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AEROSPACE APPLICATION OF GUN LAUNCHED PROJECTILES AND ROCKETS

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by

C.H. MURPHY
G.V. BULL

Dr. Charles H. Murphy, Ballistic Research Laboratories,
Aberdeen Proving Ground, Maryland

and

Dr Gerald V. Bull, Director, Space Research Institute

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SPACE RESEARCH INSTITUTE OF McGILL UNIVERSITY

892 SHERBROOKE STREET WEST

MONTREAL 2, QUEBEC

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ABSTRACT

Project High Altitude Research Program (HARP) is directed toward the use of guns for scientific probing of the upper atmosphere. The attractive features of guns for this purpose are the basic economy of such a system and the high inherent accuracy of guns for placement at altitude as well as accuracy in ground impact. The basic liability for such an approach lies in the very high accelerations experienced by gun-launched payloads.

The guns used in Project HARP vary in size from 5-inch and 7-inch extended guns on mobile mounts to transportable fixed 16-inch guns. Altitude performance varies from 20 pound, 5-inch projectiles reaching 240,000 feet to 185 pound, 16-inch projectiles reaching 590,000 feet. Single and multiple stage rockets launched from the 16-inch gun have very promising predicted performance and are under development.

Scientific results to date are primarily wind profiles measured by radar chaff, aluminized balloons and parachutes, and tri-methyl-aluminum trails, although a number of successful 250 MHz and 1750 MHz telemetry flights have been made. Sun sensors, magnetometers, and temperature sensors have been flown and an electron density sensor was fired in early June. Development of other active sensors is continuing.

I INTRODUCTION

Since 1962, Project HARP has been engaged in developing gun launched techniques for the placement of payloads into the upper atmosphere and into near space. As gun launched missile systems have been developed, they have been applied to scientific data gathering programs and hence a considerable body of operational data exists on some of the missile configurations. In this paper, a brief review will be made of some of the principle features of the program, and some comments made as to future applications.

2. MAJOR FEATURES OF THE GUN SYSTEM

The gun barrel, in addition to acting as a first stage re-usable booster, also acts as a guidance and control system. On emergence from the barrel, the vehicle is at a high velocity on a pre-determined flight path and is not significantly affected by surface winds. Thus, vehicle dispersion (in the case where there is no in-flight rocket-boost) can be closely controlled to both a predicted point in space, as well as impact into a relatively confined area. The gun-launch system from a dispersion point of view more closely approaches anti-aircraft gun fire than conventional rocket launches. In addition to the lower dispersion of a gun system compared to an unguided rocket, the re-usable booster characteristic of the gun barrel can lead to significant cost advantage over rocket systems.

The gun-launch technique takes on two different tasks in the HARP program. It may act simply as the first stage of a multi-stage rocket system with subsequent trajectory characteristics controlled by the performance and selected ignition times of the rocket stages, or may be the sole propulsive force applied to the vehicle. When it acts as the sole boosting stage, it then becomes necessary to achieve a ballistic coefficient larger than that of a conventional shell, and at the same time, double the muzzle velocity of conventional guns.[1,2] The relation between launch ballistic coefficient, muzzle velocity and apogee is shown here in Figure 1. It may be noted from this figure that below a ballistic coefficient of 2000 pounds per square foot, apogee is controlled largely by the ballistic coefficient, while beyond this, apogee is controlled largely by muzzle velocity.

Thus in order to glide to apogees of interest, it is necessary to use sabot-launched, sub-caliber vehicles, where the vehicle launch ballistic coefficient can be kept large, while the all-up shot weight can be kept small. Figure 2 shows an array of 5", 7" and 16" non-rocket assisted vehicles developed and used in the HARP program. On the left side of the Figure, the 16", Martlet 2C missile is shown in its pusher type sabot. This vehicle/sabot combination has an overall weight of a nominal 400 pounds, and has been launched at velocities over 7000 feet per second. The pusher plate converts the gun pressure to a total thrust on the vehicle, while the wooden petal arms keep the vehicle aligned during bore travel. In this system the missile is completely protected from gun gas during launch, but at a considerable penalty in vehicle weight. In the Martlet 2C system, the sabot weight is about 10% greater than the vehicle weight. A somewhat larger proportion of missile weight is required for structural loading in this case than in the center-sabot missiles shown in the rest of Figure 2. The BRL 5" missile was the first developed in the HARP series, and was followed by the 7" and Martlet 2G scale ups. In this case the sabot is only 10 to 20% the weight of the missile, so that considerably larger payloads can be flown to comparable altitudes (e.g. compare the 2C and 2G missiles in Figure 2). One possible disadvantage of the system for some applications is the fact that the sabot supports the vehicle near its center of gravity and lets the after body trail in the gun gases.

In order to achieve optimum gun performance with these lightweight shots, it is necessary to increase the barrel length to between 75 to 100 calibers (approximately double the normal barrel length) and to tailor a suitable propellant web. The muzzle velocity is further increased as much as 200 feet per second by sealing the muzzle with a thin plastic sheet and evacuating the barrel of air. The current peak performance for HARP guns is given in the following table. Th Martlet 2G missile, weighing 235 pounds is currently undergoing flight tests and should have the same peak altitude as the 185 lb. Martlet 2C currently in operation.

PEAK CURRENT PERFORMANCE FOR HARP GUNS

Gun	Gun Length	In gun Weight	Flight Weight	Muzzle Velocity	Apogee
175 mm	34'	130 lbs	130 lbs	3150 ft/sec	81,000
5"	33'	25 lbs	20 lbs	5200 ft/sec	240,000
7"	50'	75 lbs	60 lbs	5400 ft/sec	300,000
7"	50'	47 lbs	27 lbs	5800 ft/sec	330,000
16"	119'	410 lbs	185 lbs	7100 ft/sec	590,000

Vehicles are subjected to acceleration loads that decrease in inverse ratio to the gun size (i.e., doubling the barrel diameter halves the peak g load). For the 7-inch gun, peak accelerations are in the 35,000 g range, for the light shot weights, while equivalent accelerations in the 16-inch gun are of the order of 15,000 g's. For the large rocket systems under development for the 16-inch gun, peak accelerations are in the 5,000 g range. A natural handicap of high-g gun launch is the special development of telemetry units and sophisticated sensors. The work to date indicates that this liability can be overcome in a number of applications.[3-5]

3. FIVE-INCH SYSTEM

3.1 GUN-PROJECTILE PROPERTIES

The first HARP vertical firings were made in June 1961 from the Edgewood peninsula, 10 miles outside of the Baltimore city limit. These flights were made with a smoothbored 120 mm T-123 barrel and a center-sabot stabilized vehicle. The vehicles were constructed from excess parts of a defunct developmental missile. This non-optimum design reached an altitude of 130,000 feet and chaff was deployed[6].

The next year, a 10-foot extension was added to the gun and an optimum design for the vehicle established. The present gun is shown on the right of Figure 3 and the 5-inch missile is shown in Figure 2. The 45-inch long missile (HARP 5.1) weighs 20 pounds with a 5-pound center sabot. The maximum body diameter is 2.6 inches and the fins are slightly smaller than the bore diameter. The center sabot consists of a four-piece aluminum section backed up by plastic quarters. The aluminum parts are locked to the missile by buttress threads and the plastic quarters seal the gun tube and supply most of the bore riding surface. The plastic part of the sabot is made slightly oversize and the projectile-sabot combination is rammed into the tube by a hydraulic jack.

A 35-pound triple web mixture of M-17 is normally used and breech pressures range from 55,000 psi to 62,000 psi. Projectiles reach muzzle velocities of 5100-5200 ft/sec and apogees of 220-240,000 feet[7,8]. Early in the program, a significant number of apparently undamaged rounds flew to heights less than 100,000 feet, probably due to some aerodynamic difficulties. When the fins were beveled 3 degrees to induce spin, the missiles became most reliable and impact circle radii of less than one mile were routinely observed.

3.2 PAYLOADS

The first payloads flown were radar chaff and aluminized parachutes. These are tracked by radar to give winds between 200,000 feet and 80,000 feet. Figure 4 is a sample radar plot for an aluminized six-foot square parachute flown over Barbados in January 1966[25].

An acoustic source payload[9] consisting of a 180-gm charge has been developed by the Atmospheric Sciences Laboratory at White Sands Missile Range and a high-g temperature sensor for use with 250 MHz transmitter and parachute deployment is under development. 1680 MHz transmitters are also under development. Over 125 observations of winds have been made by 5-inch HARP projectiles at various locations and these are being published in the Meteorological Rocket Network[10] (MRN) Data Reports*. In addition to meteorological measurements, telemetry payloads with accelerometers and sun sensors have been successfully flown to measure missile dynamics.[11]

3.3 SITES

The first vertical firings of the 5-inch HARP gun were made on the Edgewood peninsula of the Aberdeen Proving Ground. Most of the later

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* The first report to contain this data is Volume XLVIII for August 1965.

developmental work has taken place at National Aeronautics and Space Administration (NASA) Wallops Island, Virginia facility where excellent radars are available which can skin track all projectiles to apogee. During the final stages of development, a second gun was located at White Sands Missile Range, New Mexico to initiate the MRN wind measurement program. When development of the vehicle and parac[illegible]e ejection package was complete, two more guns were deployed to the H[illegible]P Barbados range and U.S. Army's test facility at Fort Greeley, Alaska.

In mid-1966, a 5-inch system was installed adjacent to the Yuma 16-inch gun, and in early 1967, a similar installation was completed at Highwater, Quebec. All of these sites are engaged in regular meteorological soundings, some 300 flights having been made to date.

3.4 BALLOON ALTITUDE MEASUREMENTS FROM RIFLED TUBES

The primary meteorological data required by the field Army are current winds and temperatures up to 100,000 feet. Although balloons can obtain this data, balloons require moderate ground winds for launching, take over an hour to reach altitude, and can only sample points downwind of the launch point. As a result of the success of the 5-inch HARP gun, the use of presently available rifled tubes for meteorological sounding was suggested. A feasibility test of this concept was made with a standard 177 mm rifled tube mounted on an 8-inch mount[12]. A 3-foot square aluminized parachute with ejection fuze was placed in a standard shell and four shots fired at Wallops Island. Flights to between 79,000 feet and 81 000 feet were made and all parachutes were successfully tracked to provide wind data.

4. SEVEN-INCH SYSTEM

4.1 GUN-PROJECTILE PROPERTIES

The 7-inch system is essentially a scaled up version of the 5-inch system with three times the payload and an altitude capacity of 350,000 feet. The modern 175 mm M113 gun was smoothbored, extended by 26 feet[13], and placed in a modified T-76 mount*. (The extended 7-inch gun is on the left in Figure 3.) The basic vehicle (HARP 7.1) is 64-inches long, has a 3.6-inch diameter and weighs 60 pounds.

The 7-inch vehicle plastic sabot is also made oversize and must be forced into the gun by a hydraulic jack. The charge is M17 bagged .114 web powder weighing up to 110 pounds. With this charge and a gun pressure of 56,000 psi, a muzzle velocity of 5400 feet per second and apogee of 300,000 feet has been obtained for the 60-pound missile.

