turbulent condition probably existed when the warhead opened, it is possible that a few darts were trapped and rode the missile to impact and were planted deep into the cavity while some were ejected out of the hole and laid on top of the surface.

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49. It has been concluded that the WOX-9A warhead did open approximately at rocket motor burnout, and the cluster of submissiles was essentially dispersed in a pattern 100-foot diameter prior to impact. The warhead deployed 15 to 20 percent of the darts in a manner expected about the impact area when the rocket's velocity was approximately 6500 ft/sec. Many projectiles penetrated down to 30 inches deep in the alkali (gypsum composition) surface. This reflects the feasibility of the WOX-9A warhead to disperse a lethal pattern of projectiles over a prescribed area.

RECOMMENDATIONS

50. Based upon post-inspection of rounds L-2, L-3 and L-4, the following changes in design should be made:

- a. Package the projectiles in such a manner that their tails will not be distorted or broken.
- b. Prevent the recurrence of the bulkhead from interfering with the darts when released.
- c. Make sure the fairing segments open simultaneously once the release mechanism actuates at motor burnout.
- d. Improve the joint between the tungsten nose and tail of the projectile.
- e. Improve the integrity of the release mechanism.
- f. Index or code each packaged row of projectiles in the warhead, so a pattern of flight of all the darts may be determined.
- g. Since the rocket motor used at WSMR does not approach the minimum performance desired, necessary steps should be taken to improve the present rocket system, or else obtain a motor with the desired characteristics, i.e., carry a payload in excess of 8000 ft/sec within one second.
- h. Improve diagnostic techniques for obtaining data of warhead operation during flight condition, i.e., possibly incorporate a powered sled application for obtaining positive photo coverage.

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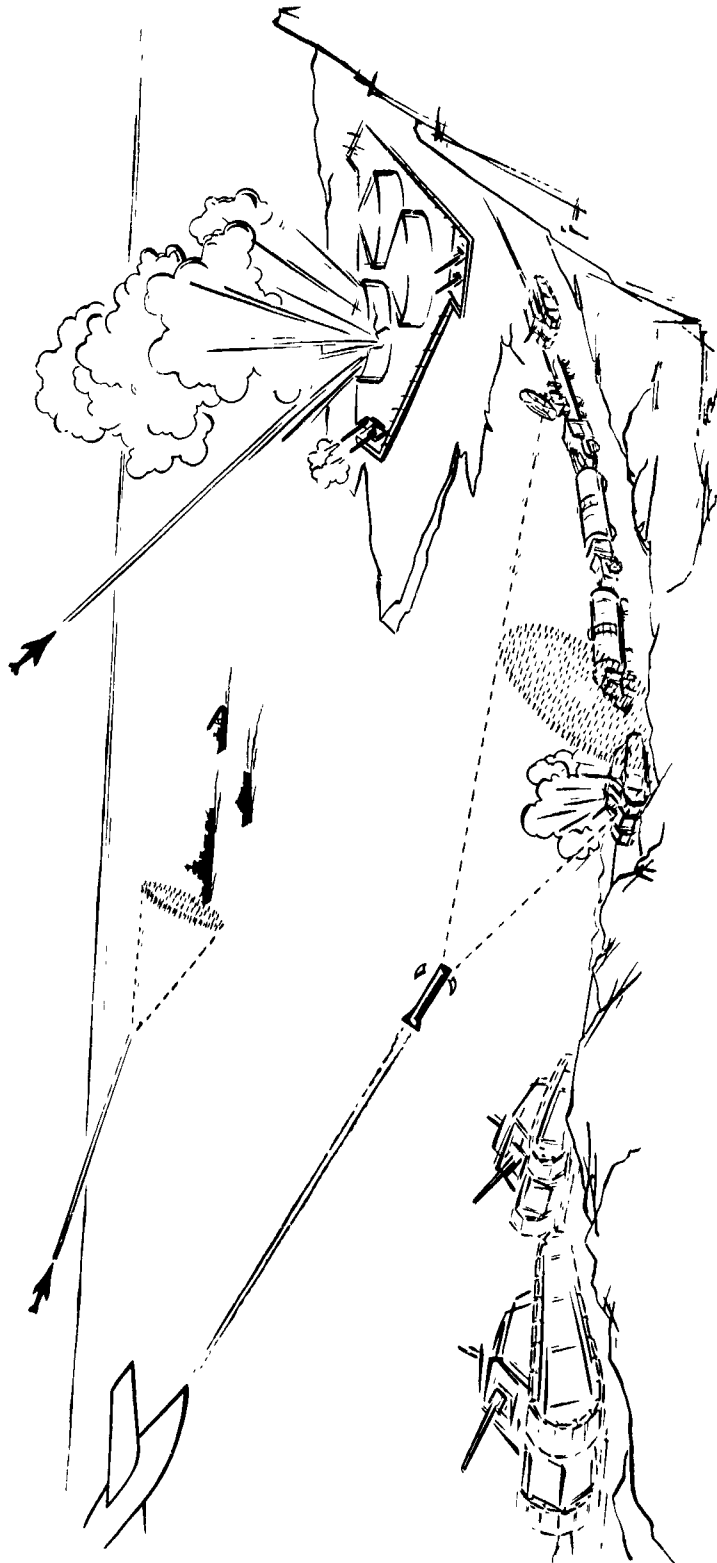


FIG. 1 ARTIST'S CONCEPT OF "FREE"

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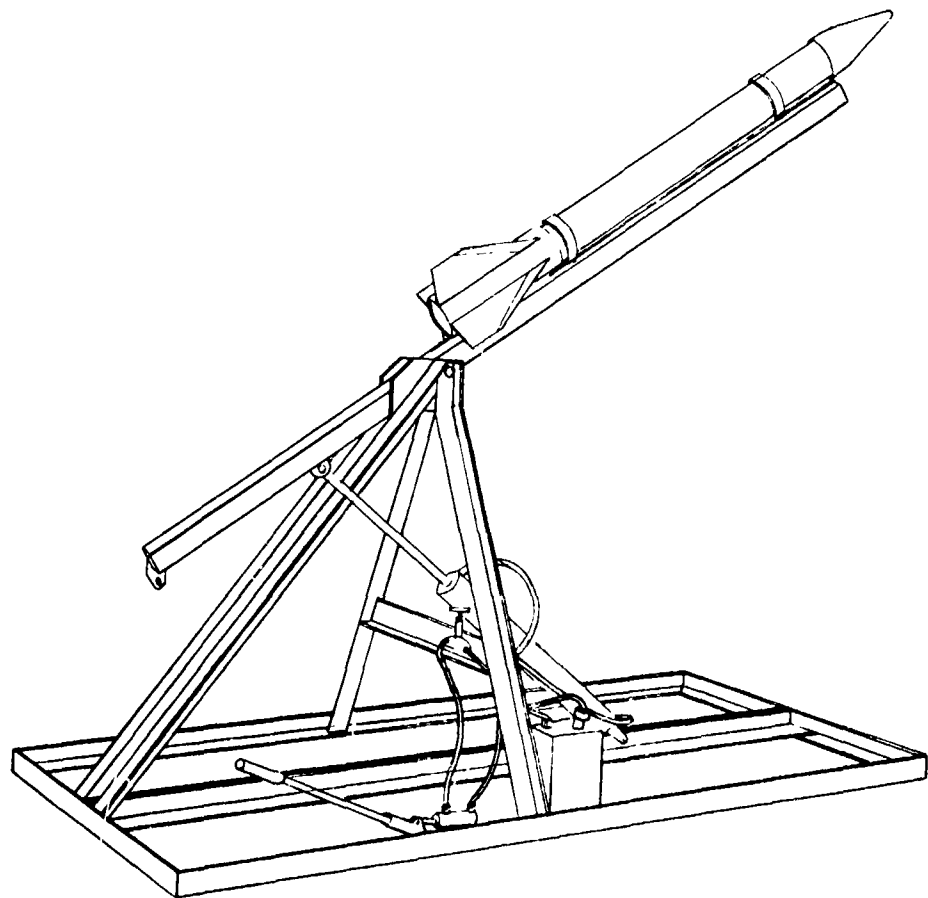


FIG. 2 CHAR ON RAIL LAUNCHER AT NASA WALLOPS STATION

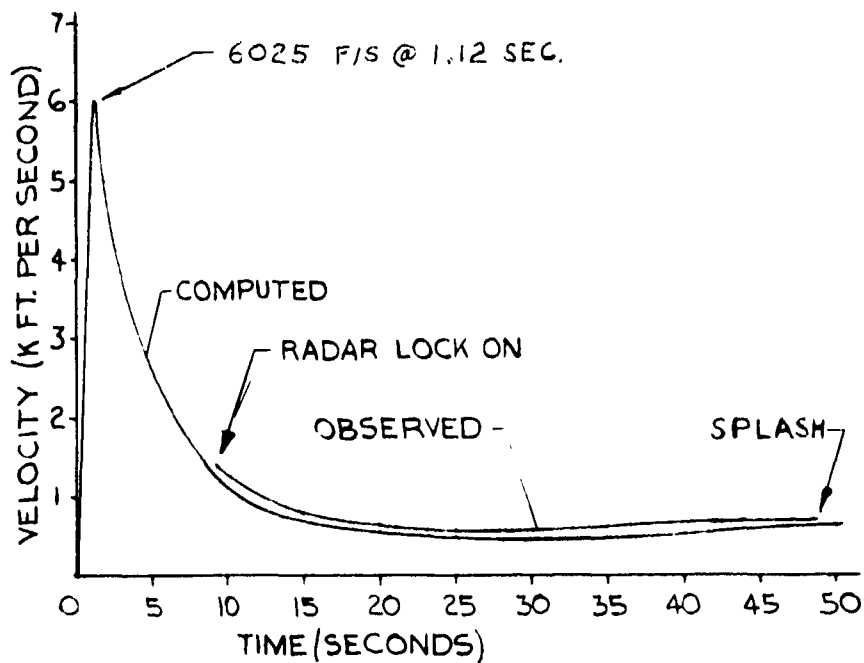
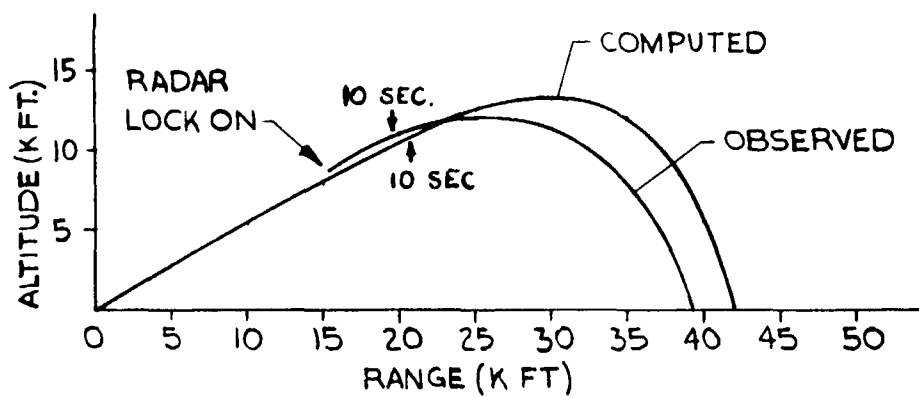
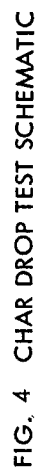