A smaller higher performance missile (HARP 7.2) is under development to reach 400,000 feet with a much smaller payload. This missile is 55-inches long, has a diameter of 3 inches and weighs 40 pounds. A preliminary version of this missile weighing 27 pounds has been placed at 330,000 feet.

4.2 PAYLOADS

The usual wind sensor, chaff and aluminized parachutes have been successfully ejected from 7-inch missiles with particular interest

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* Since there are only two T-76 mounts available, the 8-inch gun field mount has been modified for use with this system. [14]

associated with the ability of high altitude chaff to measure winds above 210,000 feet. The available payload volumes of over 125 cubic inches allows the use of chemical payloads of the type flown in Project Firefly[15]. A 10 to 12-pound mixture of cesium nitrate and high explosive is being developed for the generation of electrons at 330,000 feet. This payload has already been successfully deployed from a 16-inch missile and created an observable cloud of electrons over Barbados in late 1965.

The ability of this vehicle to reach through the D layer into the lower E layer of the ionosphere has lead to the development of a Langmuir probe with associated telemetry to make direct measurements of electron density. Early versions of this device have been successfully flown from both the 7-inch gun and the 16-inch gun.

4.3 GUN-BOOSTED ROCKETS

The use of gun-boosted rockets should retain the accuracy and economy of a gun system and provide markedly increased payload and altitude capability. The accuracy advantage of a gun over an unguided rocket is based on the gun's high launch velocity and this advantage would also apply to a gun-boosted rocket. If we consider the gun-boosted rocket to be a two-stage system with a reusable first stage, a significant economy should be realizable. For these reasons, a full bore 7-inch rocket is under development as part of the HARP program.

The current concept for this development is a 125-pound full bore, fiber glass case, solid propellant rocket with pop-out fins which can be launched at muzzle velocities exceeding 4000 feet per second.

This rocket should be able to exceed 500,000 feet with a 20-pound payload for a very modest cost. Full bore rocket grains in fiber glass cases have been successfully launched at 10,000 g's from a 6-inch gun. These are being scaled up to the 7-inch system and the pop-out fins are being flight tested.

5. SIXTEEN-INCH SYSTEM

5.1 GUN-PROJECTILE PROPERTIES

Late in 1962, McGill University obtained two U.S. Navy surplus 16-inch barrels and one complete mount. These barrels were smoothbored in the Spring of 1962 and transported to Barbados, West Indies in the summer by the U.S. Army Transportation Corps on the B.D.L. LTC John D. Page. These two 140-ton barrels with 90 tons of mount parts were landed on the beach at Foul Bay and railroaded overland 2.2 miles to the current launch site. In January 1963, the first vertical firings were made to proof test the gun installation. In June 1963, a 185-pound projectile was fired to 340,000 feet.[16] A 51-foot muzzle extension was attached in March 1964 and a 185-pound projectile was fired to 430,000 feet.[17] With sabot and powder modifications and bore evacuation, the peak altitude was increased to 468,000 feet in November 1966.

The current Barbados 16-inch gun is shown in Figure 5. To stiffen this 119 foot 5-inch long barrel, 30 tons of 1-1/2-inch thick longitudinal steel gussets and 2-inch thick radial webs were welded in place. Eight tie rods were also added to reduce droop to acceptable limits in the elevated position. The stiffened extended barrel has a total weight of approximately 200 tons and can be elevated to 85 degrees in less than 8 minutes.

The 16-inch projectile (Martlet 2C) is a 54-inch long fin-stabilized missile with a maximum body diameter of 5.4 inches and weighing 185 pounds. Its four fins have a total span of 11.4 inches and are canted

1/4 degree to produce a slow roll (shown in Figure 2). The missile is held in the gun by a 225-pound base pusher sabot consisting of an aluminum and steel base with four wooden 28-inch long arms. This sabot is also made over-size and must be forced into the gun by a hydraulic jack. A more efficient, but more sophisticated center sabot missile similar to the 5 and 7-inch missiles is under development as well as base pusher saboted vehicles with greater payload capacities.

Gun ballistic performance is shown in Figure 6 where multi-point ignition is used to ensure proper burning. The gun bore is evaluated for high velocity firings.

5.2 PAYLOADS

The usual ejection payloads of chaff and aluminized parachutes have been flown from the 16-inch gun but all of these flights were limited to a maximum apogee of 250,000 to 300,000 feet for proper deployment, thus these payloads can, in most cases, be launched from smaller caliber guns. The placement of chemical payloads[15] above 330,000 feet is, however, a 16-inch gun mission. Liquid tri-methyl-aluminum has been used to produce luminous nighttime trails from 300,000 to 460,000 feet to measure ionospheric winds and a cesium compound has been exploded at 330,000 feet to produce an artificial cloud of electrons which was observed by a ground-based ionosonde for over 15 minutes.

Active payloads using both 250 MHz and 1750 MHz telemetry have been carried on a number of 16-inch flights. Onboard sensors have included magnetometers, sun sensors, pressure gages, and Langmuir probes. Although most of these devices have functioned successfully, they must still be considered as under development. Two Langmuir probe flights made direct measurements of electron densities in June 1965 and will be described in more detail later.

Approximately 150 flights have been made from the Barbados range with the Martlet 2C missile, along with some 30 from the Yuma Proving Ground launcher. A considerable compilation of ionospheric wind shear data has been made to date, on the basis of high flight densities over specific one-night periods.

5.3 GUN BOOSTED ROCKETS

The potential of gun boosted rockets launched from 16" gun systems was studied in ref. 26. Two basic systems emerged:

The Martlet 2G-1 which is essentially a scale-up of the probes shown in Figure 2, so that a significant rocket payload can be carried inside the heavy steel case.

and The Martlet 4, which is essentially a full-bore multi-stage rocket.

Figure 7 taken from reference 16 shows the high-altitude probing potential of these systems, while Figure 8 shows the estimated orbital capability.

The Martlet 2G-1 is shown alongside a Martlet 2C in Figure 9, and a typical re-entry mission is shown in Figure 10. A smear photograph of the first launching of the 2G-1 airframe at Highwater, Quebec is shown in Figure 11. The 2G-1 is the simplest high performance flight vehicle under development for 16" gun launchings. Total flight cost currently estimated (based on first prototypes) is between $10,000 and $20,000.

The full-bore multi-stage Martlet and rocket mission profile is shown in Figure 12. This system represents the optimum making of guns and rocketry in terms of payload to given altitudes or orbits.

The development of both these high performance systems has only represented a small portion of total HARP resources, and consequently are not completed. The 2G-1 system is furthest along, and conceivably could be operational within two years. All aspects of this system have been proven as far as feasibility is concerned, and missile hardware is being assembled for first rocket ignition test flights from the Barbados range in the next few months.

The Martlet 4 system is considerably further from completion. To date the guidance and control package has been developed and gun tested on horizontal recovery ranges. The large first stage booster has been successfully launched, and some work is underway on the liquid upper stages. More detailed accounts of these developments may be found in references 27 and 28.

6. HARP RANGES

6.1 BARBADOS RANGE (57.5° W; 13.1° N)

The Barbados range combines the advantage of a tropic location with the advantages of very long flights over water and nearness of various Eastern Test Range facilities. Its major disadvantage is remoteness from the industrial centers of North America.

The 16-inch gun* is located near the East end of the main runway for Seawell Airfield and fires on an azimuth of 119 degrees (Figure 12). On the cliff behind the gun, there are four camera locations (East Fastax, Rear Smear, Side Smear, and West Fastax) and in front of the gun on a 50-foot tower a fifth location (Front Smear). Two thousand feet behind the gun are located the radar (M33 and MPS-19) and a telemetry receiving station (Figures 13 and 14). The MPS-19 can skin-track the Martlet 2 to 350,000 feet and the 5-inch projectile all the way, while the M33 is used for area surveillance. Almost 2 miles down the coast is the Range headquarters at Paragon House. This building houses the Launch Control Center, radio communications center, another telemetry receiving station, machine shop, and other supporting administrative activities. In view of the gun-runway location, all flights are cleared with the Seawell Control tower in addition to advising the Eastern Test Range (Cape Kennedy) as to firing schedule and results.

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* The 5-inch gun is located directly in front of the 16-inch gun and fires on the same azimuth.

For proper coverage of the nighttime TMA trails, K-24 camera stations are operated on the islands of St. Vincent, Grenada, and Tobago, as well as on Barbados itself (Figure 15). All photographic stations are in radio communication with the HARP Launch Control Center. When they are available, additional radar support is supplied by the Eastern Test Range's radar on Trinidad as well as the ETR radar ship Twin Falls. The Trinidad radar has no difficulty in skin-tracking both the Martlet 2 and the 5-inch projectile from a range of over 200 miles.

6.2 HIGHWATER RANGE (73° 31' W; 45° 2' N)

The Highwater Range is located in the Province of Quebec about 2 miles north of the Vermont border in the Green Mountains. It is in a natural valley which allows a restricted line of fire to the southwest. The range has been designed for large rocket flights with earth butts bulldozed at regular distances to destroy the vehicle should it deviate from the normal flight path which passes through a series of concrete tunnels. The natural valley also contributes to the overall safety of the range. Impact butts are located at 500 feet and 3000 feet (Stages 1 and 2) and a third butt can be located further down range to allow a flight of 10,000 feet (Stage 3). The particular impact point can be selected by adjusting the gun elevation.

A 5-inch gun installation is located beside the 16-inch gun and flies regular meteorological soundings to altitudes of 70 km.

7. TWO HARP EXPERIMENTS

7.1 D-LAYER ELECTRON DENSITY

The most sophisticated HARP experiment that has been carried out is the measurement of electron densities and temperatures by means of Langmuir probes[23]. The basic Langmuir payload has been hardened to 30,000 g's for launch from both the 7-inch gun as well as the 16-inch gun. (Figure 16 shows the probe packaged for the Martlet 2.) The first successful flight of this probe was made in June of 1965 from the Barbados gun, using 1750 MHz telemetry (Figure 17). A number of additional flights of the Langmuir probe are planned for both guns in the summer of 1966.

7.2 IONOSPHERIC WINDS

The most detailed HARP experiment has been the measurement of ionospheric winds[24] by means of luminous TMA trails released from a Martlet 2((Figure 18). The luminous trail which can be seen for over 200 miles and persists for over 15 minutes is photographed by the K-24 camera stations (Figure 19). The resulting photograph can be analyzed to yield wind profiles from 90 to 140 km (Figure 20). Records are concurrently taken by a ground-based ionosonde and correlations between location of sporadic E layers and high EW wind shear layers are studied. Fifty trails have been successfully photographed over Barbados and more are planned both at Barbados and at Yuma. With these synoptic studies in progress, an understanding of air circulation above 90 km and its effect on weather and communications seems to be realizable. The rapid variation of ionospheric wind throughout a night can be graphically shown by contour plots based on six HARP trails made in September 1965 (Figures 21 and 22).

8. SUMMARY

a. HARP gun-launched projectiles have reached an operational condition of routine synoptic sounding to 140 km at low unit costs.

b. HARP full-bore gun-launched rockets promise much greater performance but retain the economy of the gun system.

c. Full-bore multi-stage gun-boosted rockets have tremendous performance potentialities and the key problem areas of the rocket motor and attitude control units are under intensive study.

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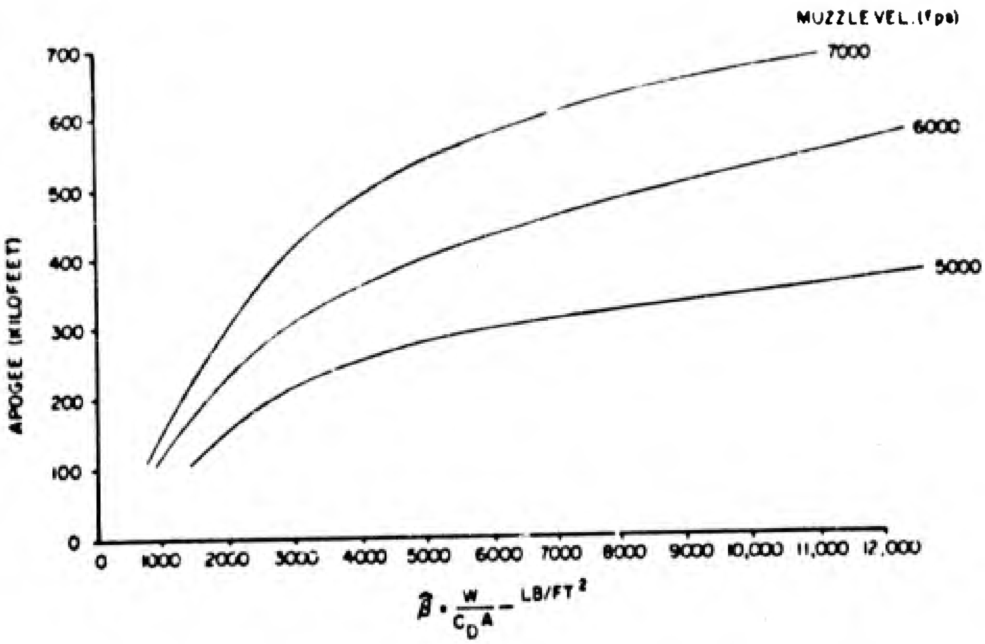


FIGURE 1
APOGEE AS A FUNCTION OF BALLISTIC
COEFFICIENT AND MUZZLE VELOCITY

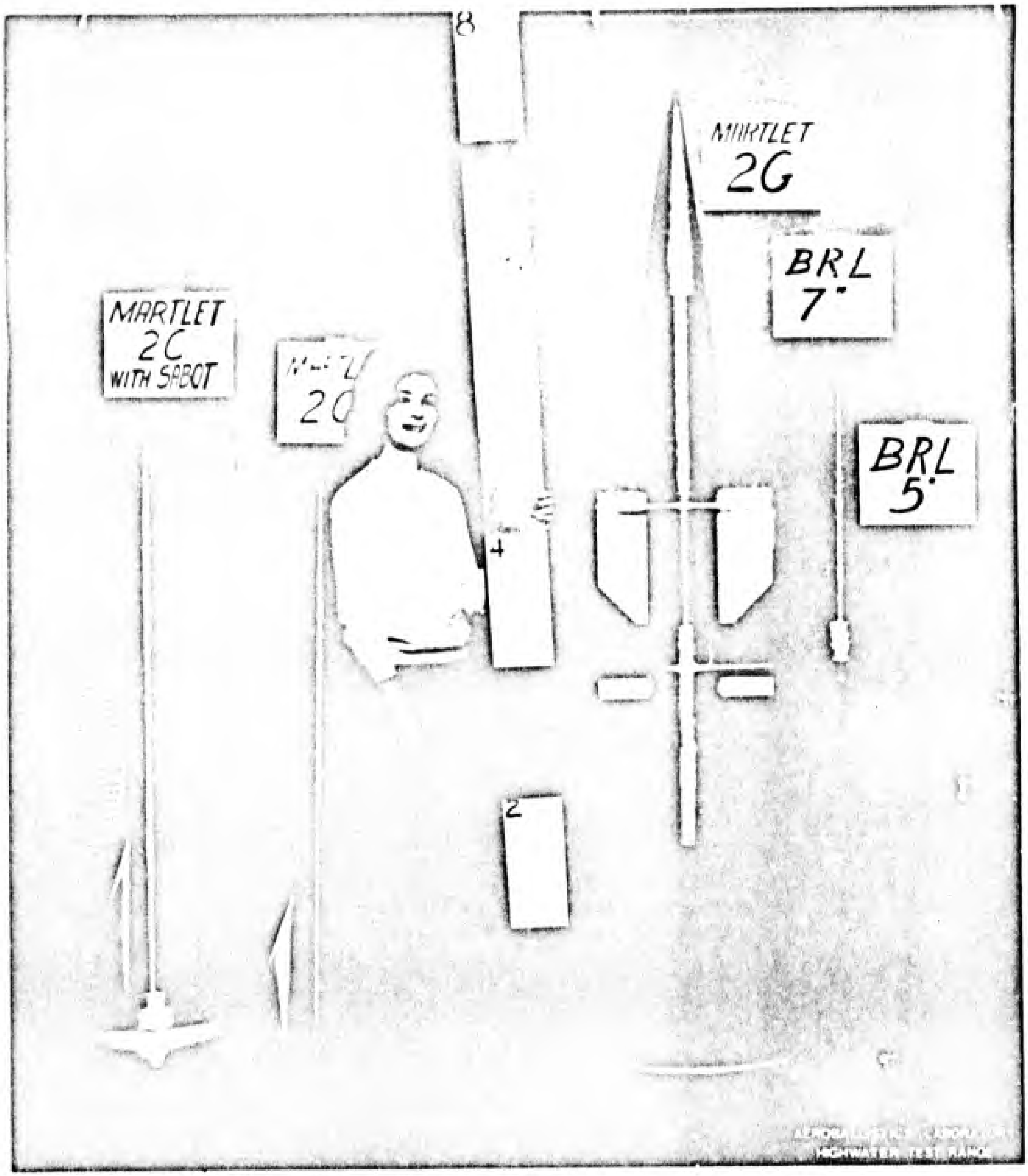
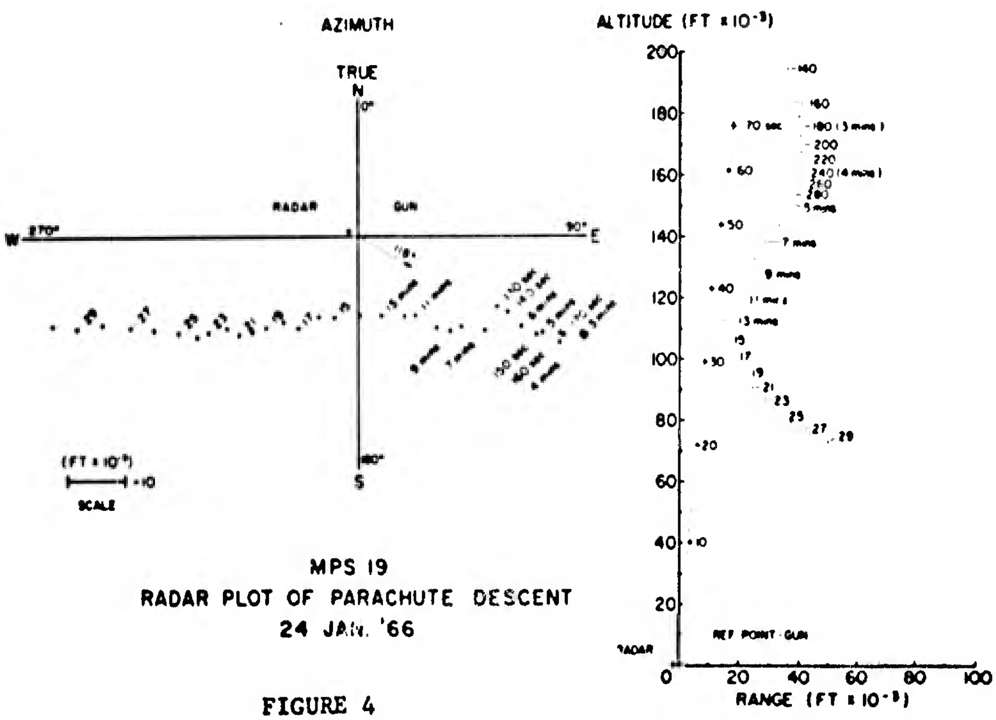


FIGURE 2
ARRAY OF HARP VEHICLES FOR THE 5-INCH
7-INCH AND 16-INCH GUNS

FIGURE 3
5-INCH AND 7-INCH EXTENDED SMOOTHBORE
GUNS AT WALLOPS ISLAND, VA.