FIG. 3 CHAR TRAJECTORIES AND VELOCITY CURVES, NASA WALLOPS STATION



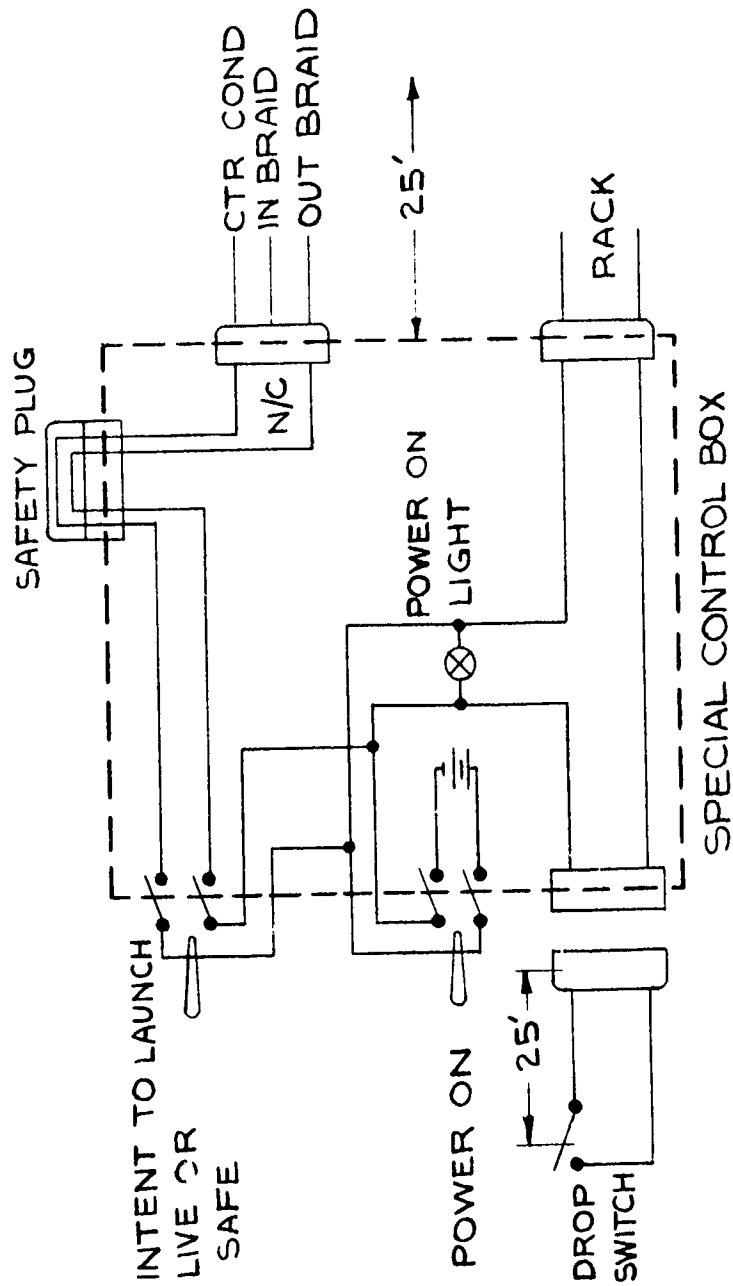


FIG. 5 CONTROL BOX WIRING DIAGRAM

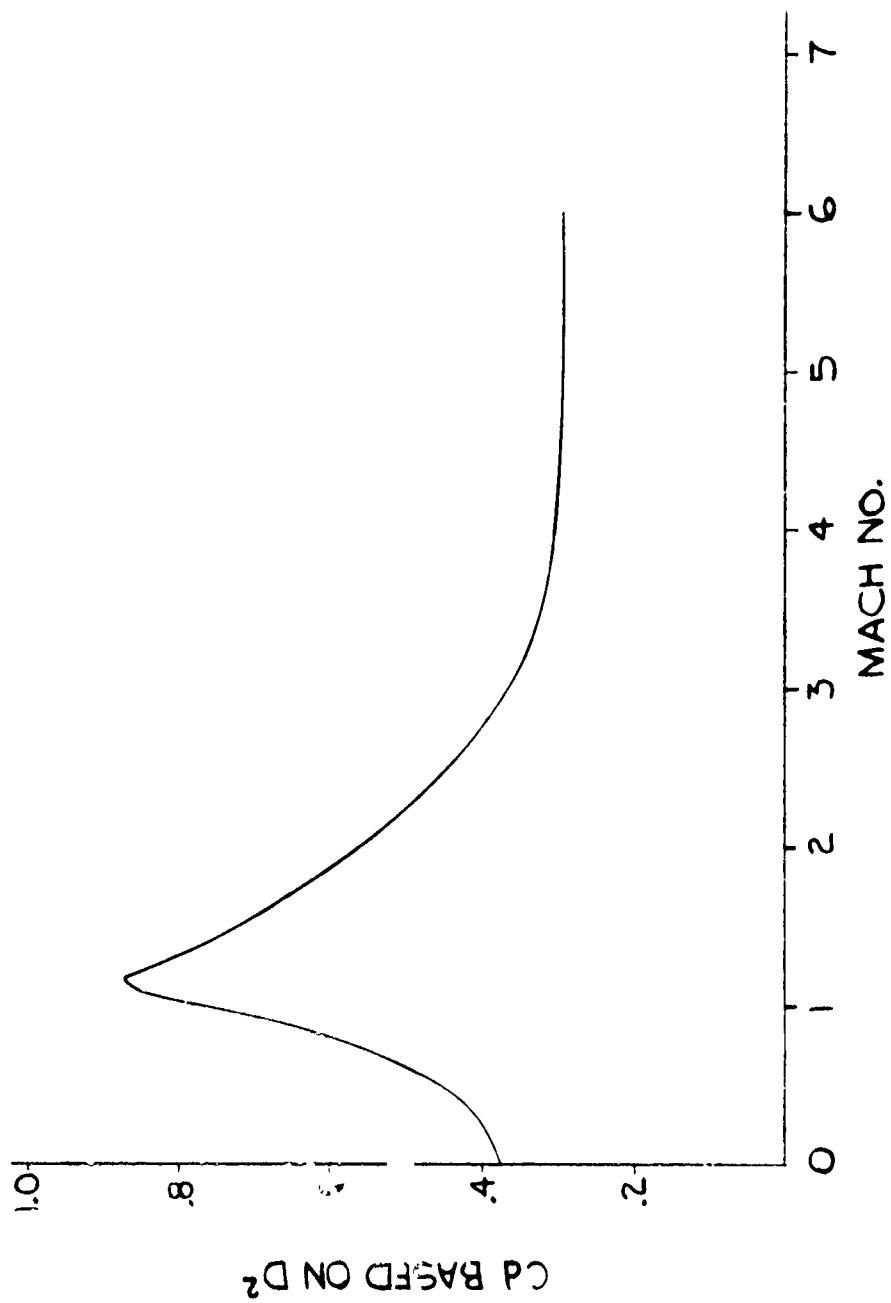


FIG. 6 DRAG FUNCTION

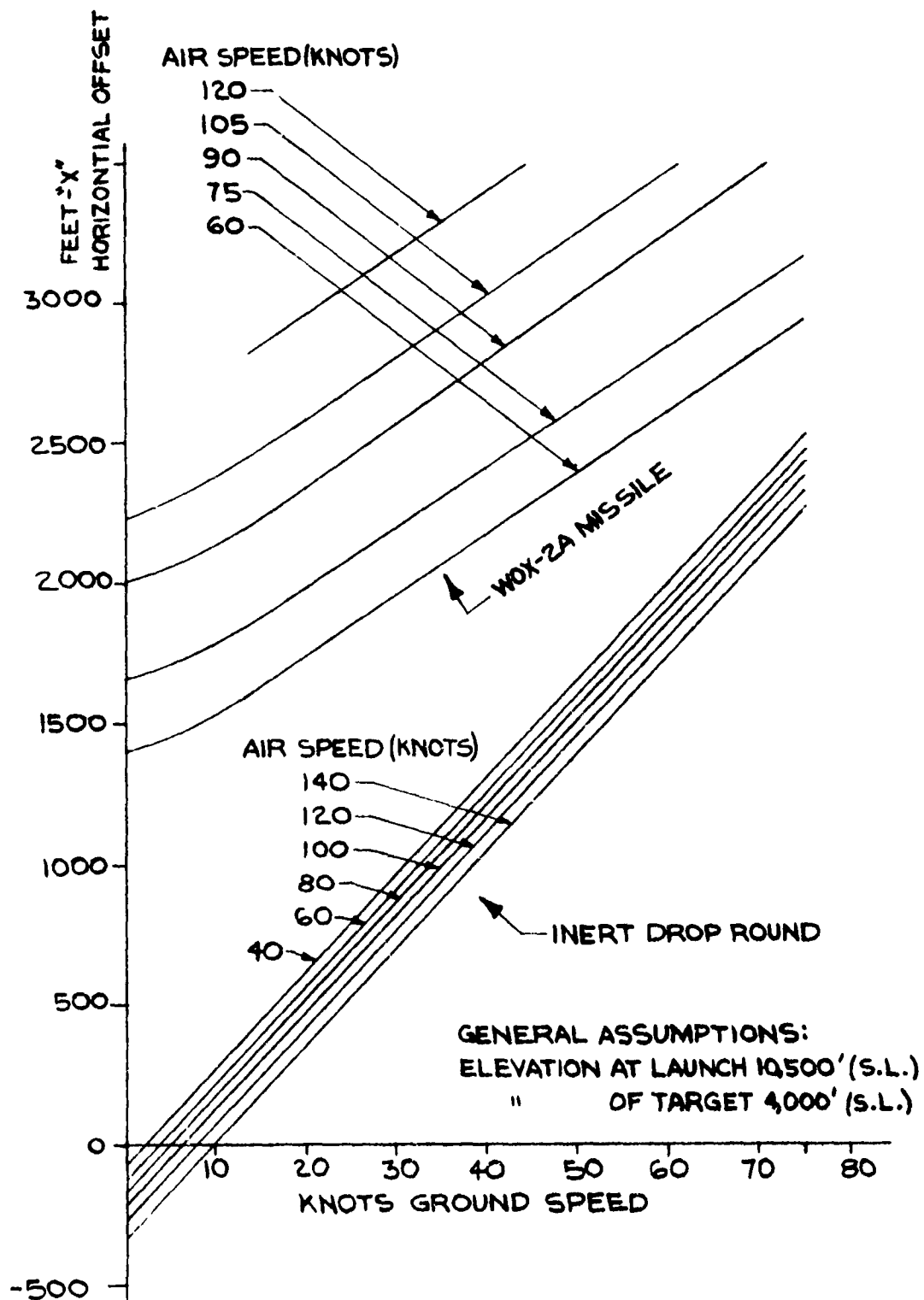


FIG. 7 PREDICTED OFFSET

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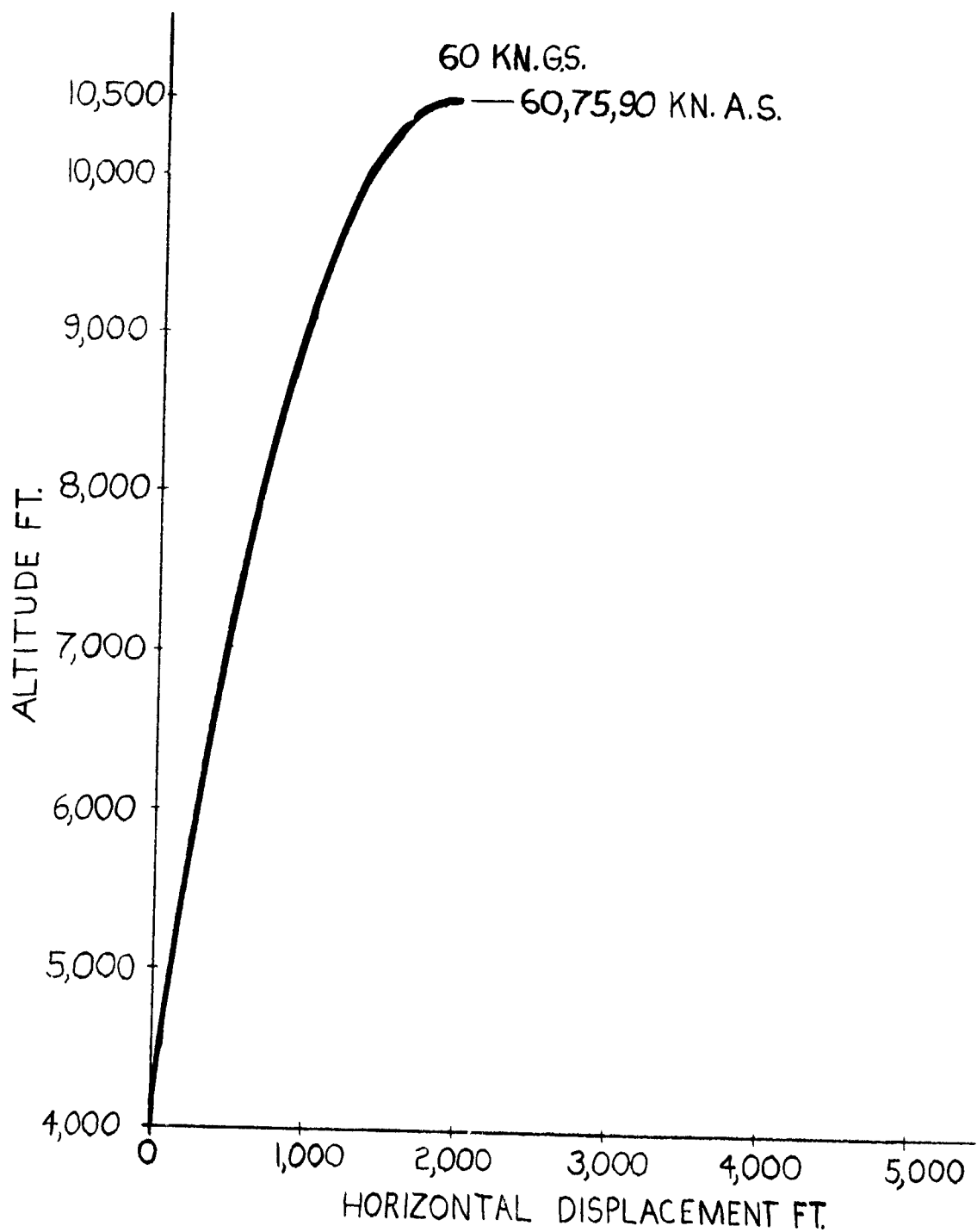


FIG 8 COMPUTED INERT DROP ROUND D-3 TRAJECTORIES

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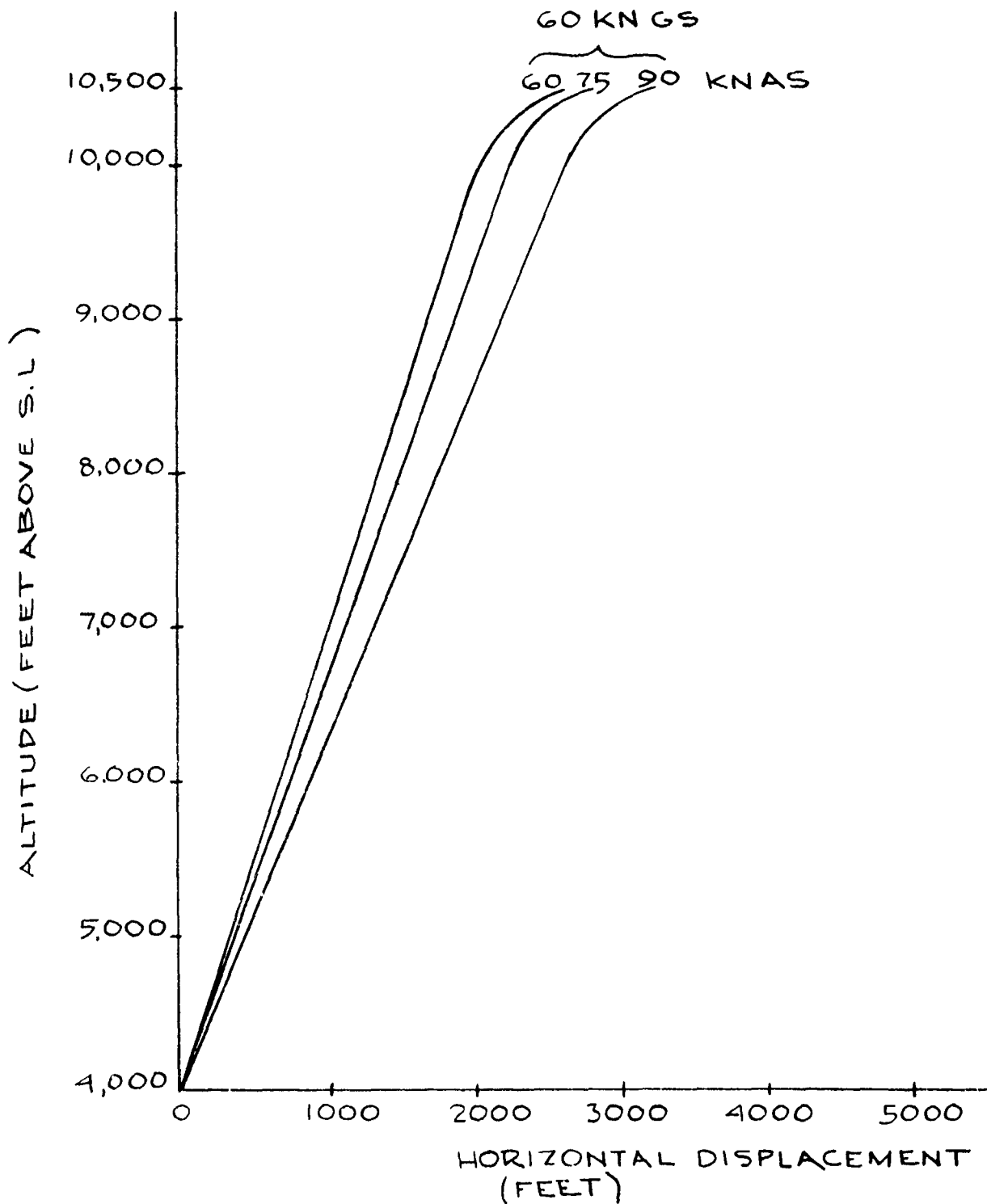


FIG. 9 COMPUTED WOX-2A TRAJECTORIES

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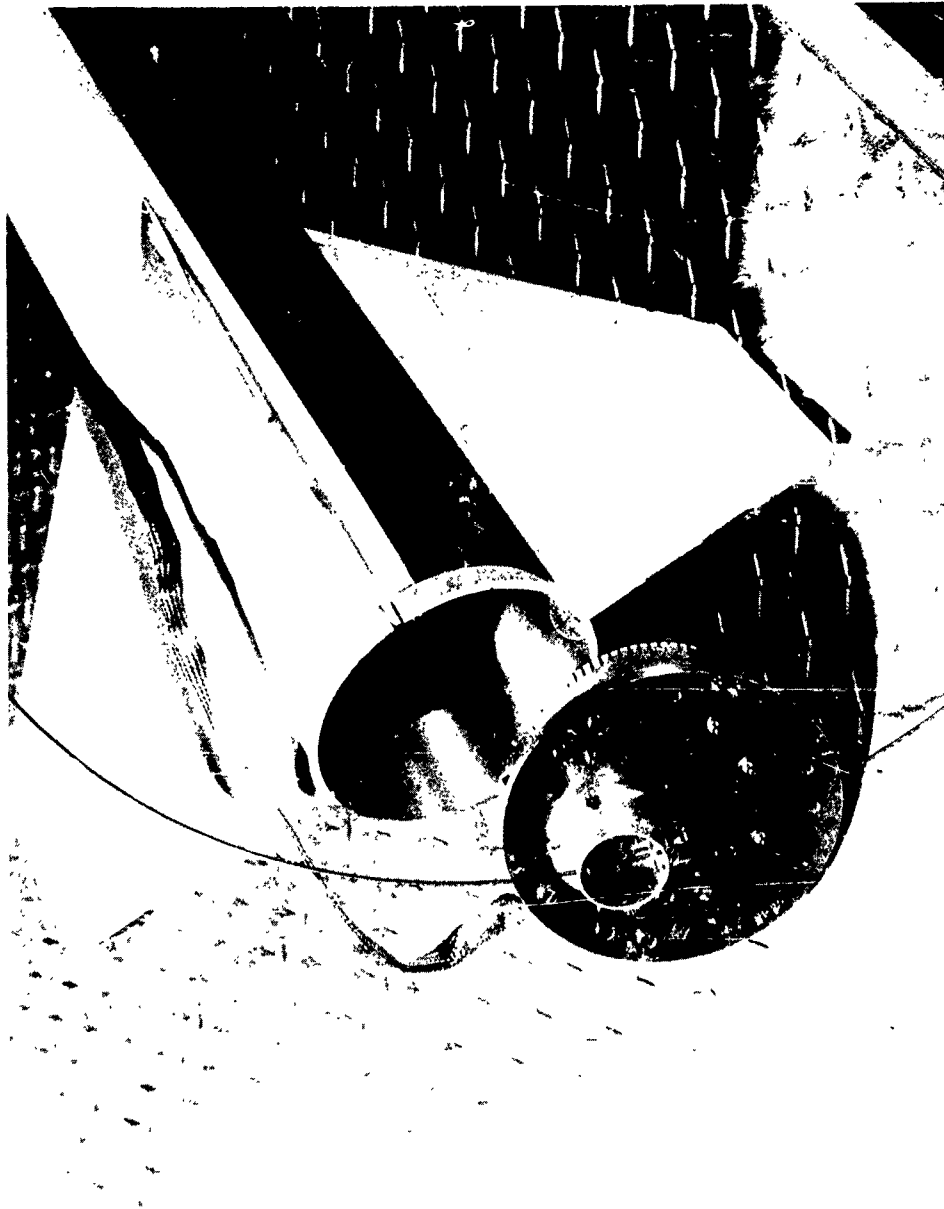


FIG.10 IGNITION SAFETY DEVICE AND ROCKET NOZZLE

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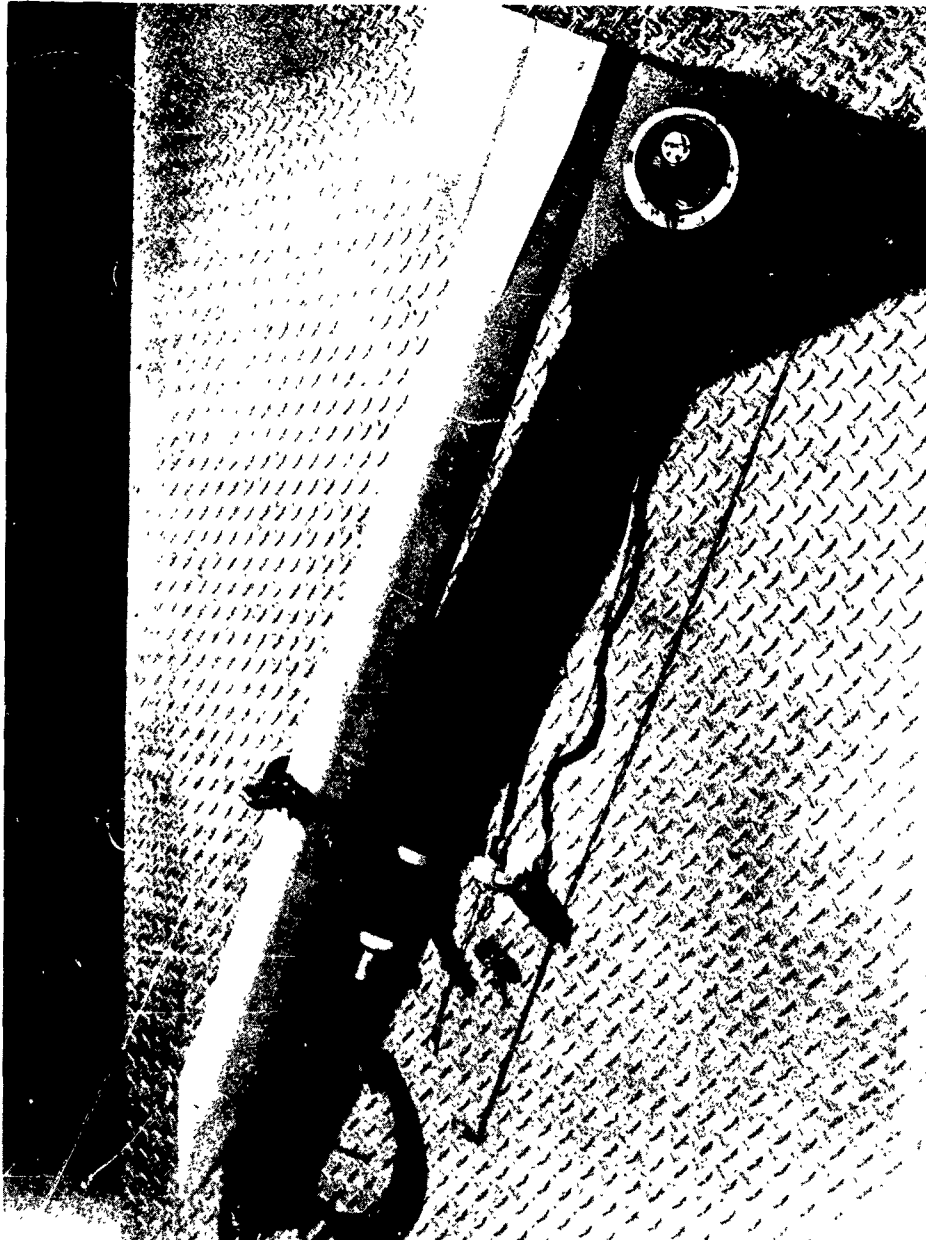


FIG. 11 WOX-2A PARTS PRIOR TO ASSEMBLY



FIG. 12 WOX-2A ASSEMBLED

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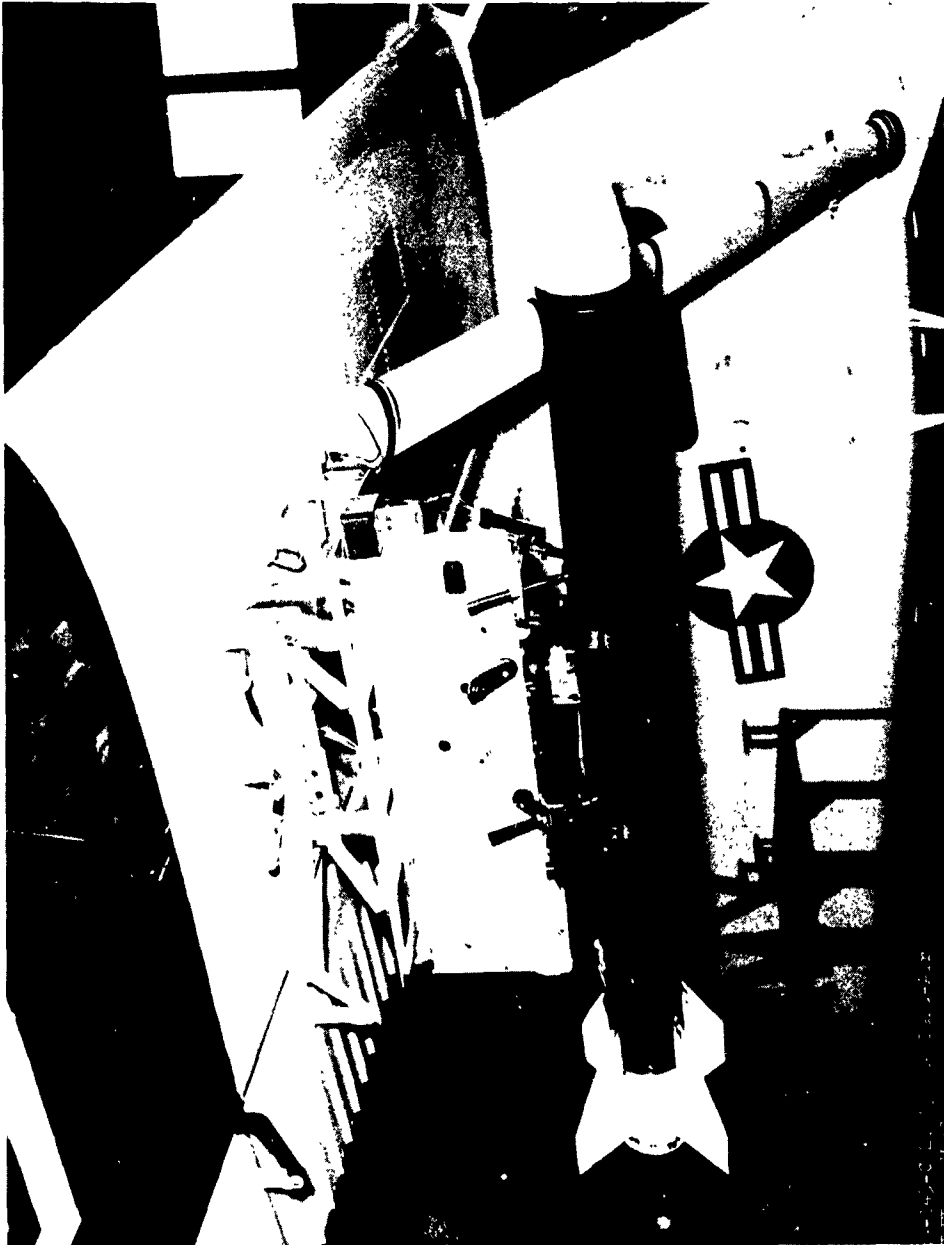


FIG. 13 WOX-2A FIT-UP TO L-20 AIRCRAFT

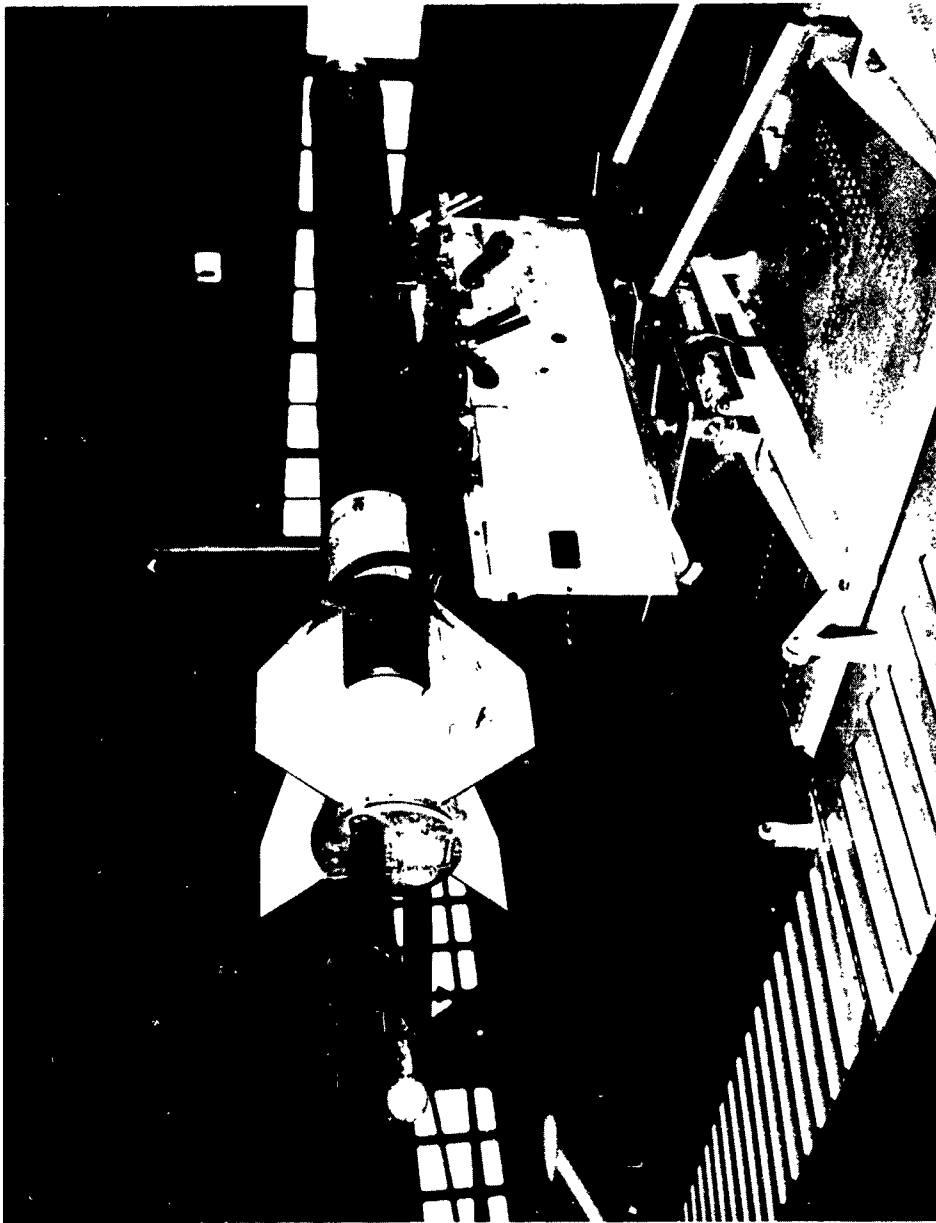


FIG. 14 TEST MISSILE USED FOR RADHAZ CHECKS

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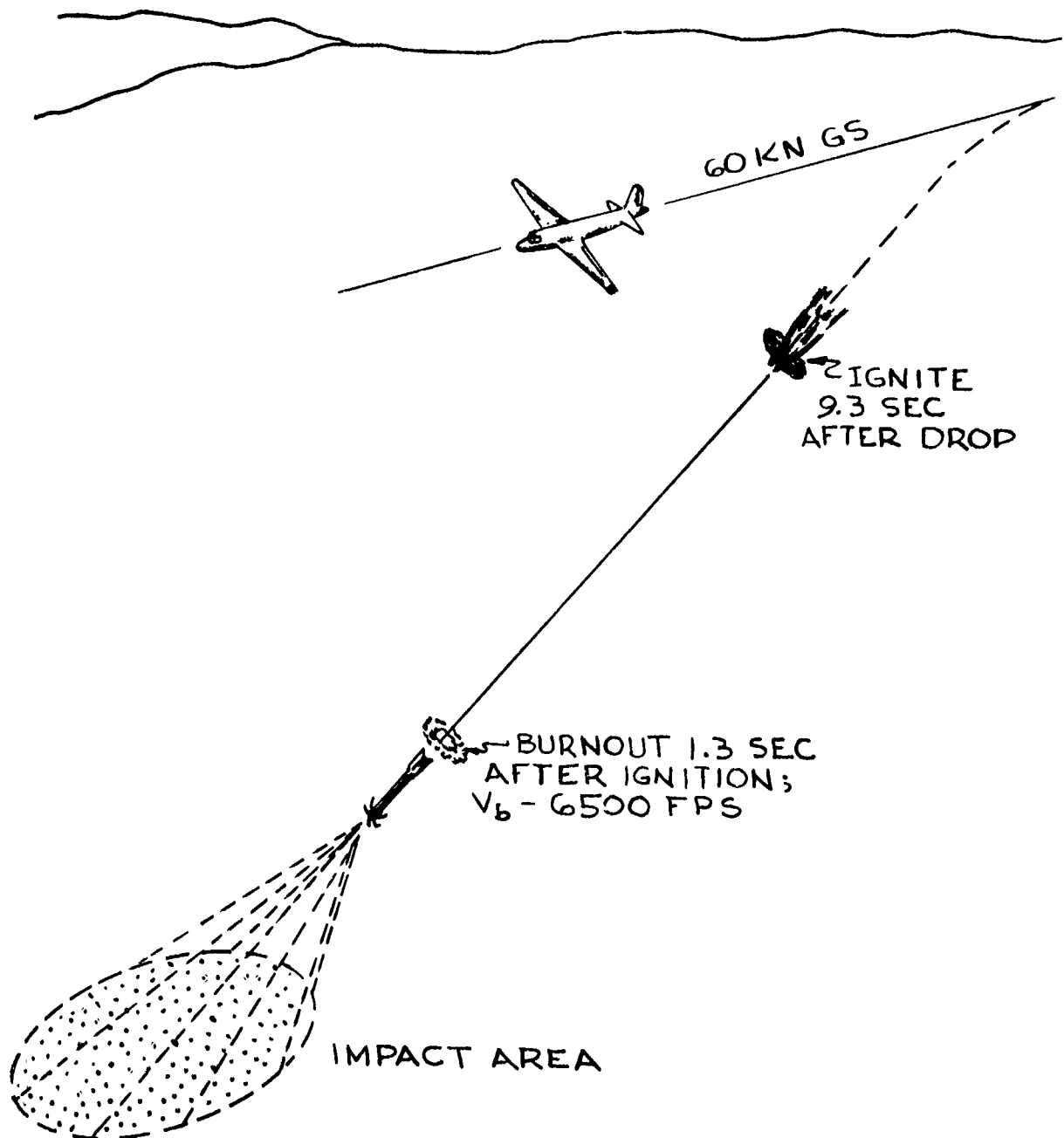


FIGURE 15

TEST TECHNIQUE OF WOX-9A
WARHEAD AT WSMR

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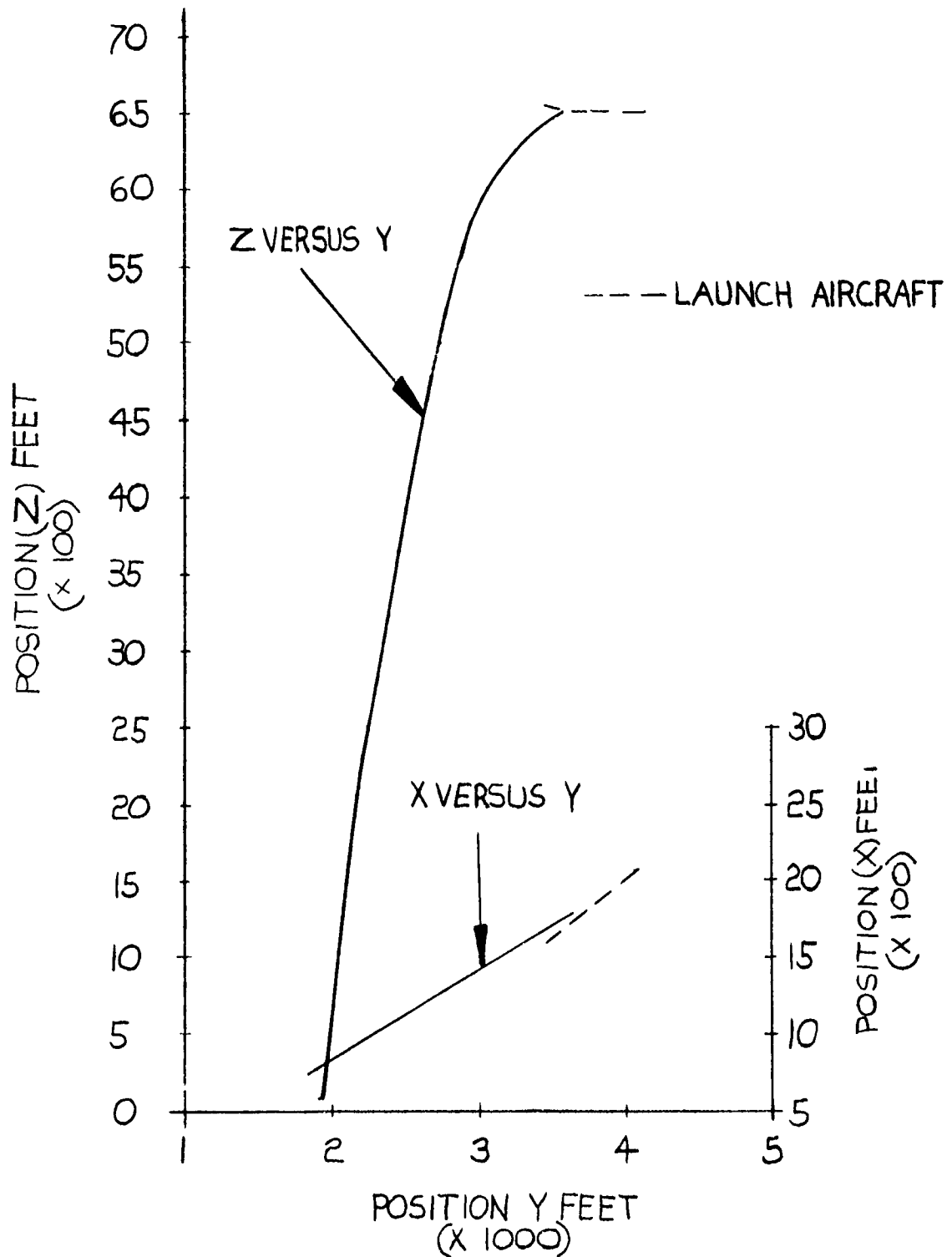