MPS 19
RADAR PLOT OF PARACHUTE DESCENT
24 JAN. '66

FIGURE 4

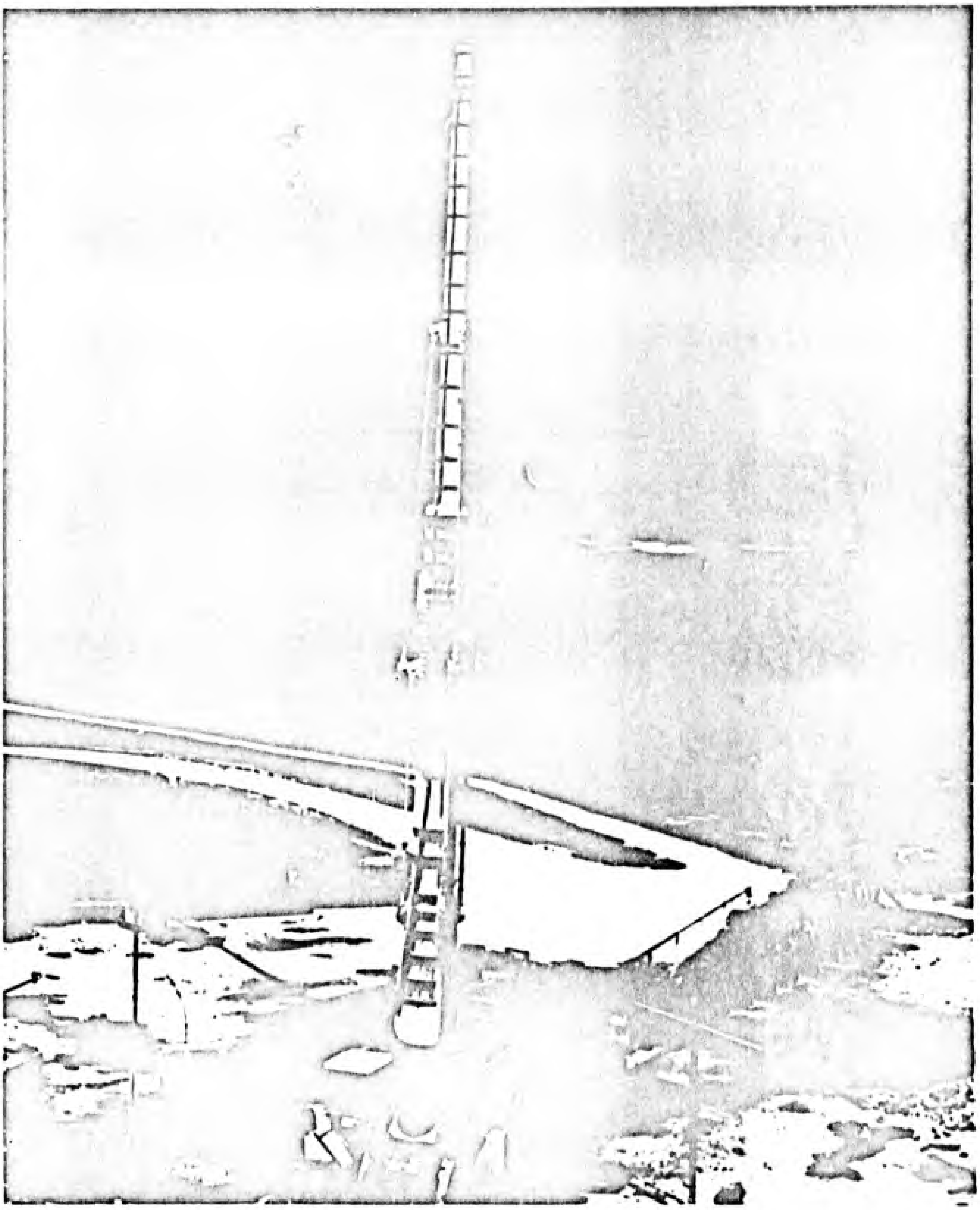


FIGURE 5
16-INCH EXTENDED SMOOTHBORE GUN AT
BARBADOS, W.I.

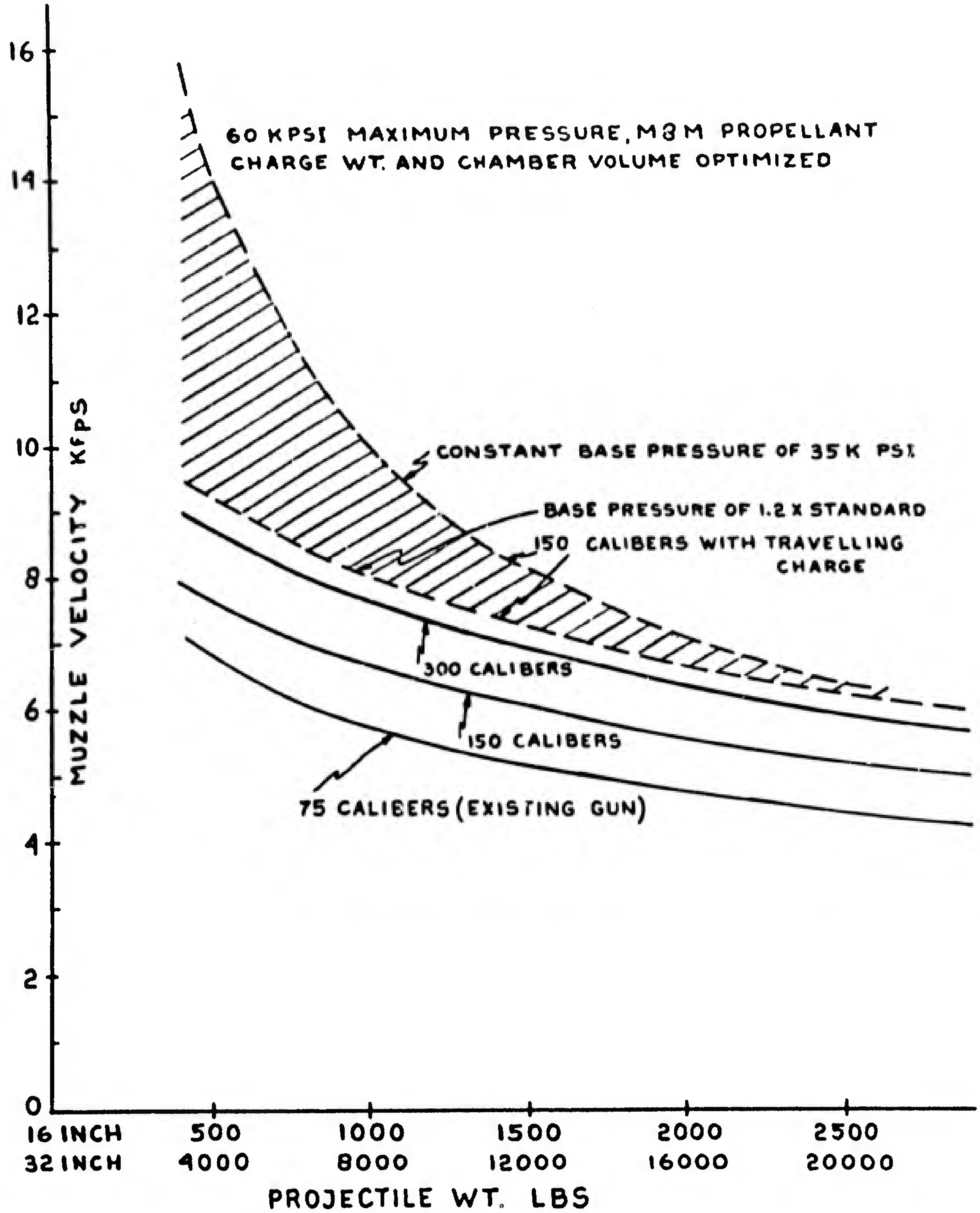


FIGURE 6
BALLISTIC PERFORMANCE OF 16-INCH SMOOTH-BORE GUN

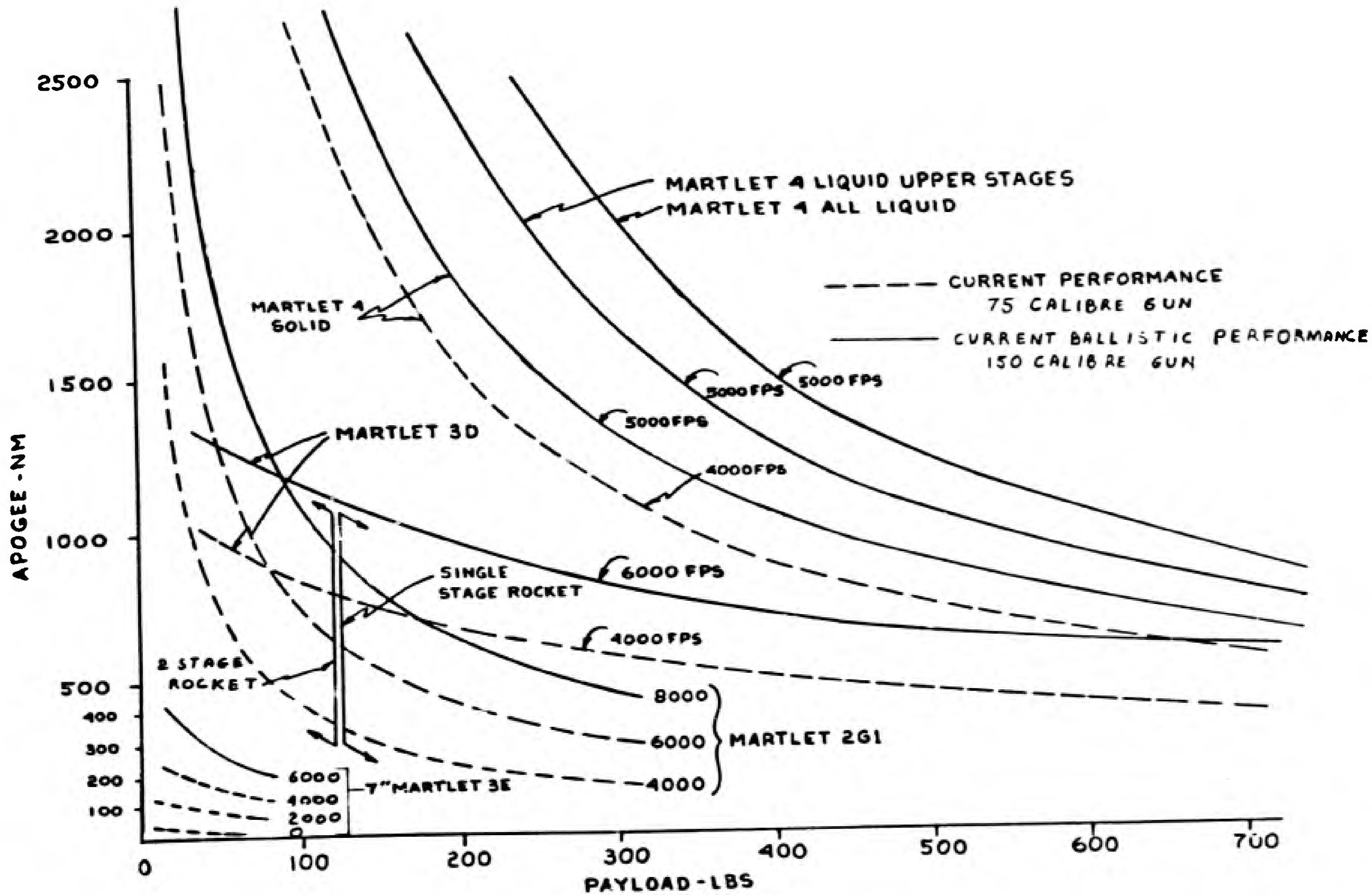


FIGURE 7
PAYLOAD CAPABILITIES OF HIGH ALTITUDE PROBES (REFERENCE 26)

FIGURE 8
MARTLET 4 PAYLOAD CAPABILITY 16-INCH GUN (REFERENCE 26)
(PAYLOAD INCLUDES ATTITUDE CONTROL MODULE)