FIG 16 L-1 TRAJECTORY

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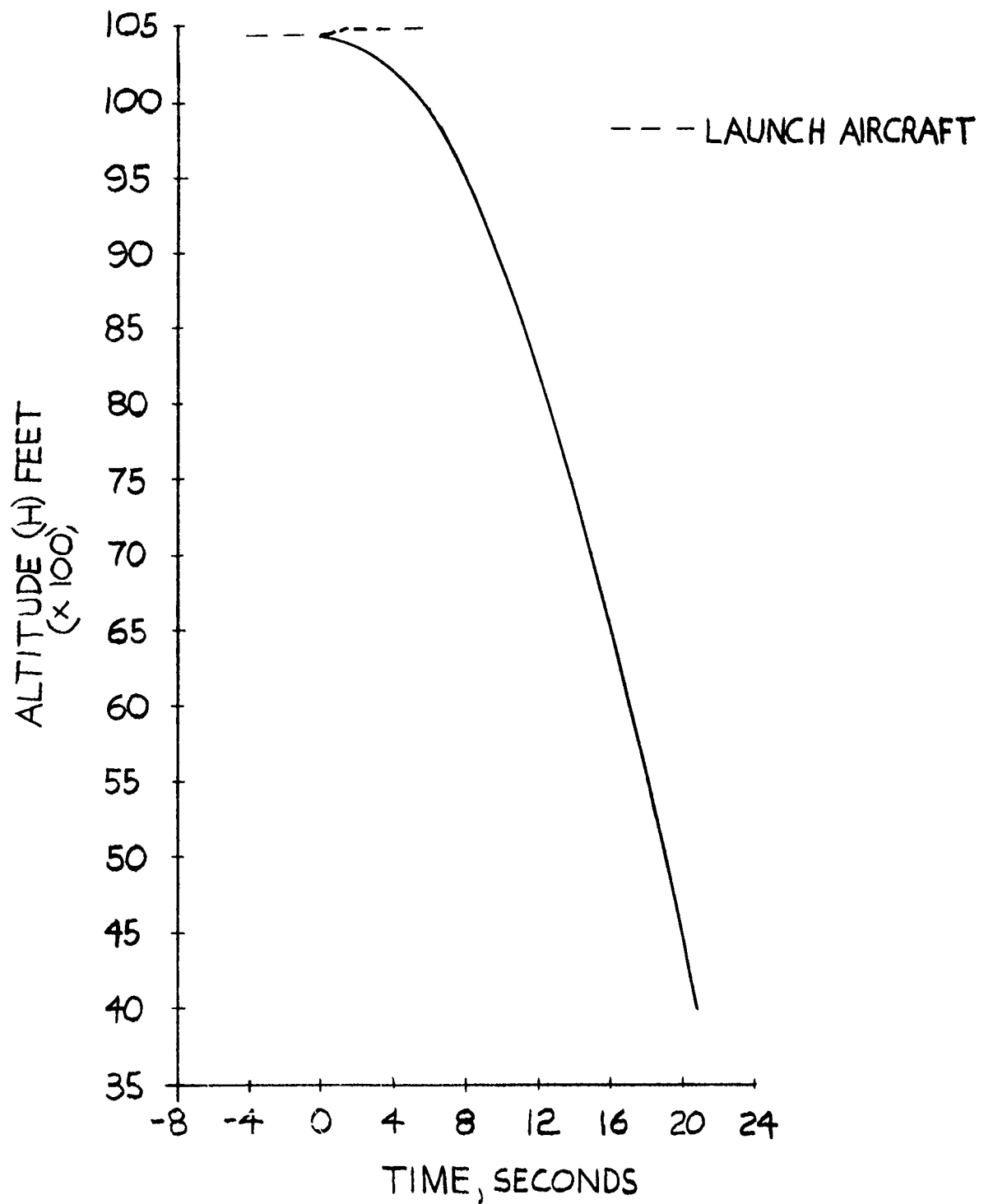


FIG 17 L-1 ALTITUDE VERSUS TIME

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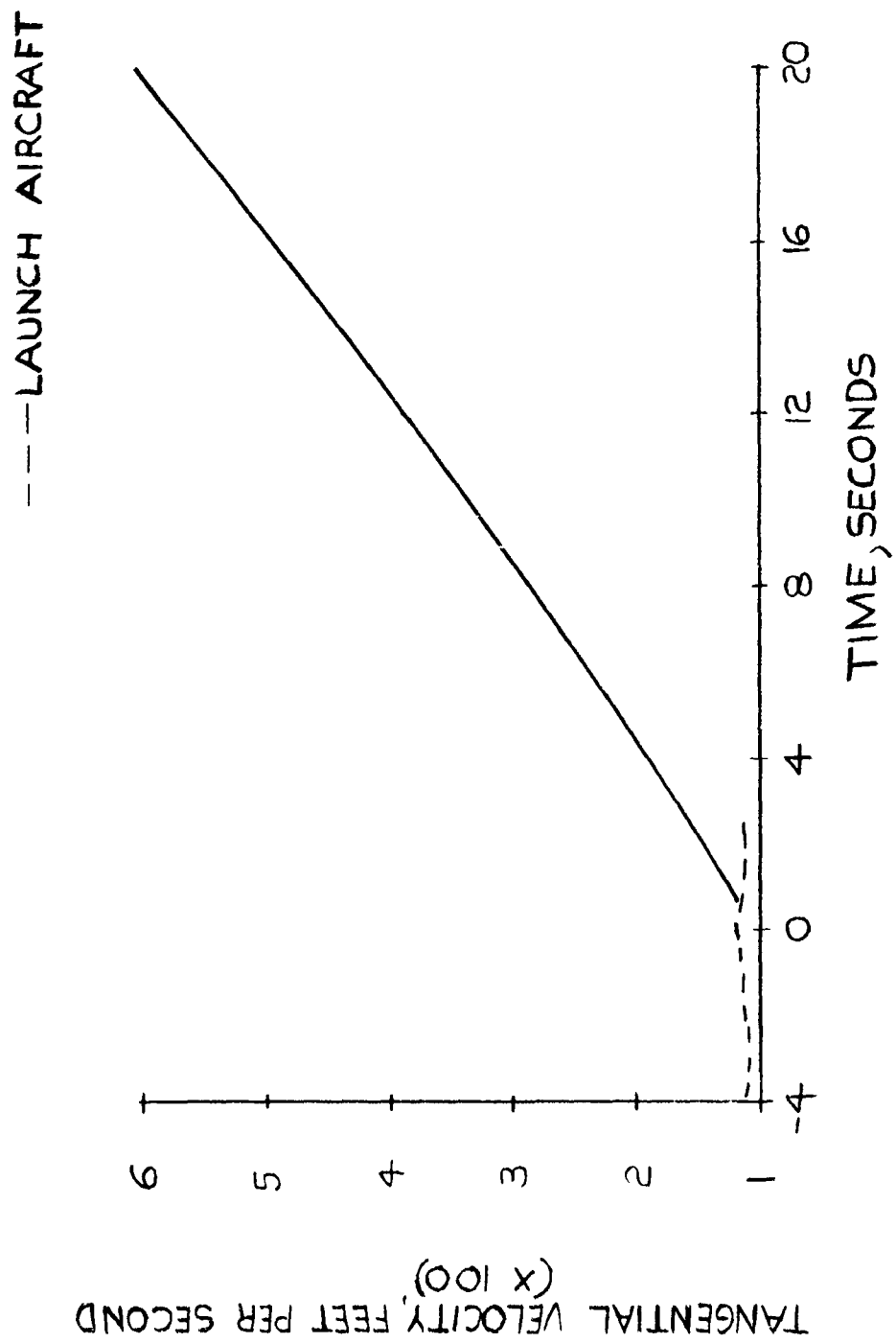


FIG 18 L-1 TANGENTIAL VELOCITY VERSUS TIME

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--- LAUNCH AIRCRAFT

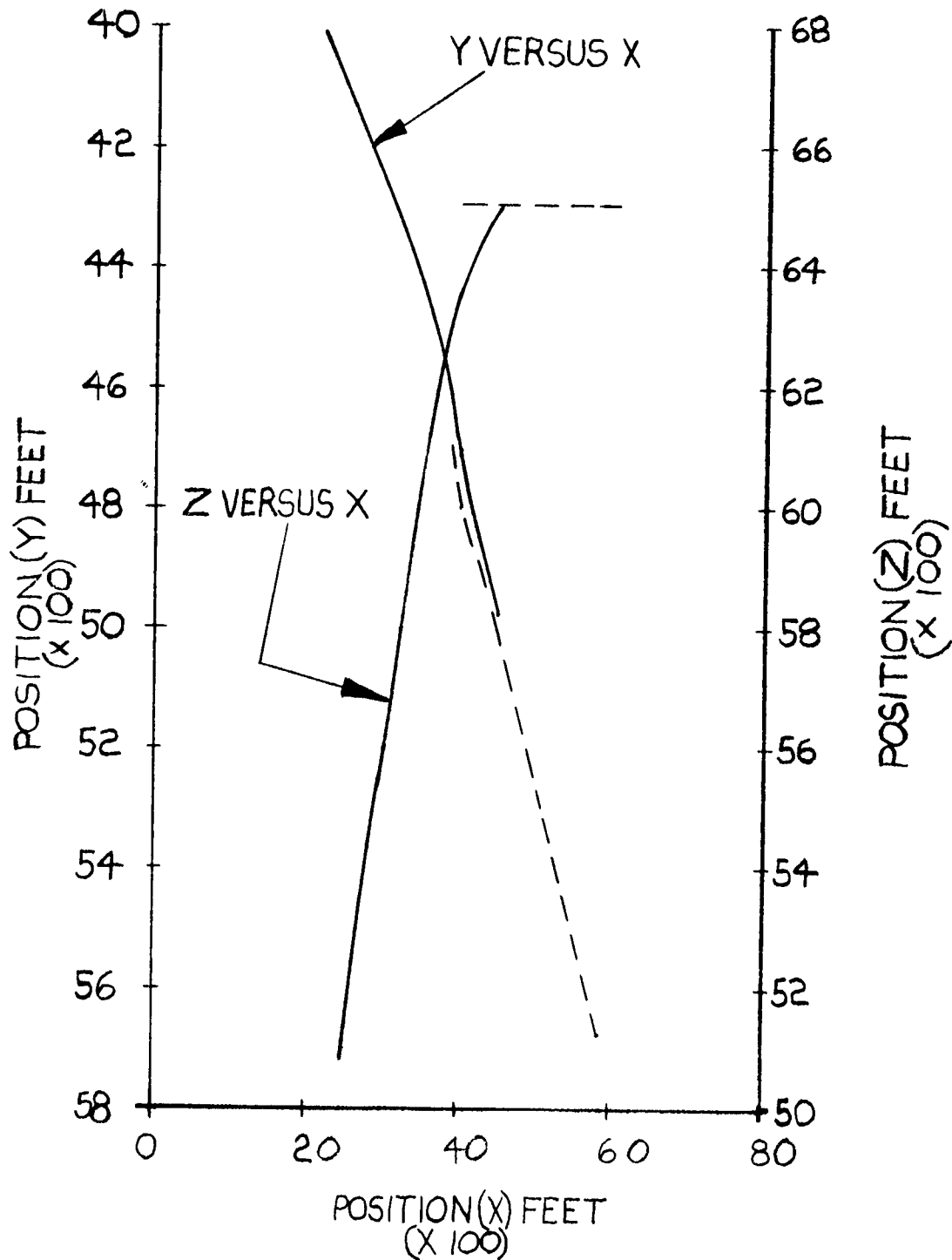


FIG 19 L-2 TRAJECTORY

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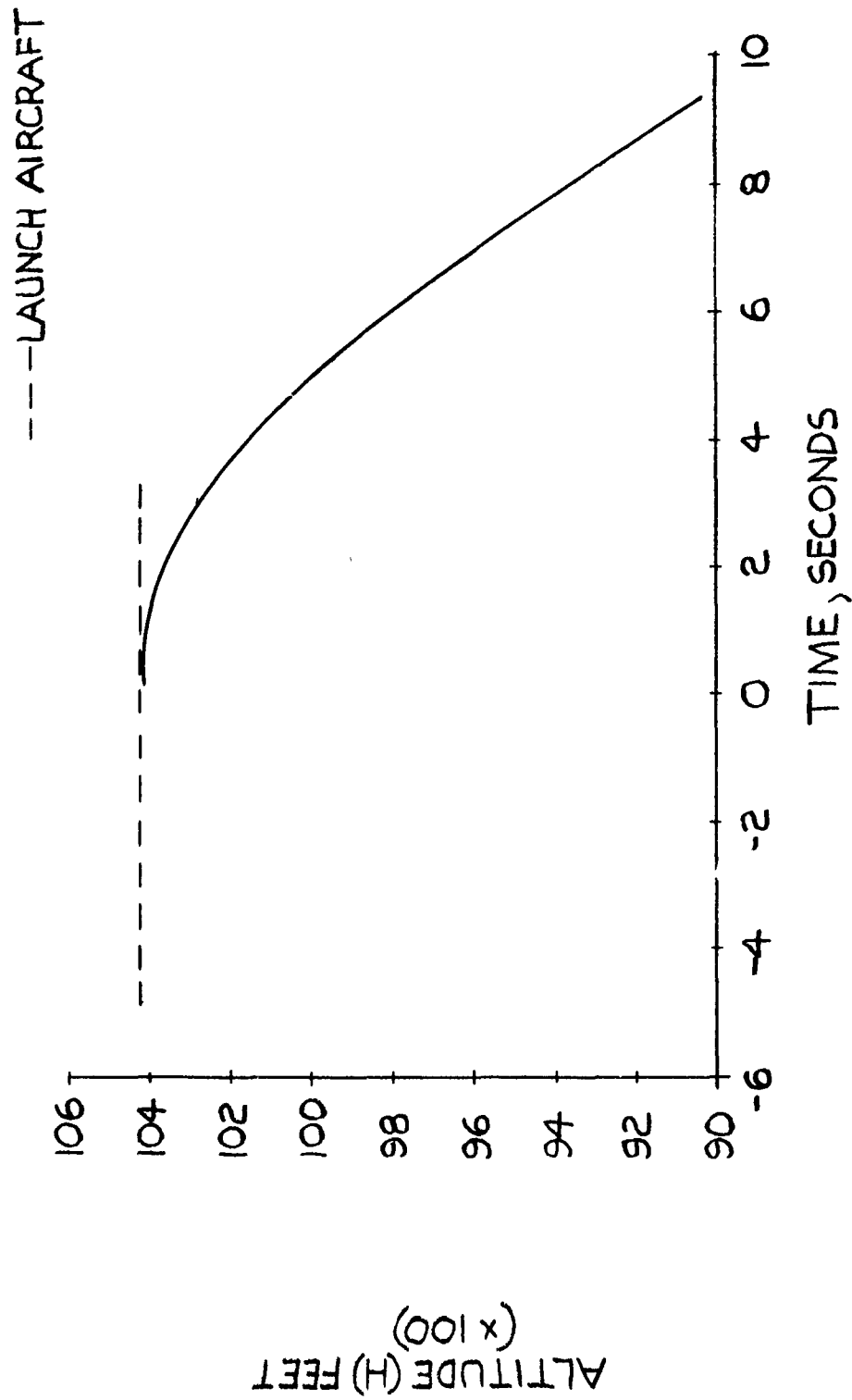