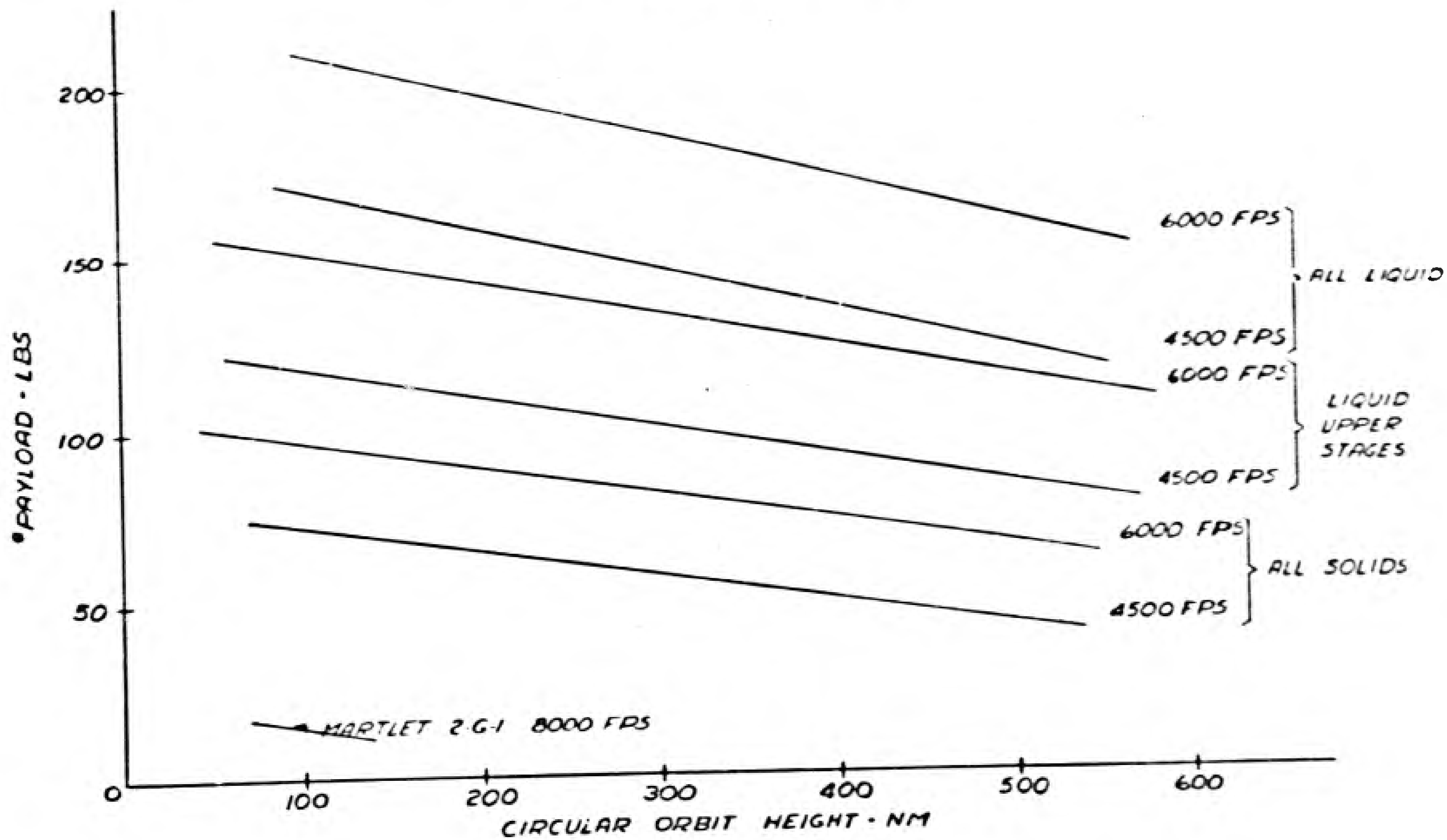


FIGURE 9
MARTLET 2G-1 AND 2C VEHICLES AT
HIGHWATER, QUEBEC

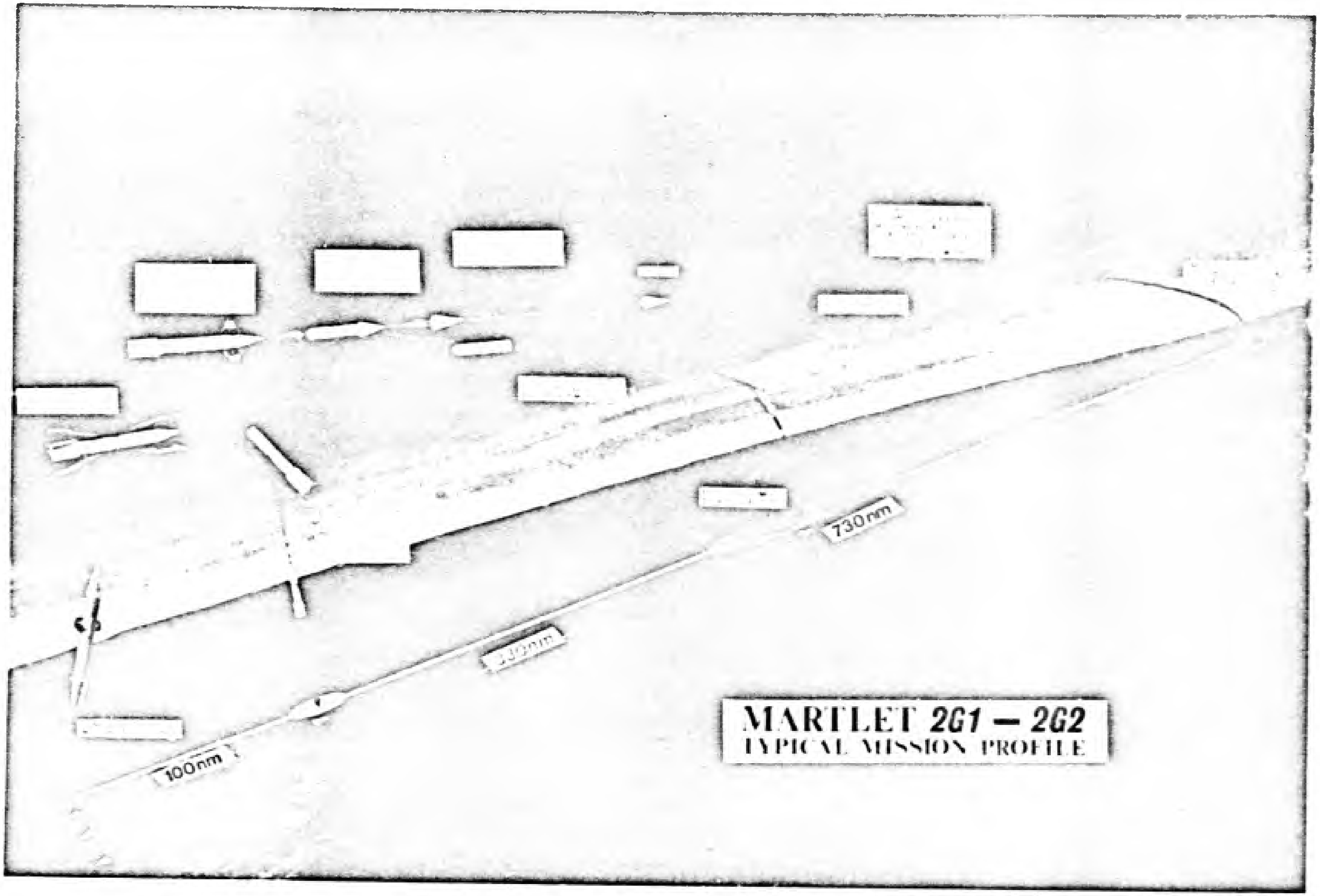


FIGURE 10
RE-ENTRY MISSION MARTLET 2G1-2G2

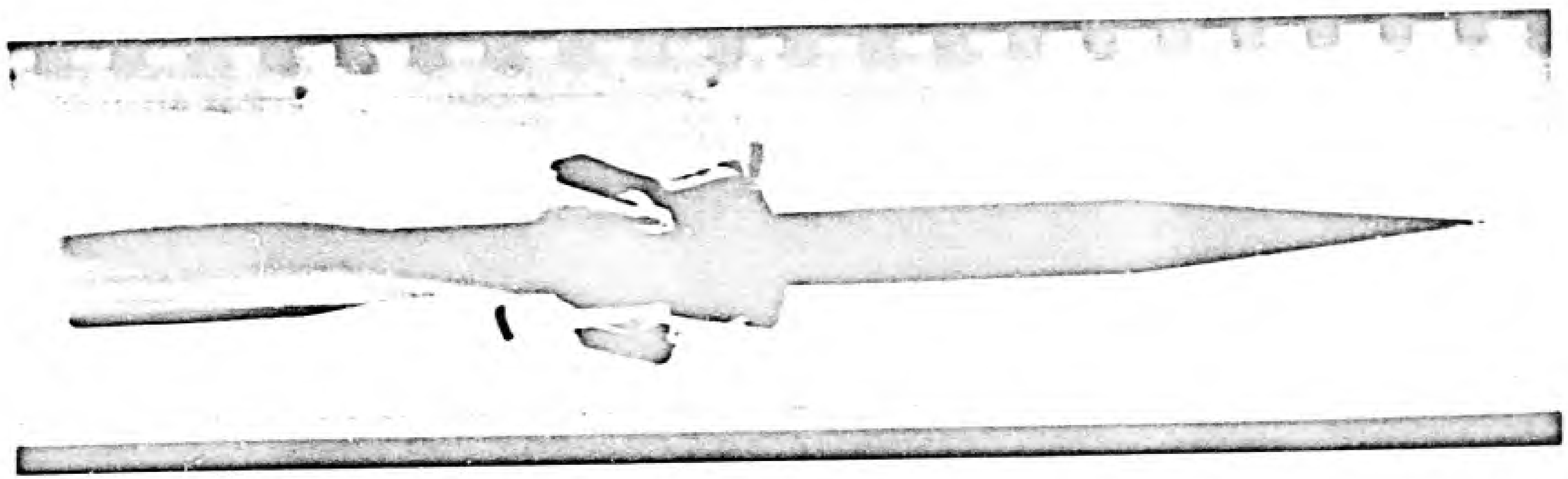


FIGURE 11
SMEAR PHOTOGRAPH OF 2G-1 MISSILE
LAUNCHED AT HIGHWATER, QUEBEC
JANUARY 31, 1967

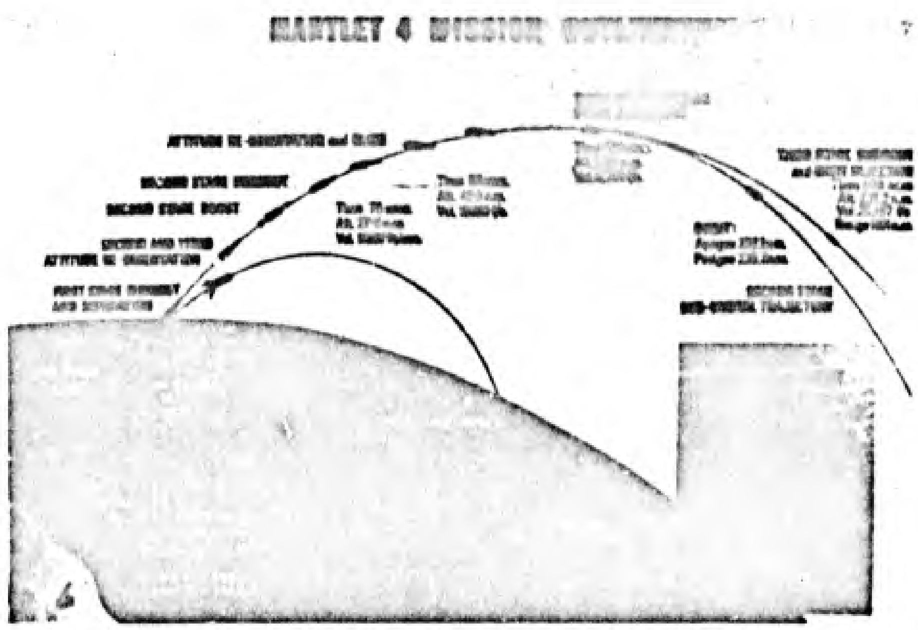
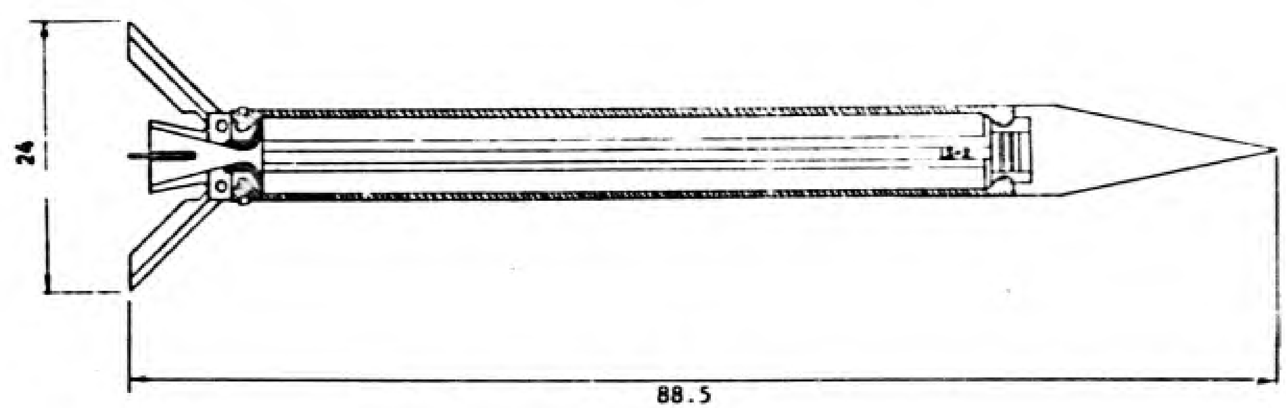


FIGURE 12
MARTLET 4 MISSION OUTLINE

Details - Typical