FIG 20 L-2 ALTITUDE VERSUS TIME

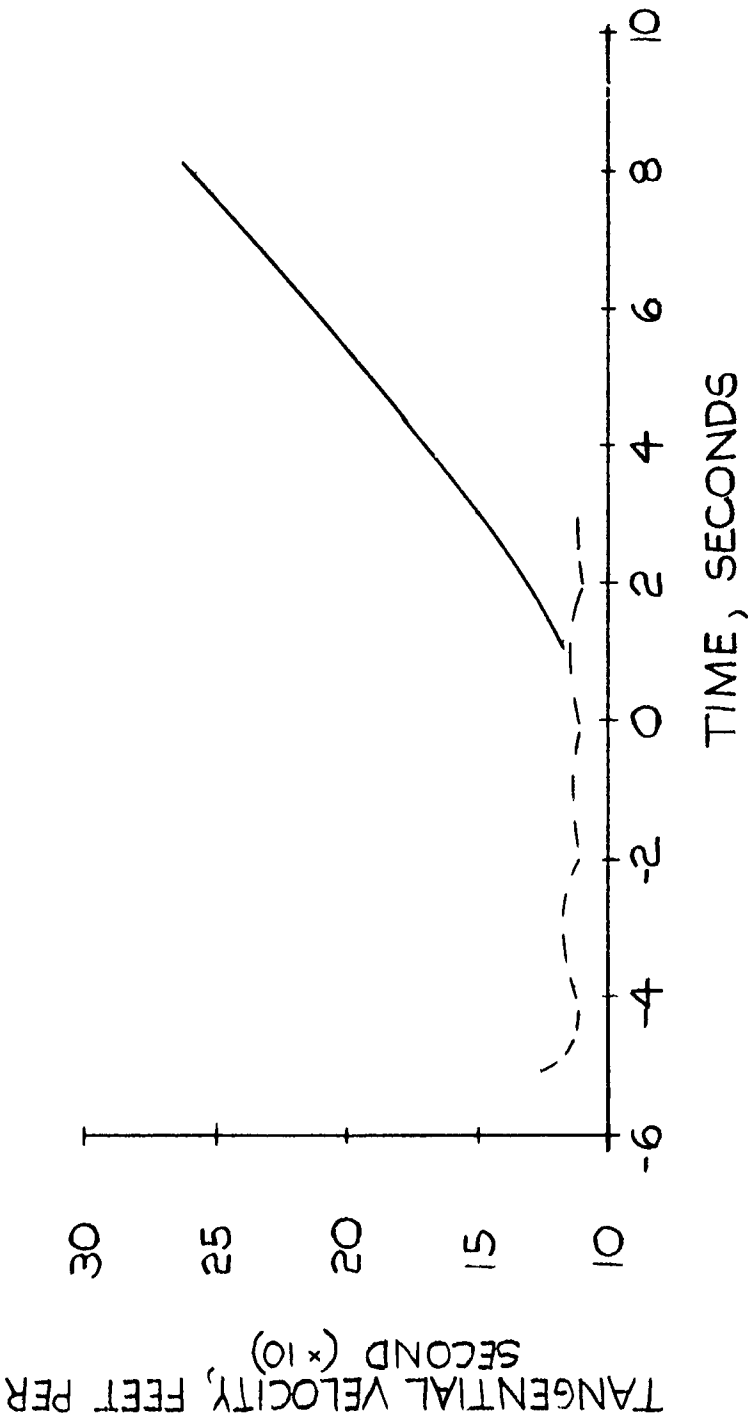


FIG 2/ L-2 TANGENTIAL VELOCITY VERSUS TIME

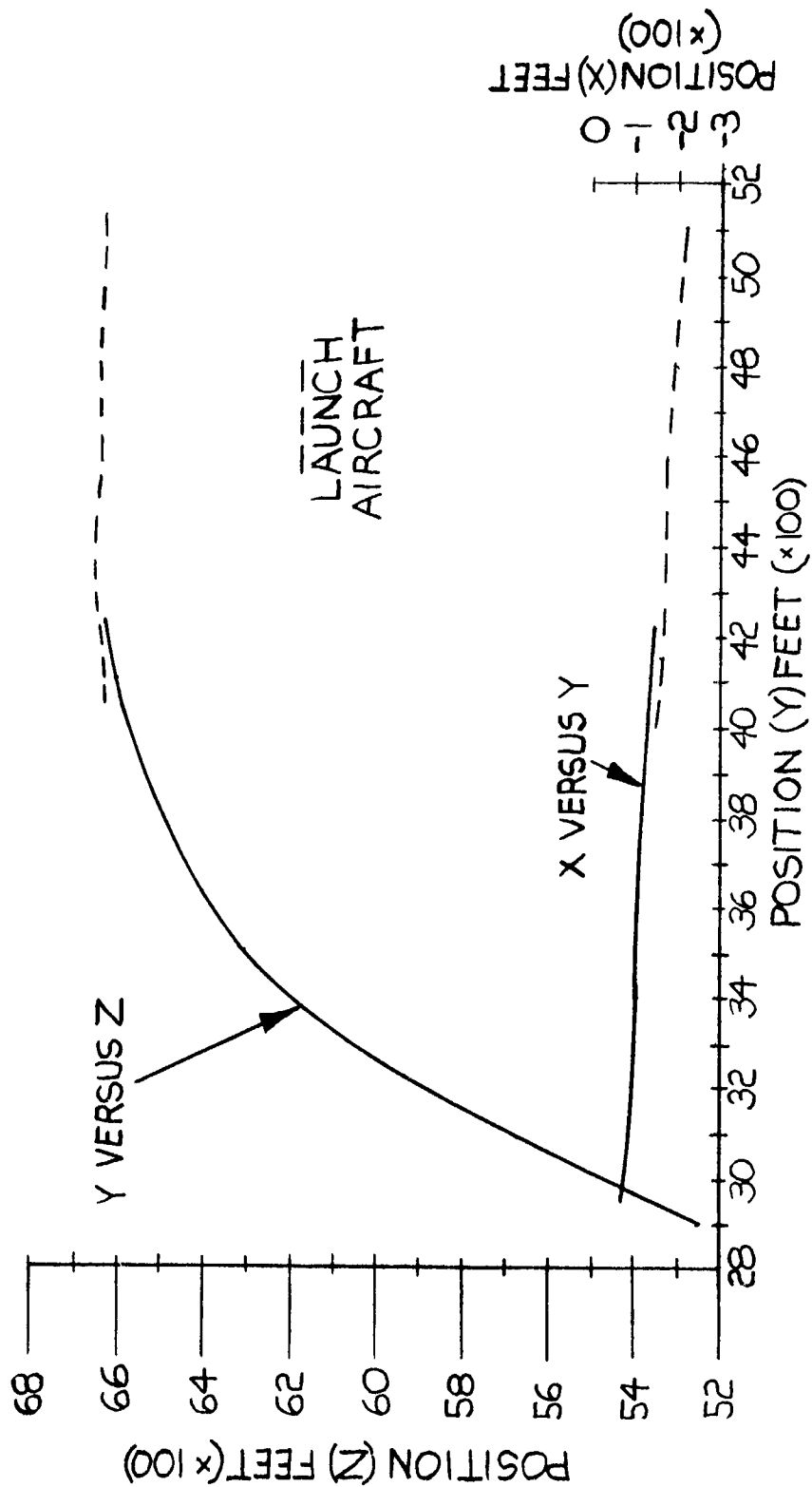


FIG.22 L-3 TRAJECTORY

--- LAUNCH AIRCRAFT

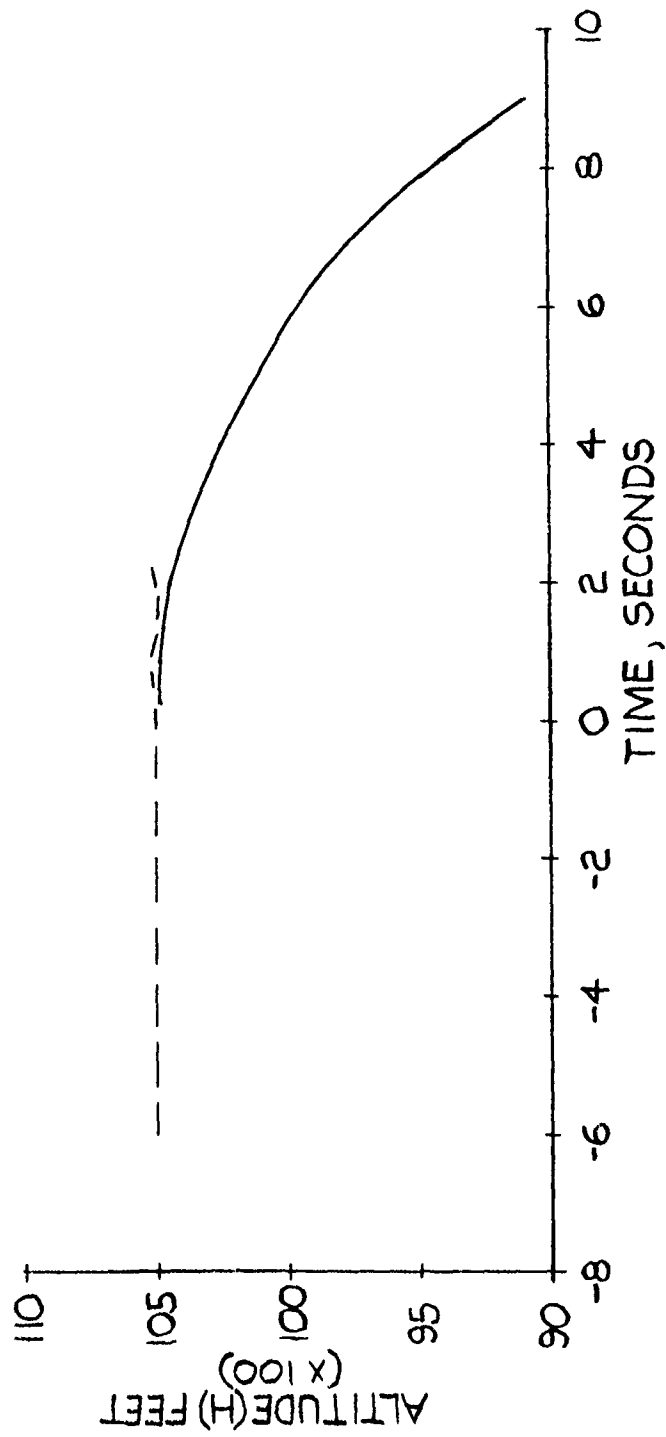


FIG. 23 L-3 ALTITUDE VERSUS TIME

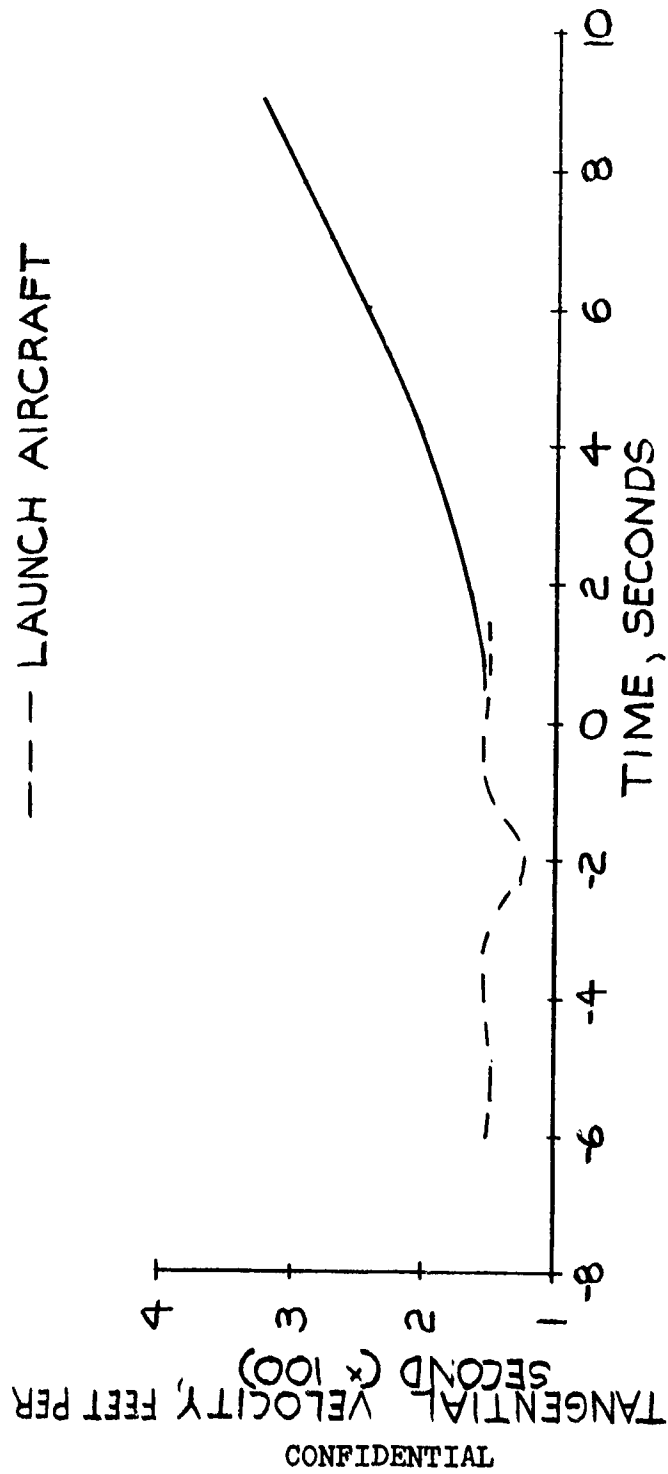


FIG.24 L-3 TANGENTIAL VELOCITY VERSUS TIME

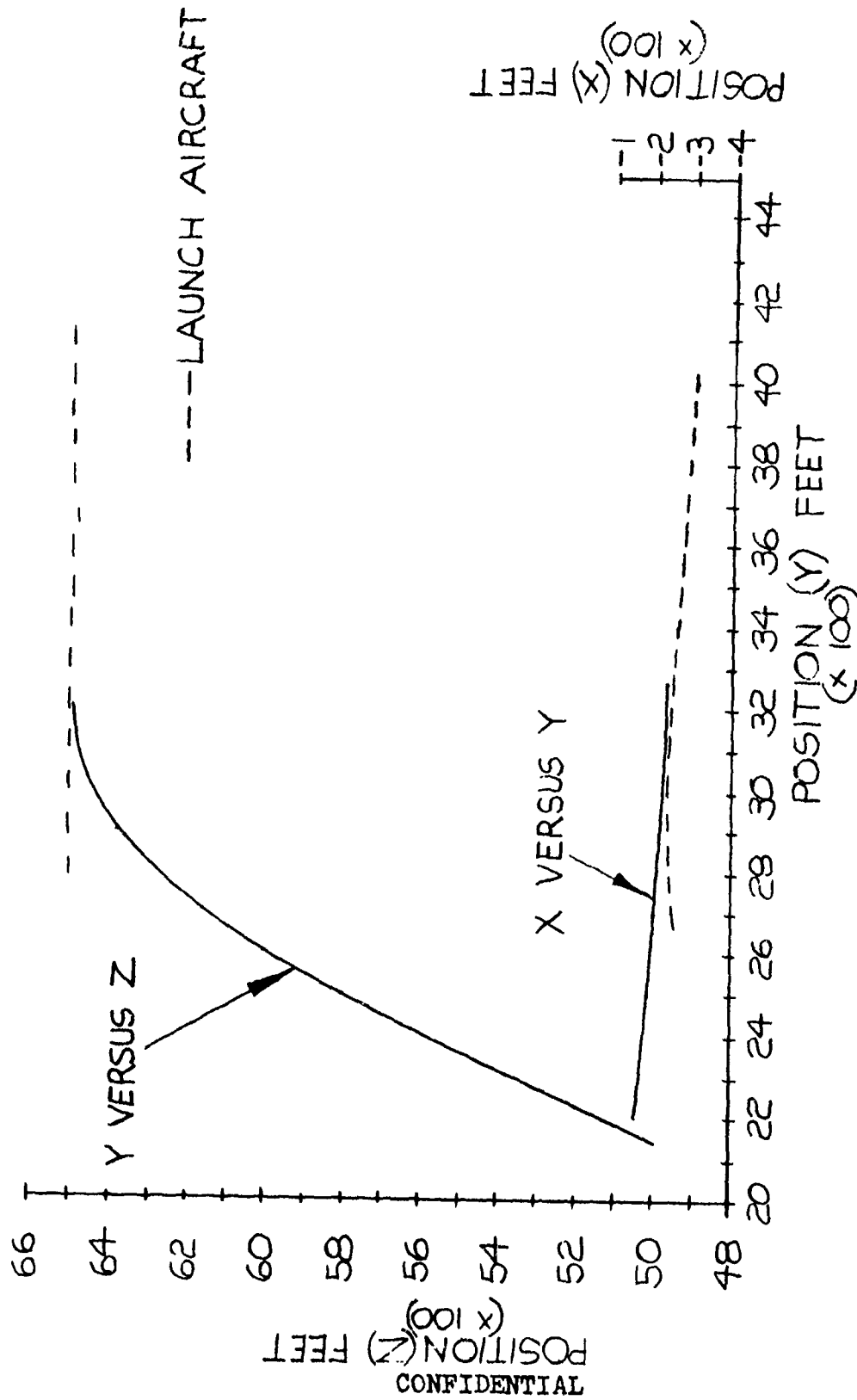


FIG.25 L-4 TRAJECTORY

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--- LAUNCH AIRCRAFT

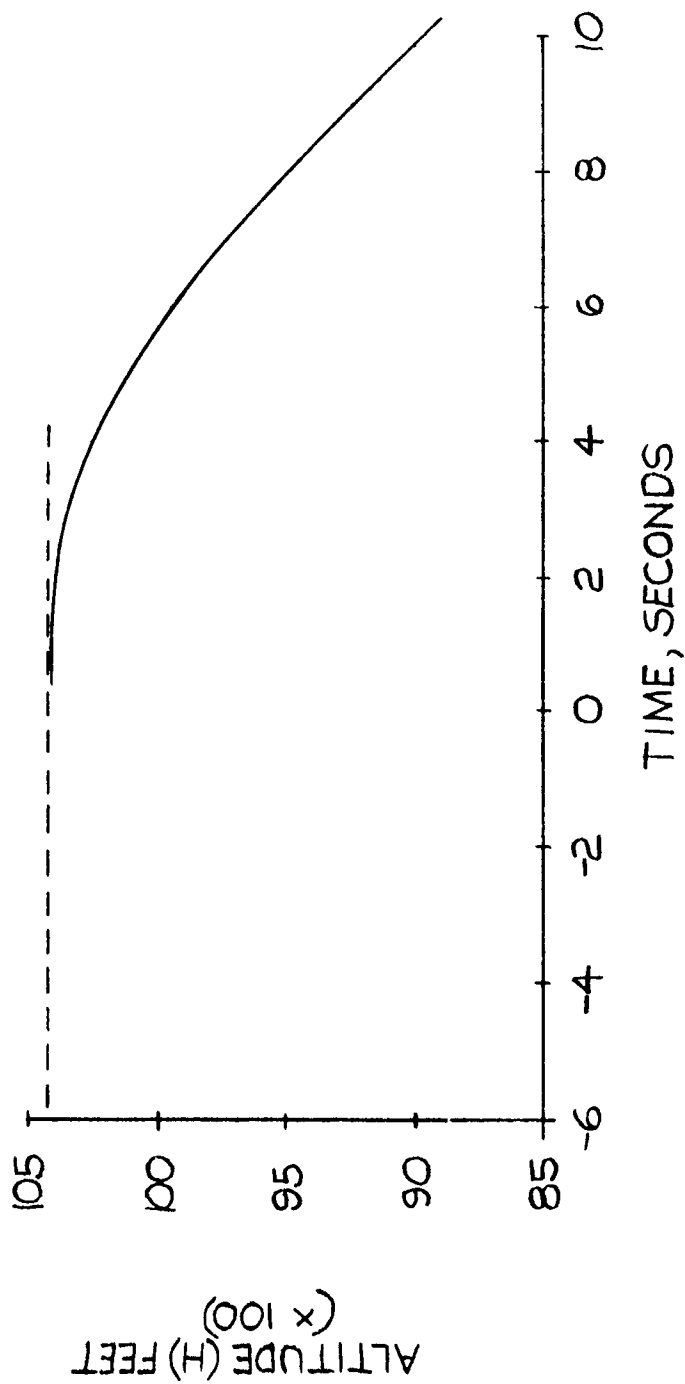


FIG 26 L-4 ALTITUDE VERSUS TIME

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---LAUNCH AIRCRAFT

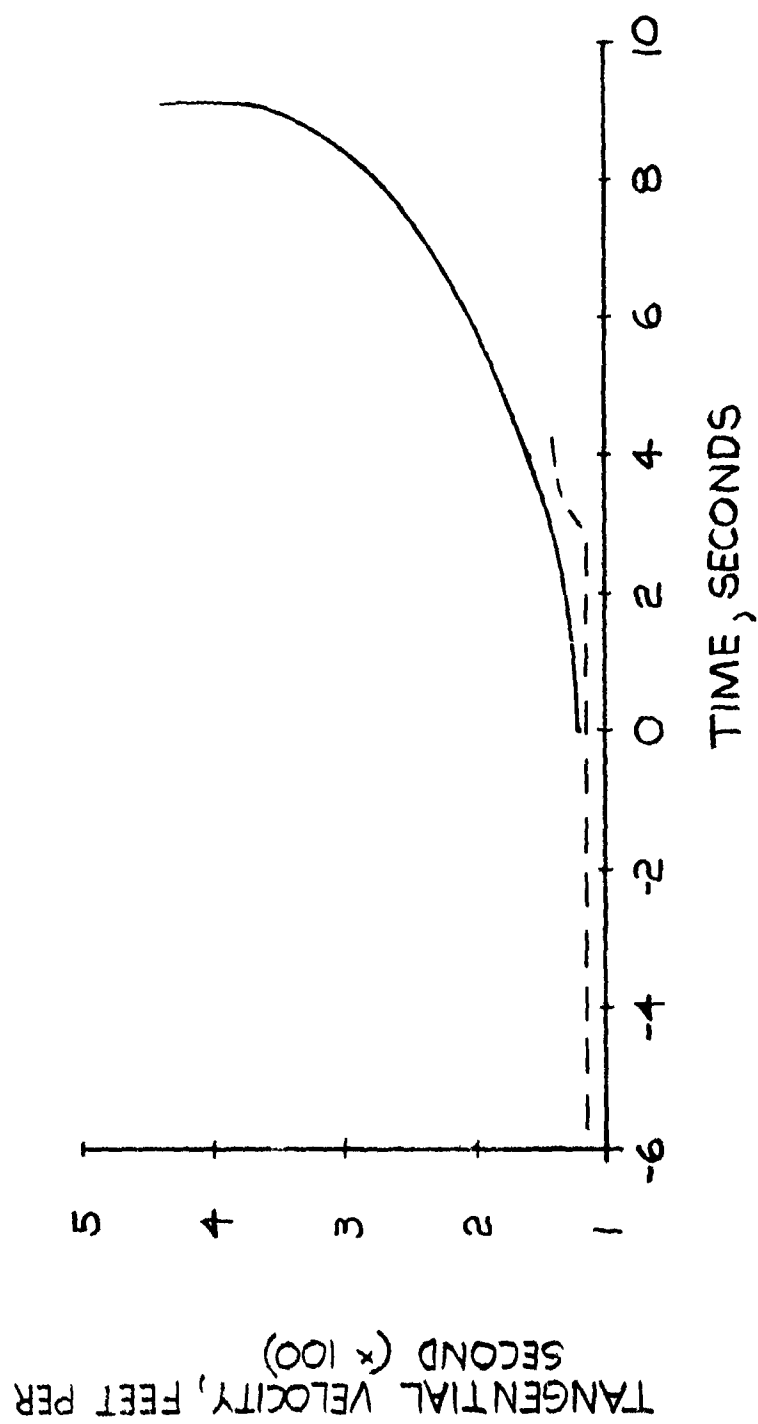


FIG 27 L-4 TANGENTIAL VELOCITY VERSUS TIME

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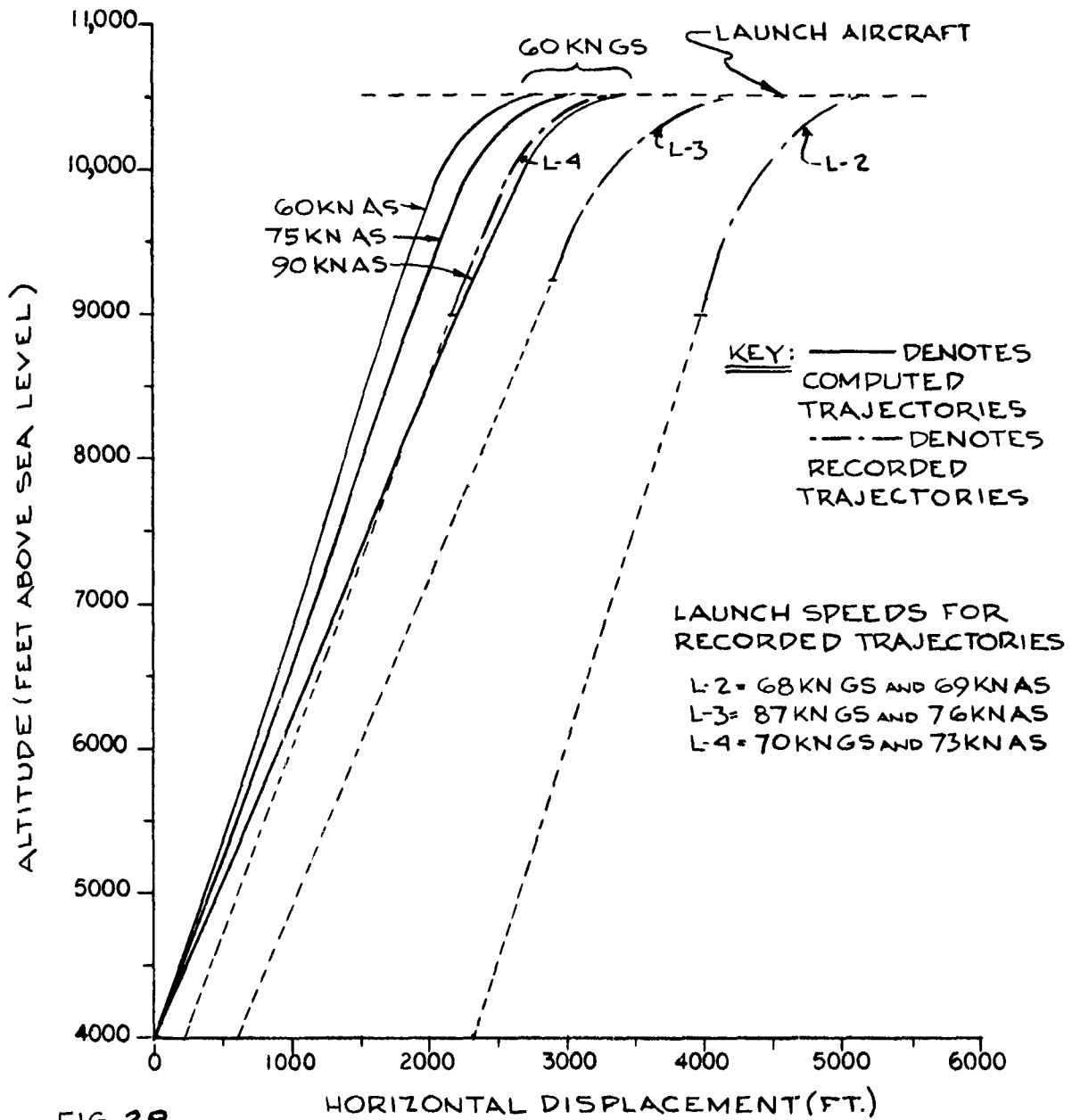


FIG 2B

COMPARISON OF MEASURED VERSUS
COMPUTED TRAJECTORIES OF
WOX-2A MISSILES.

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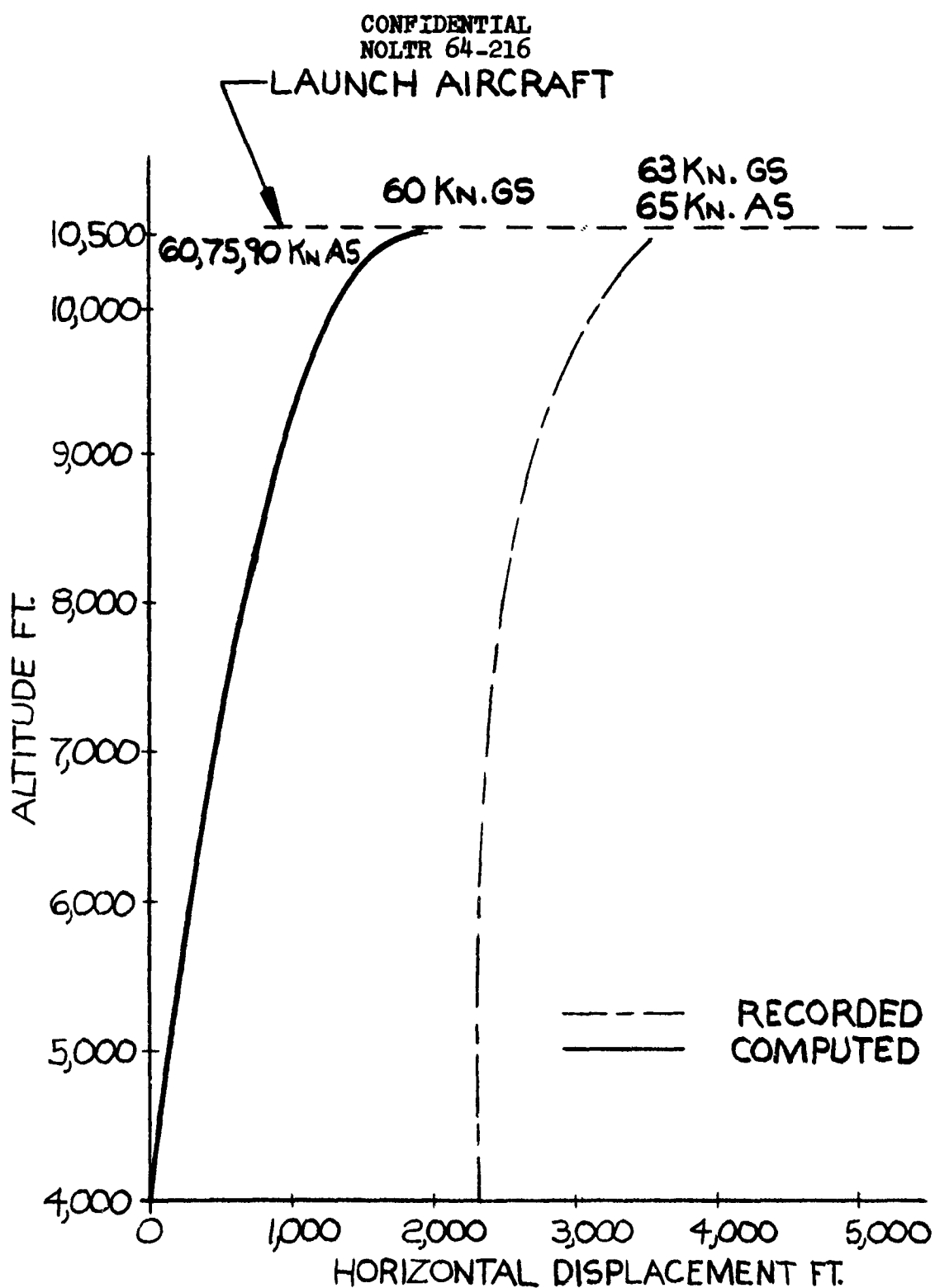


FIG. 29 COMPARISON OF MEASURED VERSUS COMPUTED
FLIGHT PATH OF D-3 DROP ROUND

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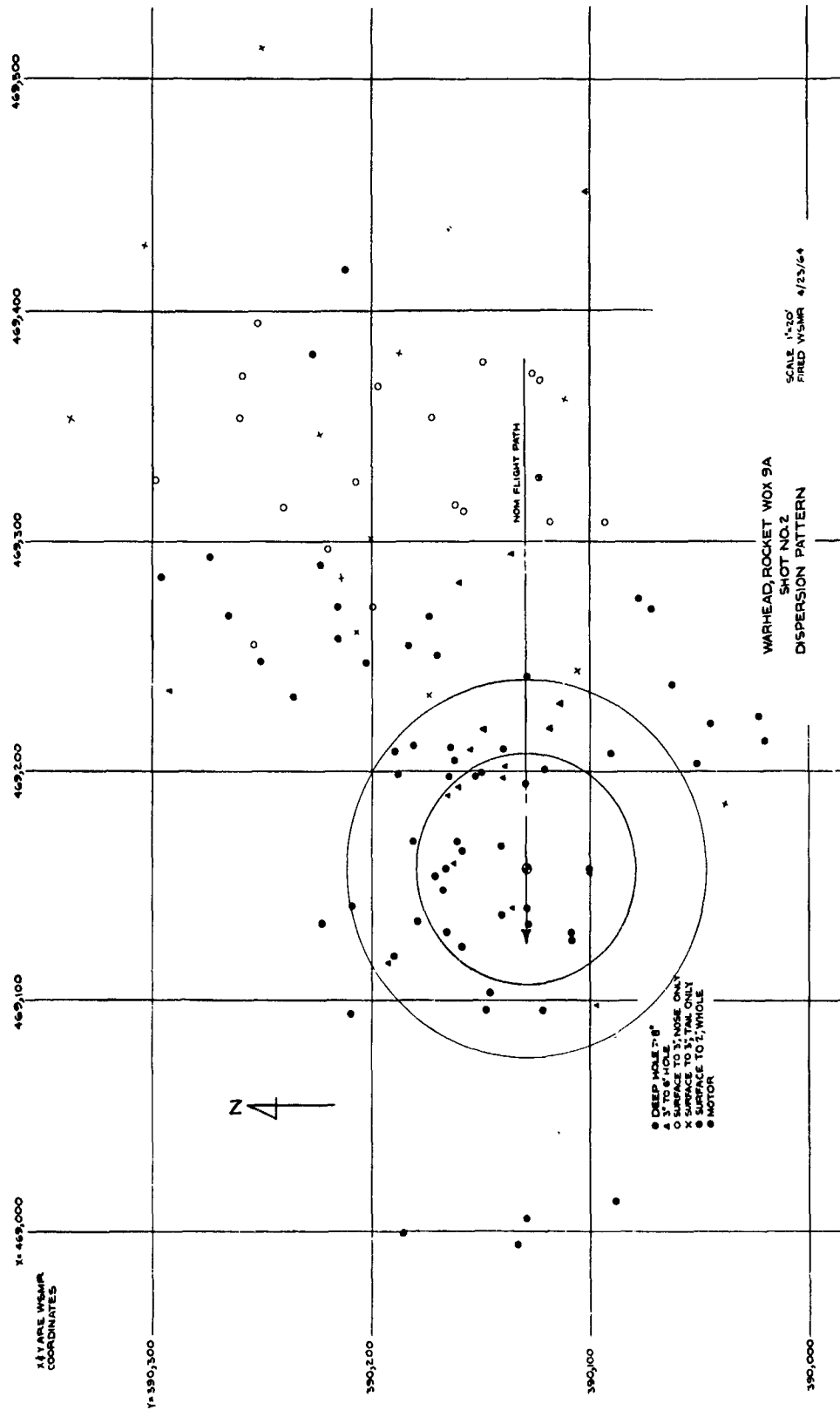


FIG. 30 ROUND L-2 IMPACT PATTERN

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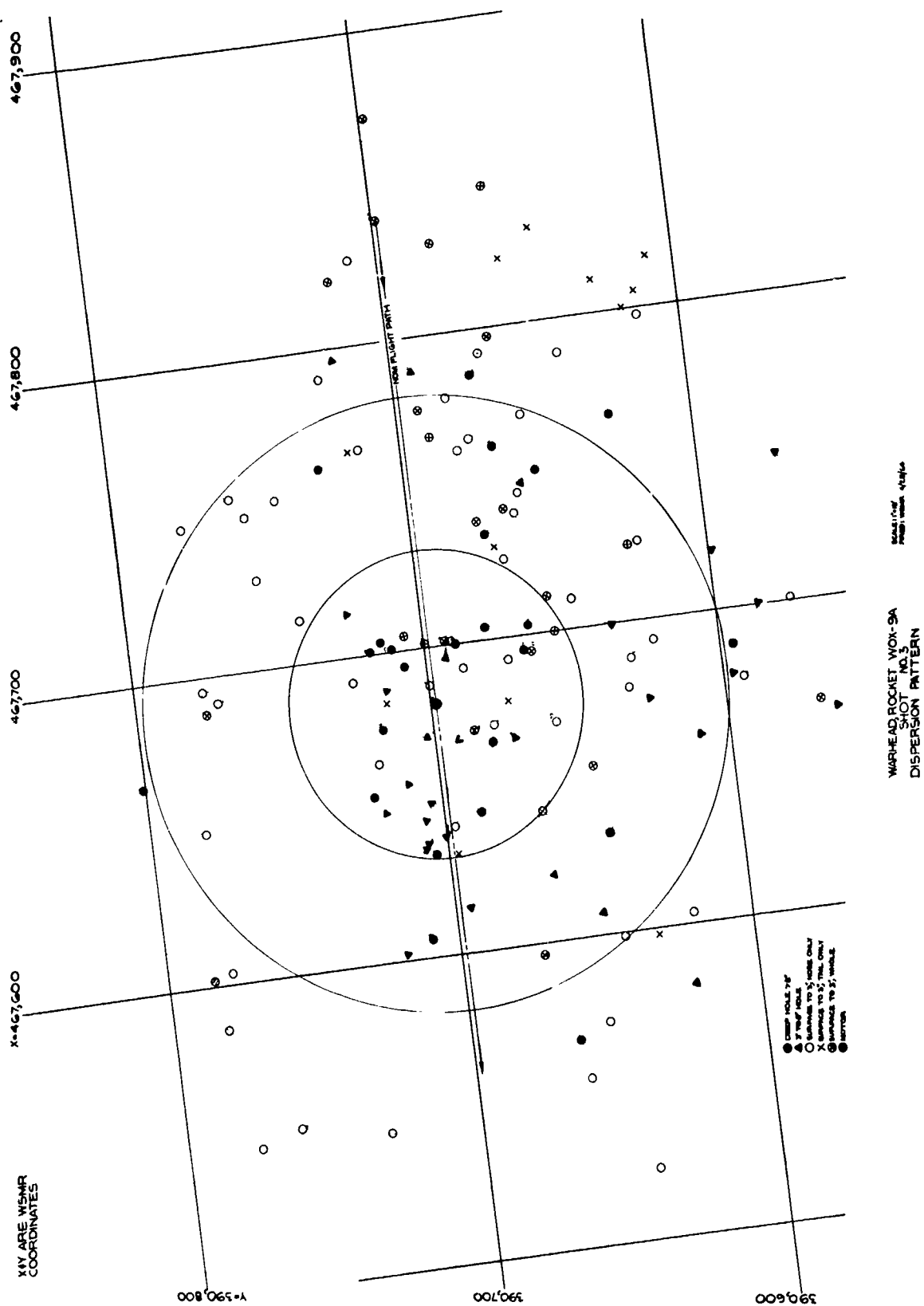