Total Wt.	145 lbs.
Payload Wt.	10 lbs.
Fuel Wt.	94 lbs.
Specific Impulse	280 sec.
Ignition Delay	15 sec.
Burn Time	8 sec.
Muzzle Velocity	4000 fps.
Elevation Angle	85^{o}
Apogee	250 NM



7 INCH MARTLET 3E FIBERGLASS

FIGURE 15

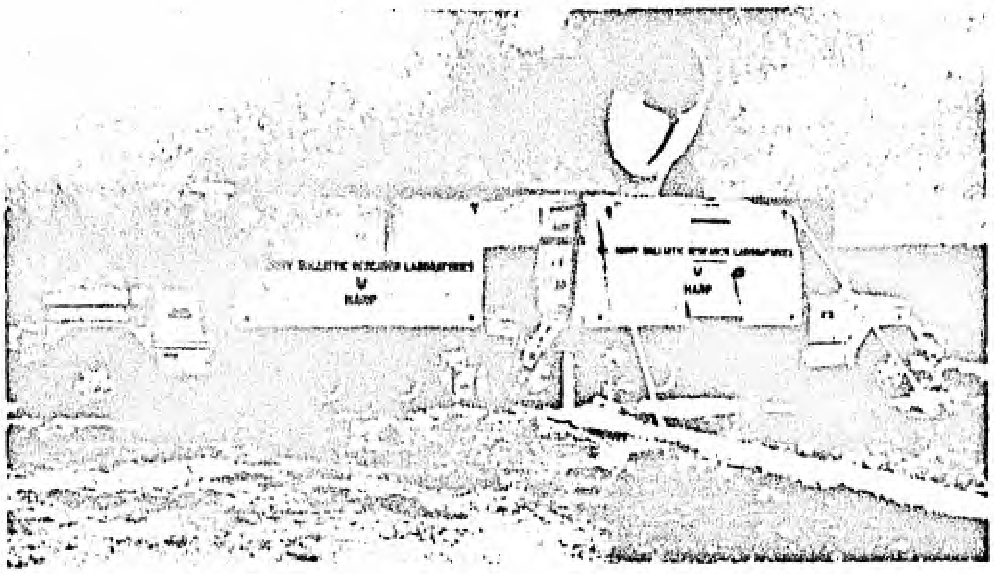


Fig. 13 HARP-Barbados MPS-19 radar.

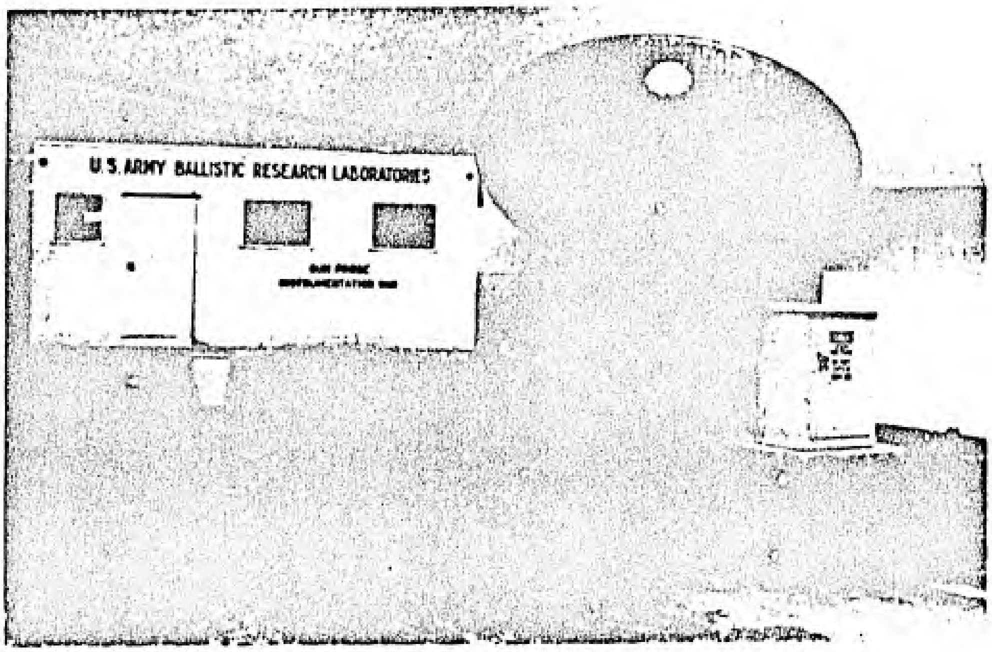
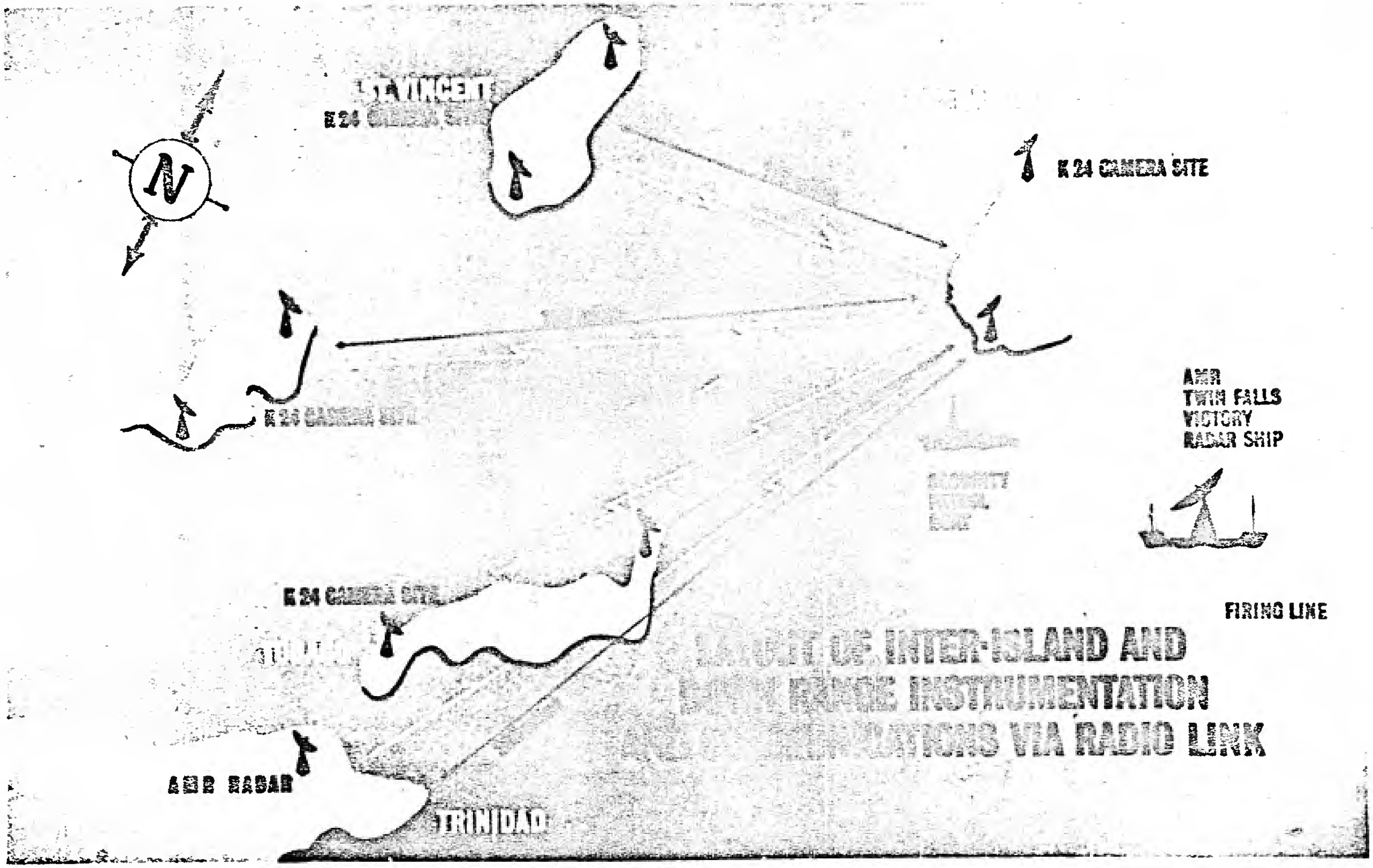


Fig. 14 1750 MHz receiving station and tracking antenna (modified GMD-1).