FIG. 31 ROUND L-3 IMPACT PATTERN

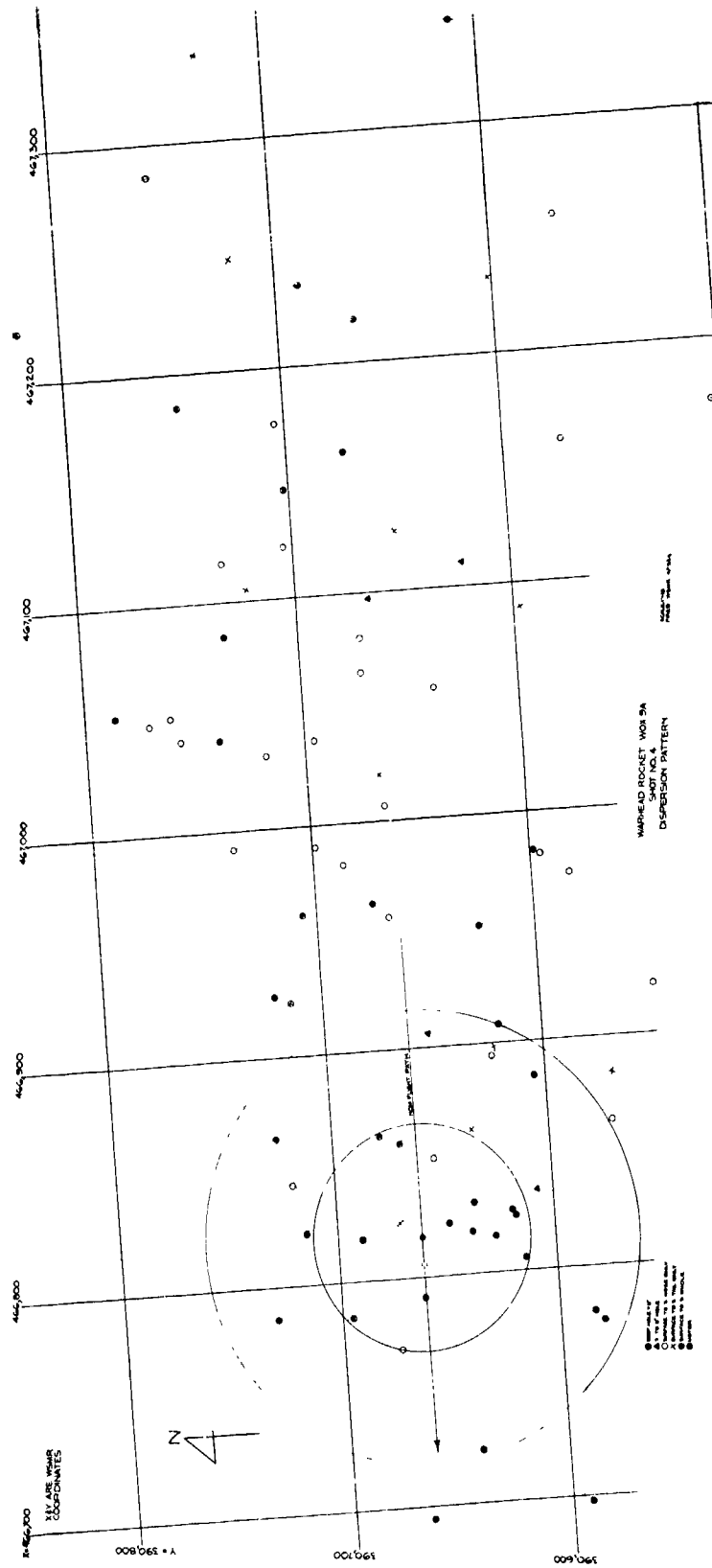


FIG. 32 ROUND L-4 IMPACT PATTERN

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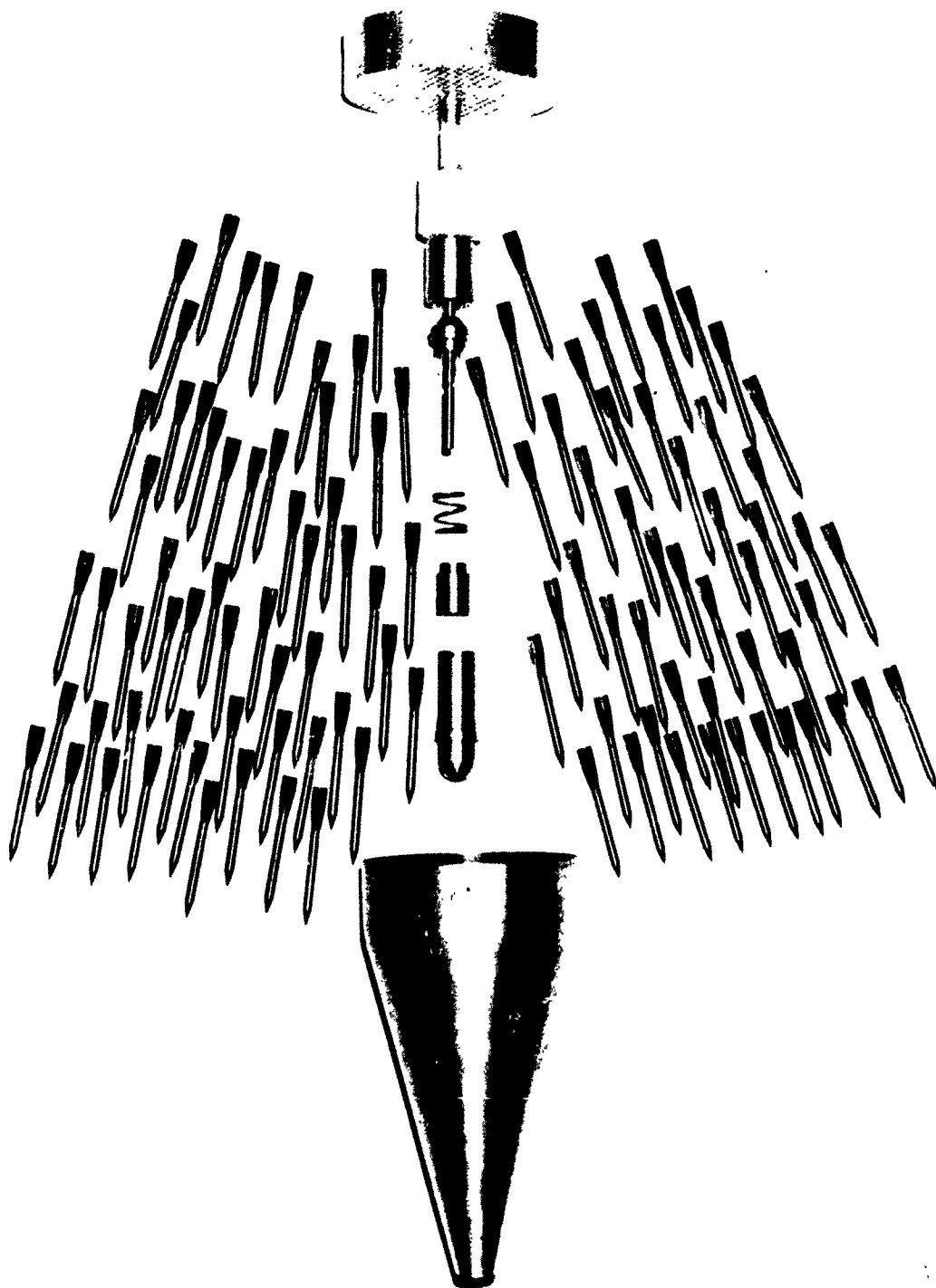


FIG. 33 DISASSEMBLED WOX-9A WARHEAD

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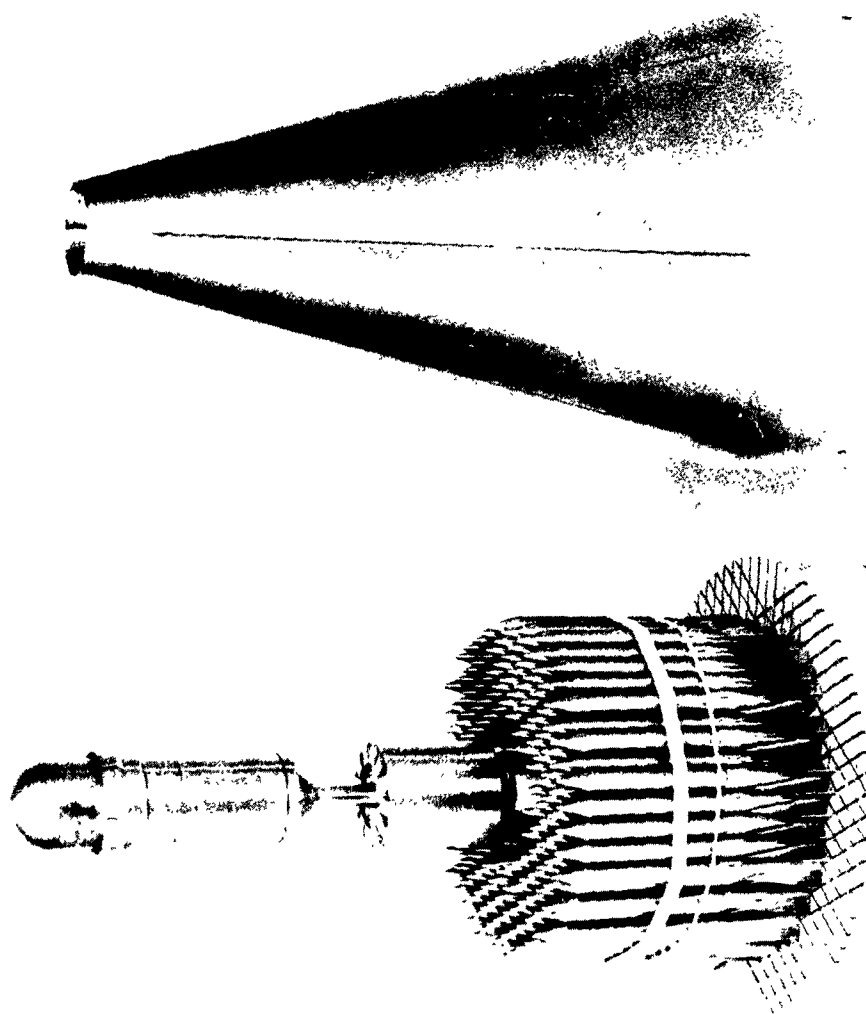


FIG. 34 PARTIALLY ASSEMBLED WOX-9A WARHEAD

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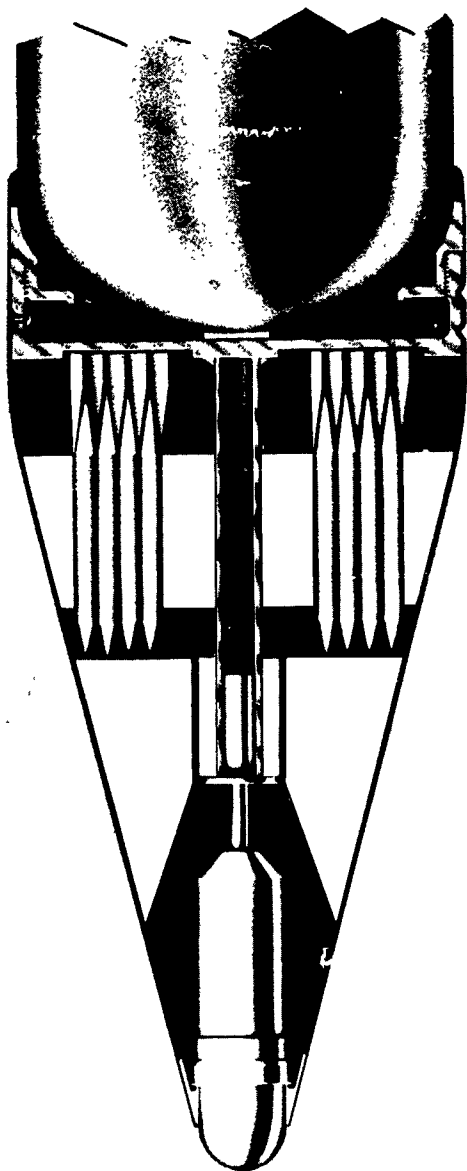


FIG. 35 ASSEMBLED WOX-9A WARHEAD

TABLE 1
TERMINAL BALLISTIC TESTS OF HIGH DENSITY PENETRATORS

No.	Type Dart	Date Fired (1963)	Dart Wt gms.	Vel. fps	Thk in	Type	Qty, deg	Penetration
1	Mallory 1000-Blunted Cone-Cone	4/25	202	3980	2.25	STS	0	Complete Perforation
2	"	4/25	204	1407	2.25	STS	0	Small crater 1/4" deep
3	"	4/25	199	7347	2.25	STS	0	Complete Perforation
4	"	4/25	206	6266	2.25	STS	0	"
5	"	5/6	200	6132	3	STS	30	"
6	"	5/6	198	6256	3	STS	45	"
7	"	5/6	201	5791	3	STS	0	"
8	"	5/7	200	6107	3	STS	60	3" penetration normal to plate. Back of plate bulged - no spall.
9	"	Jun	18.8	8149	2	240 BHN	0	Complete Perforation
10	"	Jun	19.1	7960	2	240 BHN	45	Back bulged. No spall.
11	"	Jun	19.1	8059	2	240 BHN	30	Back bulged & cracked. No spall.
12	"	Jun	19.0	8033	1.5	240 BHN	45	Complete Perforation.
13	"	Jun	18.8	7983	1.5	390 BHN	0	"
14	"	12/14	19.0	7820	1.8	T-34	0	Projectile yaw at impact 17.2°
15	"	12/14	18.6	7270	1.8	T-34	0	Projectile yaw at impact 1.7°
16	High Density Cone - Cone	6/64	86.6	8930	6	STS	0	Complete Perforation
17	"	6/64	86.6	8440	6	STS	0	"
18	"	6/64	86.6	7850	6	STS	0	Not Perforated
19	"	6/64	86.6	8140		STS	0	Perforated 1/2" plate followed by 5-1/4" plates 6" apart.
20	Mallory 3000 - Finned Rods	3/64	228	7650	7	BHN	0	Complete Perforation
21	"	3/64	228	7950	8	BHN	0	"
22	"	3/64	86.6	8800	6	BHN	0	"

TABLE 2
HORIZONTAL OFFSET "X" FEET ALONG GROUND IN FLIGHT DIRECTION

GROUND SPEED G.S.	WIND							
	0	25 FPS (15 KN)	50 (30)	75 (45)	100 (60)	125 (75)	150 (90)	
0				POWER FLT	1400	1649	2020	
25 FPS (15 KN)				DROP RND	1118	-158	-193	
50 (30)			POWER FLT	1634	1877	2233	2473	
75 (45)			DROP RND	384	355	319	276	
100 (60)			POWER FLT	1966	2191	2562	3164	
125 (75)			DROP RND	900	833	791	743	
150 (90)			POWER FLT	2283	2505	2891	3487	
175 (105)			DROP RND	1410	1384	1306	1256	
200 (120)			POWER FLT	2617	2821	3220	3811	
225 (135)			DROP RND	1927	1900	1820	1770	
250 (150)			POWER FLT	2941	3112	3433	3811	
275 (165)			DROP RND	1348	1306	1256	1206	
300 (180)			POWER FLT	3433	3811	4291	4873	
325 (195)			DROP RND	1770	1770	1770	1770	
350 (210)			POWER FLT	4291	4873	5455	6037	
375 (225)			DROP RND	2191	2191	2191	2191	
400 (240)			POWER FLT	5455	6037	6619	7201	
425 (255)			DROP RND	2562	2562	2562	2562	
450 (270)			POWER FLT	6619	7201	7783	8365	
475 (285)			DROP RND	2923	2923	2923	2923	
500 (300)			POWER FLT	7783	8365	8947	9529	
525 (315)			DROP RND	3283	3283	3283	3283	
550 (330)			POWER FLT	8947	9529	10111	10693	
575 (345)			DROP RND	3643	3643	3643	3643	
600 (360)			POWER FLT	10111	10693	11275	11857	
625 (375)			DROP RND	4003	4003	4003	4003	
650 (390)			POWER FLT	11275	11857	12439	13021	
675 (405)			DROP RND	4363	4363	4363	4363	
700 (420)			POWER FLT	12439	13021	13603	14185	
725 (435)			DROP RND	4723	4723	4723	4723	
750 (450)			POWER FLT	13603	14185	14767	15349	
775 (465)			DROP RND	5083	5083	5083	5083	
800 (480)			POWER FLT	14767	15349	15931	16513	
825 (495)			DROP RND	5443	5443	5443	5443	
850 (510)			POWER FLT	15931	16513	17095	17677	
875 (525)			DROP RND	5803	5803	5803	5803	
900 (540)			POWER FLT	17095	17677	18259	18841	
925 (555)			DROP RND	6163	6163	6163	6163	
950 (570)			POWER FLT	18259	18841	19423	20005	
975 (585)			DROP RND	6523	6523	6523	6523	
1000 (600)			POWER FLT	19423	20005	20587	21169	
1025 (615)			DROP RND	6883	6883	6883	6883	
1050 (630)			POWER FLT	20587	21169	21751	22333	
1075 (645)			DROP RND	7243	7243	7243	7243	
1100 (660)			POWER FLT	21751	22333	22915	23497	
1125 (675)			DROP RND	7603	7603	7603	7603	
1150 (690)			POWER FLT	22915	23497	24079	24661	
1175 (705)			DROP RND	7963	7963	7963	7963	
1200 (720)			POWER FLT	24079	24661	25243	25825	
1225 (735)			DROP RND	8323	8323	8323	8323	
1250 (750)			POWER FLT	25243	25825	26407	26989	
1275 (765)			DROP RND	8683	8683	8683	8683	
1300 (780)			POWER FLT	26407	26989	27571	28153	
1325 (795)			DROP RND	9043	9043	9043	9043	
1350 (810)			POWER FLT	27571	28153	28735	29317	
1375 (825)			DROP RND	9403	9403	9403	9403	
1400 (840)			POWER FLT	28735	29317	29900	30482	
1425 (855)			DROP RND	9763	9763	9763	9763	
1450 (870)			POWER FLT	29900	30482	31064	31646	
1475 (885)			DROP RND	10123	10123	10123	10123	
1500 (900)			POWER FLT	31064	31646	32228	32810	
1525 (915)			DROP RND	10483	10483	10483	10483	
1550 (930)			POWER FLT	32228	32810	33392	33974	
1575 (945)			DROP RND	10843	10843	10843	10843	
1600 (960)			POWER FLT	33392	33974	34556	35138	
1625 (975)			DROP RND	11203	11203	11203	11203	
1650 (990)			POWER FLT	34556	35138	35720	36302	
1675 (1005)			DROP RND	11563	11563	11563	11563	
1700 (1020)			POWER FLT	35720	36302	36884	37466	
1725 (1035)			DROP RND	11923	11923	11923	11923	
1750 (1050)			POWER FLT	36884	37466	38048	38630	
1775 (1065)			DROP RND	12283	12283	12283	12283	
1800 (1080)			POWER FLT	38048	38630	39212	39794	
1825 (1095)			DROP RND	12643	12643	12643	12643	
1850 (1110)			POWER FLT	39212	39794	40376	40958	
1875 (1125)			DROP RND	13003	13003	13003	13003	
1900 (1140)			POWER FLT	40376	40958	41540	42122	
1925 (1155)			DROP RND	13363	13363	13363	13363	
1950 (1170)			POWER FLT	41540	42122	42704	43286	
1975 (1185)			DROP RND	13723	13723	13723	13723	
2000 (1200)			POWER FLT	42704	43286	43868	44450	
2025 (1215)			DROP RND	14083	14083	14083	14083	
2050 (1230)			POWER FLT	43868	44450	45032	45614	
2075 (1245)			DROP RND	14443	14443	14443	14443	
2100 (1260)			POWER FLT	45032	45614	46196	46778	
2125 (1275)			DROP RND	14803	14803	14803	14803	
2150 (1290)			POWER FLT	46196	46778	47360	47942	
2175 (1305)			DROP RND	15163	15163	15163	15163	
2200 (1320)			POWER FLT	47360	47942	48524	49106	
2225 (1335)			DROP RND	15523	15523	15523	15523	
2250 (1350)			POWER FLT	48524	49106	49688	50270	
2275 (1365)			DROP RND	15883	15883	15883	15883	
2300 (1380)			POWER FLT	49688	50270	50852	51434	
2325 (1395)			DROP RND	16243	16243	16243	16243	
2350 (1410)			POWER FLT	50852	51434	52016	52598	
2375 (1425)			DROP RND	16603	16603	16603	16603	
2400 (1440)			POWER FLT	52016	52598	53180	53762	
2425 (1455)			DROP RND	16963	16963	16963	16963	
2450 (1470)			POWER FLT	53180	53762	54344	54926	
2475 (1485)			DROP RND	17323	17323	17323	17323	
2500 (1500)			POWER FLT	54344	54926	55508	56090	
2525 (1515)			DROP RND	17683	17683	17683	17683	
2550 (1530)			POWER FLT	55508	56090	56672	57254	
2575 (1545)			DROP RND	18043	18043	18043	18043	
2600 (1560)			POWER FLT	56672	57254	57836	58418	
2625 (1575)			DROP RND	18403	18403	18403	18403	
2650 (1590)			POWER FLT	57836	58418	59000	59582	
2675 (1605)			DROP RND	18763	18763	18763	18763	
2700 (1620)			POWER FLT	59000	59582	60164	60746	
2725 (1635)			DROP RND	19123	19123	19123	19123	
2750 (1650)			POWER FLT	60164	60746	61328	61910	
2775 (1665)			DROP RND	19483	19483	19483	19483	
2800 (1680)			POWER FLT	61328	61910	62492	63074	
2825 (1695)			DROP RND	19843	19843	19843	19843	
2850 (1710)			POWER FLT	62492	63074	63656	64238	
2875 (1725)			DROP RND	20203	20203	20203	20203	
2900 (1740)			POWER FLT	63656	64238	64820	65402	
2925 (1755)			DROP RND	20563	20563	20563	20563	
2950 (1770)			POWER FLT	64820	65402	65984	66566	
2975 (1785)			DROP RND	20923	20923	20923	20923	
3000 (1800)			POWER FLT	65984	66566	67148	67730	
3025 (1815)			DROP RND	21283	21283	21283	21283	
3050 (1830)			POWER FLT	67148	67730	68312	68894	
3075 (1845)			DROP RND	21643	21643	21643	21643	
3100 (1860)			POWER FLT	68312	68894	69476	70058	
3125 (1875)			DROP RND	22003	22003	22003	22003	
3150 (1890)			POWER FLT	69476	70058	70640	71222	
3175 (1905)			DROP RND	22363	22363	22363	22363	
3200 (1920)			POWER FLT	70640	71222	71804	72386	
3225 (1935)			DROP RND	22723	22723	22723	22723	
3250 (1950)			POWER FLT	71804	72386	72968	73550	
3275 (1965)			DROP RND	23083	23083	23083	23083	
3300 (1980)			POWER FLT	72968	73550	74132	74714	
3325 (1995)			DROP RND	23443	23443	23443	23443	
3350 (2010)			POWER FLT	74132	74714	75296	75878	
3375 (2025)			DROP RND	23803	23803	23803	23803	
3400 (2040)			POWER FLT	75296	75878	76460	77042	
3425 (2055)			DROP RND	24163	24163	24163	24163	
3450 (2070)			POWER FLT	76460	77042	77624	78206	
3475 (2085)			DROP RND	24523	24523	24523	24523	
3500 (2100)			POWER FLT	77624	78206	78788	79370	
3525 (2115)			DROP RND	24883	24883	24883	24883	
3550 (2130)			POWER FLT	78788	79370	79952	80534	
3575 (2145)			DROP RND	25243	25243	25243	25243	
3600 (2160)			POWER FLT	79952	80534	81116	81698	
3625 (2175)			DROP RND	25603	25603	25603	25603	
3650 (2190)			POWER FLT	81116	81698	82280	82862	
3675 (2205)			DROP RND	25963	25963	25963	25963	
3700 (2220)			POWER FLT	82280	82862	83444	84026	
3725 (2235)			DROP RND	26323	26323	26323	26323	
3750 (2250)			POWER FLT	83444	84026	84608	85190	
3775 (2265)			DROP RND	26683	26683	26683	26683	
3800 (2280)			POWER FLT	84608	85190	85772	86354	
3825 (2295)			DROP RND	27043	27043	27043	27043	
3850 (2310)			POWER FLT	85772	86354	86936	87518	
3875 (2325)			DROP RND	27403	27403	27403	27403	
3900 (2340)			POWER FLT	86936	87518	88100	88682	
3925 (2355)			DROP RND	27763	27763	27763	27763	
3950 (2370)			POWER FLT	88100	88682	89264	89846	
3975 (2385)			DROP RND	28123	28123	28123	28123	
4000 (2400)			POWER FLT	89264	89846	90428	91010	
4025 (2415)			DROP RND	28483	28483	28483	28483	
4050 (2430)			POWER FLT	90428	91010	91592	92174	
4075 (2445)			DROP RND	28843</				

TABLE 3

HYPER- TEST ROCKET PHYSICAL DATA						
ROCKET DESIGNATION	CONFIGURATION OR CONDITION	WEIGHT lbs.	C.G. FT. (FROM NOSE)	MOM I (TRANS) SLUG-FT ²	MOM I (SPIN) SLUG-FT ²	
WOX-2A WSMR TEST	AS DROPPED ¹	96.00	3.10	10.41	0.1425	
	BARE	93.75	3.03	9.786	0.1411	
	BURNT	41.45	3.183	6.68	0.0547	
	W/H DISPERSED	29.70	4.215	3.36	0.0500	
INERT DROP RND D3	AS DROPPED ¹		3.14	9.505	0.0975	
	BARE	94.3	3.12	9.0	0.0961	
CHAR ASSY 1 NASA WALLOPS TEST	AS LAUNCHED ²	93.6	3.15 APPROX	8.85	0.1418 APPROX	
	BARE	90.07	3.15	8.77	0.1365	
	BURNT	37.8	3.30 APPROX	6.54 APPROX	0.0505	
1. WITH SAFETY DEVICE, IGNITION, WOX 27A (1SD)						
2. WITH 2 STD 5" HVAR LAUNCHING LUGS						

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TABLE 4
TABLE OF TEST DROPS

No.	1964 Date	MST Time	Designation		SN	Result
			Round	Type		
1	4/21	A.M. Hour	I-1	D3	20	Normal drop 1270' short
2	4/22	A.M. Hour	I-2	D3		Normal drop 1850' short
3	4/22	0741	L-1	WOX-2A	12	Igniter pulled off. Did not fire. Low order det. at impact 2040' short
4	4/23	1035	I-3	D3		Normal drop
5	4/23	1058	L-2	WOX-2A	2	Ignition OK Whd opened Impact 2300' short
6	4/28	1005	I-4	D3A		Normal drop, smoke grenade attached and activated
7	4/28	1027	L-3	WOX-2A	7	Sim. to L-2 More impacts & whd parts recov. 594' short
8	4/30	1025	I-5	D3A		Normal drop, smoke grenade attached and activated
9	4/30	1049	L-4	WOX-2A-1	4	Sim. to L-2 but more scatter, 192' s.w.

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TABLE 5

Types of Projectile Impact Holes Located

Round	Deep Holes 8"	Medium Holes 3 to 8" deep	Surface & Nose Only to 3"	Misc. Notes
L-2	31	17	49	All deep & medium holes essentially impact ahead of missile impact center within 150' dia. Most surface to 3" deep holes were behind missile impact within 200' dia.
L-3	23	28	72	Most deep & medium holes were within 200' dia. of missile impact center. Surface to 3" are within 400' dia.
L-4	21	4	45	Most deep & medium holes are within 200' dia. Surface to 3" deep holes were scattered over 500' dia. area.

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APPENDIX A

SELECTION OF TEST SITE

A-1. Williams Bombing Range. Lt. Col. W. C. Terry, Marine Corps Air Station, Yuma, Arizona is the operations officer in charge of scheduling the western portion of this range and is familiar with the entire range area. A detailed discussion of requirements and a look at a typical range area was sufficient to eliminate this as a possible site. The area is sand or loose rock with few access roads. There would not be any helicopter services available and only limited assistance in the form of work area, transportation, and crews and equipment for target preparation. At Lt. Col. Terry's suggestion, a visit was also made to the Army's Yuma Test Station. The terrain is similar, and it was not suitable for these tests.

A-2. Naval Ordnance Test Station. Mr. Al Staud was contacted at NOTS, and he made all of the required arrangements for test site visits and coordinated the conferences with the various groups involved. Wilson Mesa, Wilson Canyon, and several up-range dry lake beds were visited. The Wilson Mesa/Wilson Canyon area is very rough and would have required an excessive amount of site preparation. It was also noted that there would be a long run for power and control lines. The only dry lake bed suitable both from a safety and an operational point of view is Airport Lake. This is up-range about 20 miles and has a 500 to 600-ft high ridge between the lake bed and the main station. The surface of the lake was dry and firm but had formed cracks about 1/4 to 1/2 inch wide. These would have had to be eliminated by rolling in order to be sure that the individual submissile impacts could be found. The usable area is 2000 to 3000 feet in diameter.

A-3. Either launch method could have been used effectively although there were some drawbacks to both. If the ground launcher was to be used, 1500 to 2000 feet of roadway would have had to be built for access to a suitable launch site. This would not have been a major problem because the terrain is not too rough or precipitous. If the helicopter was used, a rather large area of the lake would have had to be smoothed because range safety required controlling the drop by radar from the range control station. This would allow an error of several hundred feet in the release point and consequently would require a large target area. This also would require additional camera coverage to assure pictures of the impacts. On the credit side, the helicopter was available to NOTS and

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because the lake is remote, operations would seldom have been held up because of activity on other ranges. The cost of a 10 shot program using either launch method would have been about \$45,000. In NOTS' favor were the facts that they have a large variety of cameras, they could accomplish either launch method, they have a good target area, and they have suitable experience and range instrumentation. There was a good possibility of getting data; however, this site was eliminated because of the cost.

A-4. Dugway Proving Ground. A visit to Dugway showed that there was ample area for safety and that the instrumentation could be provided. The ground launch impact areas would have required a great deal of site preparation because of the rough terrain, but there were flat impact areas on the Great Salt Lake Desert suitable for use with the helicopter launch. There was no possibility of Dugway providing the necessary A/C support and this eliminated Dugway as a possible test area.

A-5. White Sands Missile Range. LCDR Robert Hatten was the operations officer for the Naval Ordnance Missile Test Facility (NOMTF) located at the range and was the contact. There are no sites on the range that can be readily used to ground launch the rocket into a flat area. There is, however, a large area where several hard, flat, unbroken target surfaces are located. The area needed some cleanup to clear a small amount of missile debris and scattered dead bushes but this would require a very small effort. The helicopter could be furnished by WSMR, and there would be work space, vehicles, range crews, and film all available at no cost. The numbers and types of suitable cameras available are somewhat limited, and it was originally planned that NOL would have to provide any expendable cameras, any infrared film, and probably the 16 mm color film. Target area preparation and bunker construction would be charged to NOL. WSMR costs were estimated to be less than \$1000 per shot. Use of WSMR would require more NOL manpower and might take longer to finish the series. It was estimated that we could get range time twice a week and might be able to get two shots each time. There could be scheduling delays because of range workload and because the project had no priority.

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APPENDIX B

OPERATION OF WOX-9A WARHEAD

B-1. Figures 33, 34 and 35 show the warhead disassembled, partially assembled, and assembled. It was intended to function as follows:

a. Darts fixed in position by having tails in slots on the aluminum base, noses held down by the spot welded bulkheads inside the fairing, with foamed plastic segments giving lateral support between the darts and fairing and around the center post.

b. Fairing slotted with .006 inch remaining wall along six longitudinal lines, with only .002 remaining in the nose section. This was calculated and tested to be capable of rupture by stagnation pressure behind the normal shock at burnout velocity.

c. The nose "bubble" with retaining ring holding the fairing nose pieces in against it contains the inertial device intended to release the bubble as soon as drag forces exceed motor thrust. Referring to Figure 31, the nose assembly is held in place by the detent fingers pushed into the groove in the rod extending from the warhead base. The detents are held by the sliding "g" weight which in turn is prevented from moving prematurely by the shear wire. Upon firing the rocket, forward acceleration of about 250 gravities occurs. The wire shears under the inertial force of the weight at 90 to 95 gravities, and the weight moves back compressing the spring. Laboratory tests showed that approximately ten pounds are required to overcome the friction in the system when the nose is loaded as in flight. This force is supplied by the spring when compressed. The intent is to get the g weight to move forward under action of the spring plus inertia as soon as deceleration of the missile starts. This releases the detents which hold the nose assembly in place.

d. When the bubble is released, high stagnation pressure at the spherical nose pushes it back into the fairing cavity along the guide rod. As this motion occurs, pressure immediately builds up inside the fairing nose piece. This is calculated to be nearly 700 psi (pitot pressure) compared to pressure of about 70 psi on the outside of the 15° half-angle cone. This difference is sufficient to bend the fairing segments outward, tearing the remaining material along the grooves. As the forward portions move out, the pressure

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inside should act on larger areas to completely strip the fairing (including the spot welded parts) away from the darts.

e. As the drag starts to exceed motor thrust at burnout the darts start to push against their restraining bulkhead attached inside to the fairing. As this bulkhead is pulled away by the aerodynamic forces, the darts should be free to separate from the base plate. Their low drag shape and high density are designed to this end.

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Security Classification

14	KEY WORDS	LINK A		LINK B		LINK C	
		ROLE	WT	ROLE	WT	ROLE	WT
	hyper hypervelocity rockets cluster warhead FREE						

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DEMONSTRATION OF THE FEASIBILITY OF A HYPER-
VELOCITY CLUSTER WARHEAD (U), by K. F. Cannon
and others. 19 Aug. 1964. v.p. illus.,
charts, tables, diagrs. BuWeps task RMO-42-
040/212-1/FO08-08-06.

CONFIDENTIAL

This report describes a field experiment conducted to study the feasibility of using only inertial and aerodynamic forces to deploy a cluster of dense, inert, low-drag submissiles into a narrow conical pattern subsequent to burnout of a high-acceleration rocket which has accelerated the warhead to a velocity in the low hypersonic region.

Abstract card is confidential.

1. Warheads - Cluster
2. Missiles, Hypervelocity
3. Warheads - Design
- I. Title
- II. Cannon, Kenneth F.
- III. Project

DOWNGRADED AT 3
YEAR INTERVALS
DECLASSIFIED
AFTER 12 YEARS
DDO DIR 5200.10