ST. VINCENT
K 24 CAMERA SITE
K 24 CAMERA SITE
AMR
TWIN FALLS
VICTORY
RADAR SHIP
FIRING LINE
INTER-ISLAND AND
INSTRUMENTATION
VIA RADIO LINK
AMR RADAR
TRINIDAD

FIGURE 15

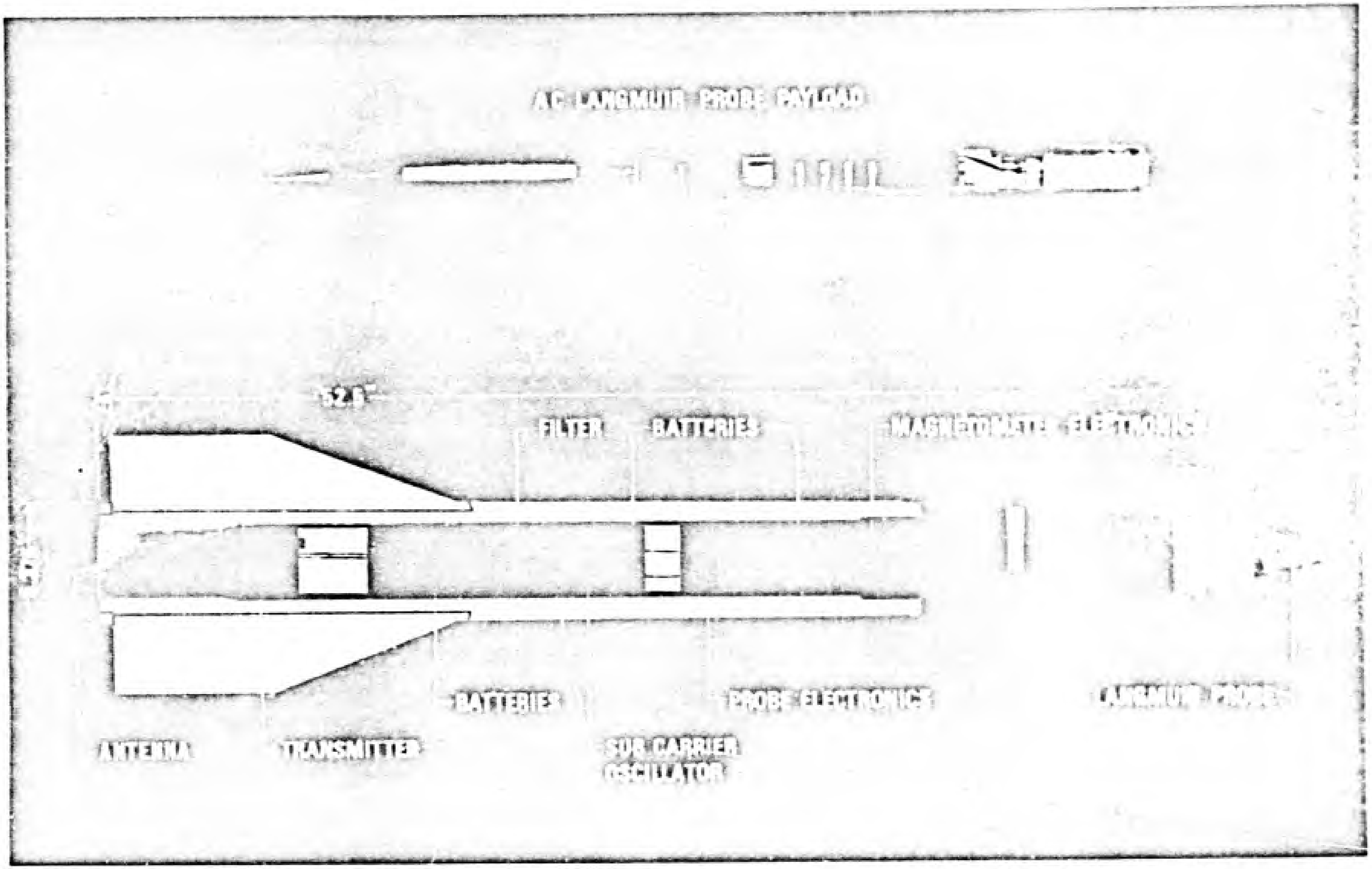


FIGURE 16
MARTLET 2C LANGMUIR PROBE VEHICLE

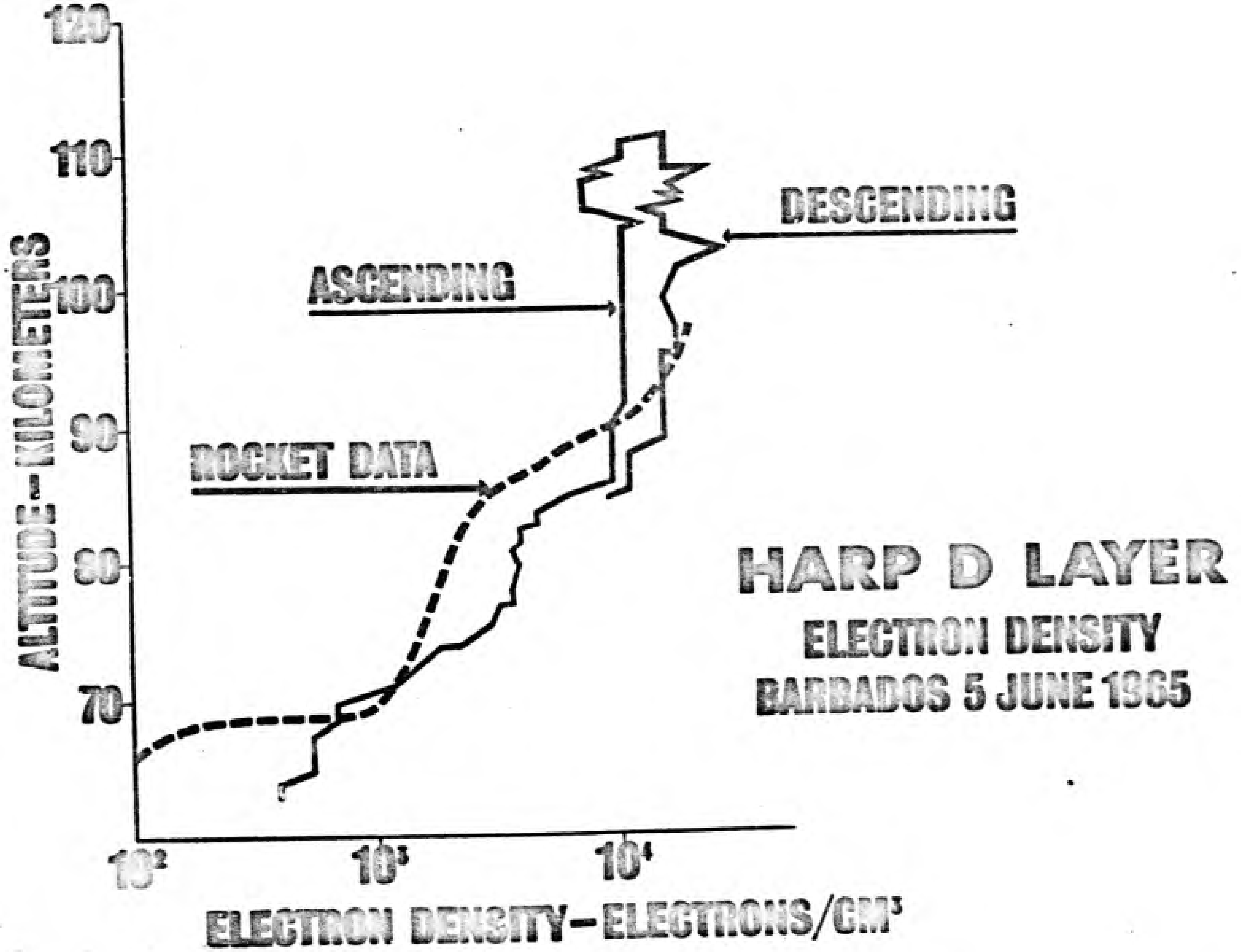

HARP D LAYER
ELECTRON DENSITY
BARBADOS 5 JUNE 1965
DESCENDING
ASCENDING
ROCKET DATA
ALTITUDE-KILOMETERS
120
110
100
90
80
70
10^2
10^3
10^4
ELECTRON DENSITY-ELECTRONS/CM^3

FIGURE 17

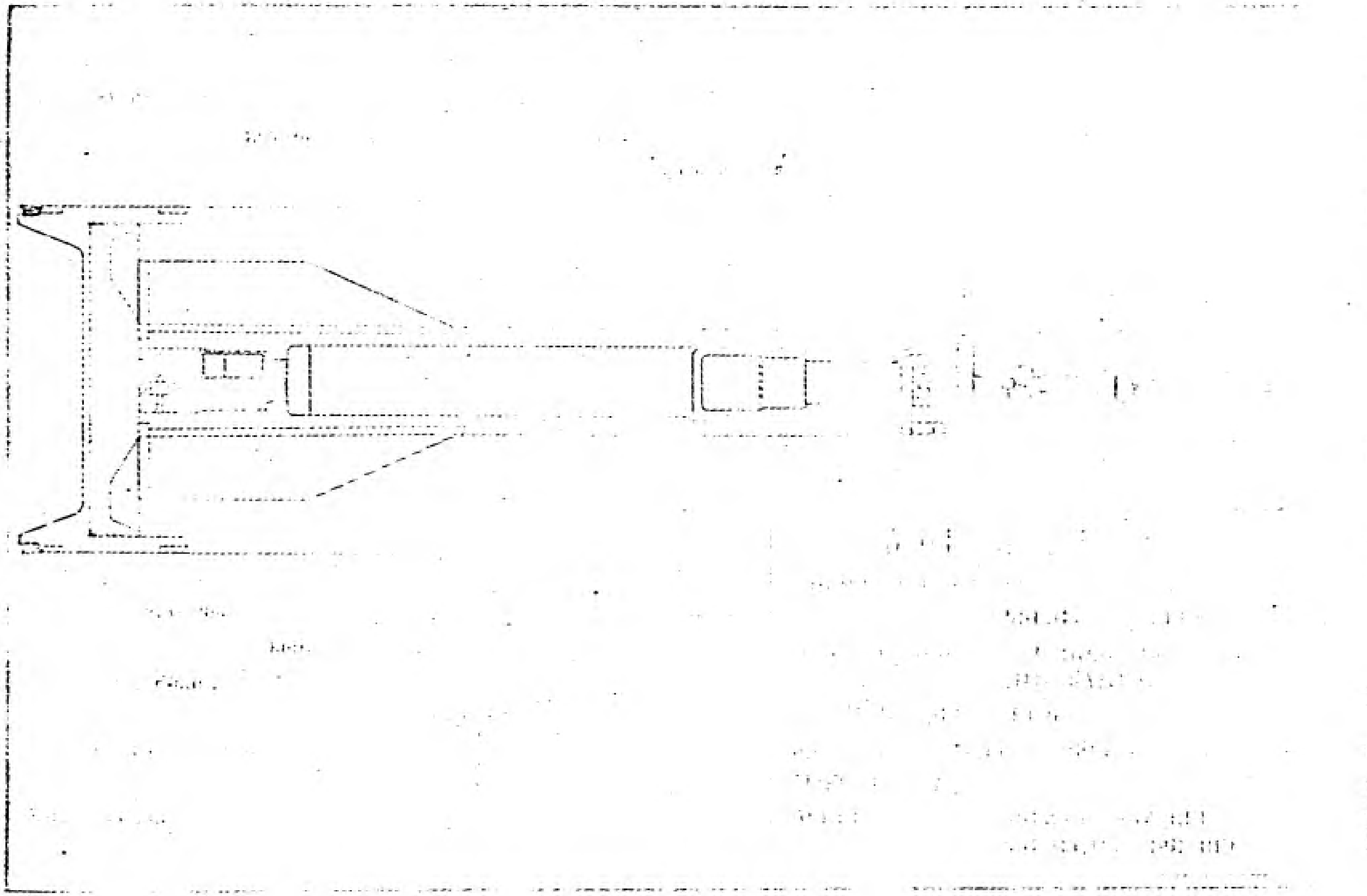


FIGURE 18

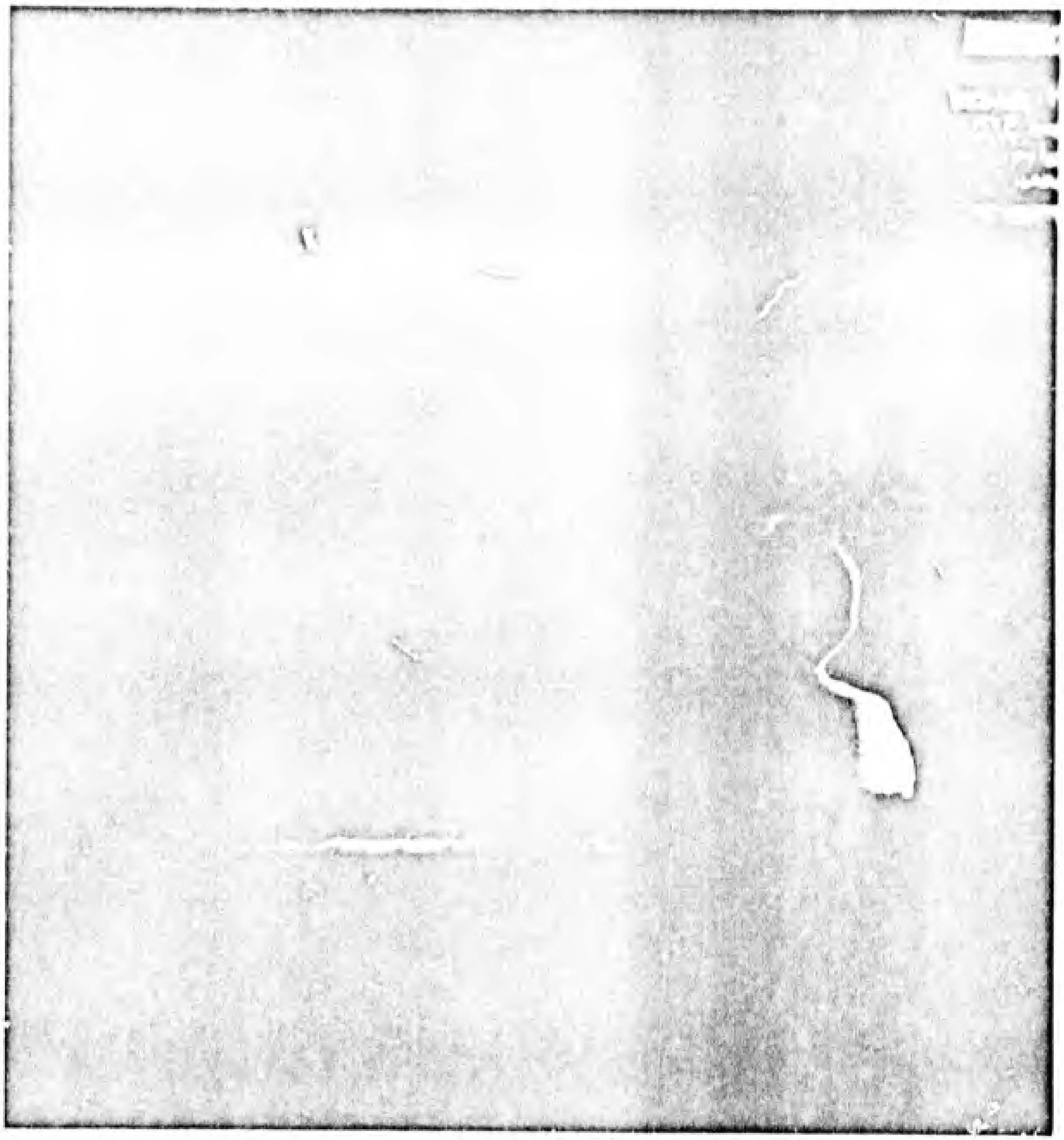


FIGURE 19
TMA TRAIL OVER BARBADOS W.I.

WIND COMPONENTS VERSUS ALTITUDE

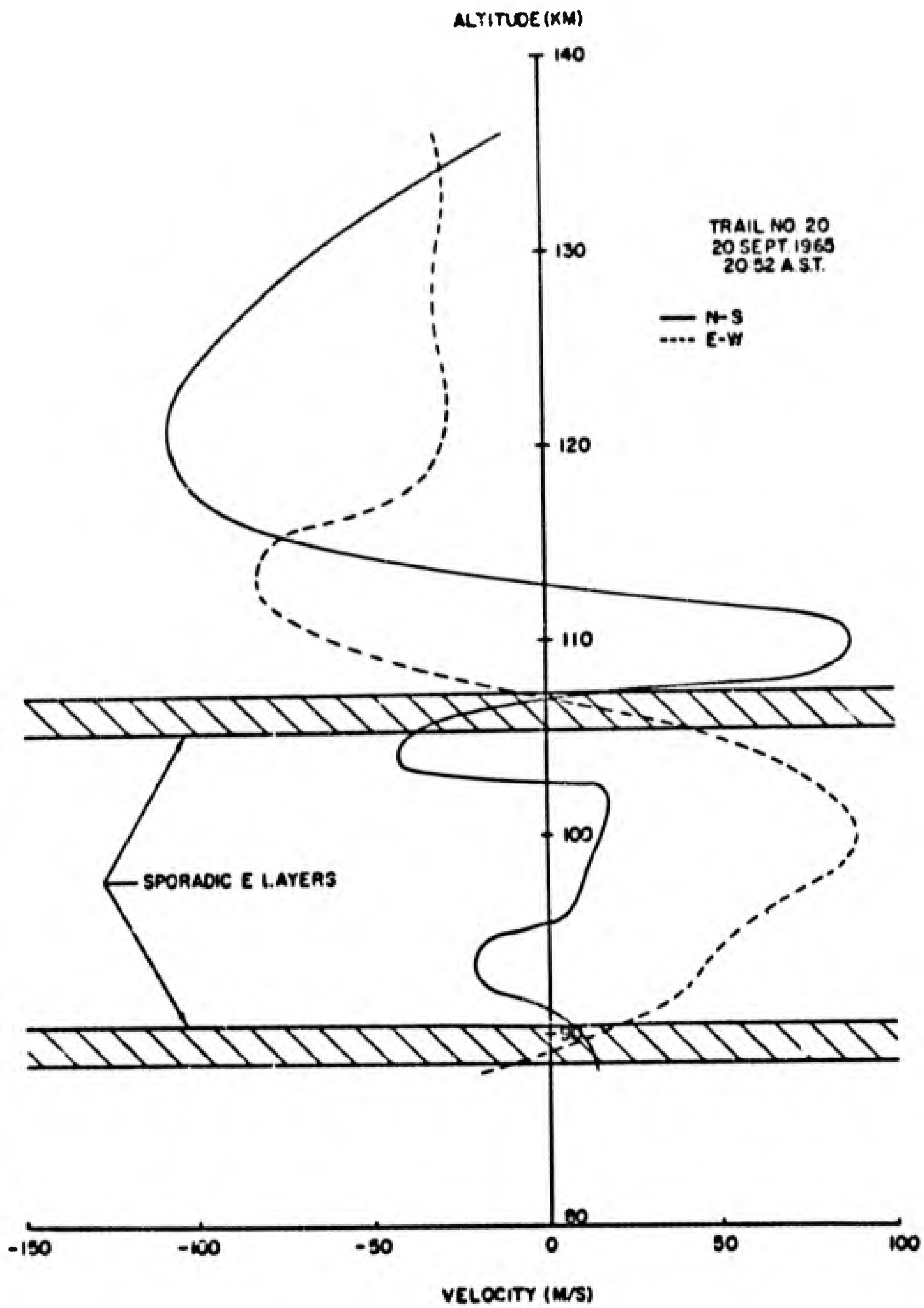


FIGURE 20

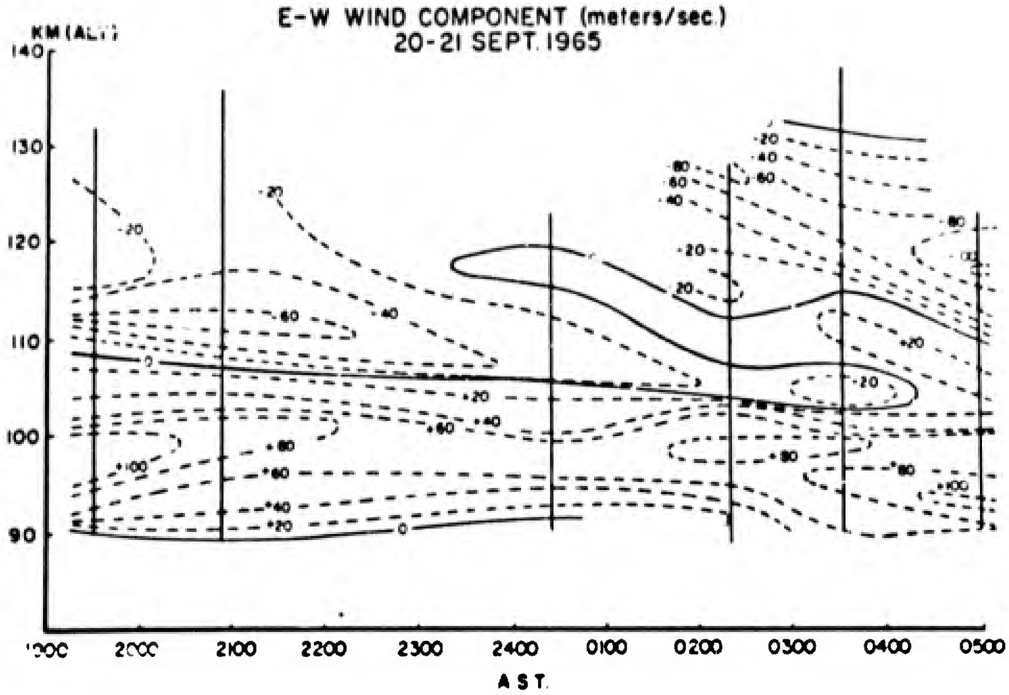

E-W WIND COMPONENT (meters/sec.)
20-21 SEPT. 1965
KM (ALT)
140
130
120
110
100
90
2000
2100
2200
2300
2400
0100
0200
0300
0400
0500
A.S.T.

FIGURE 21

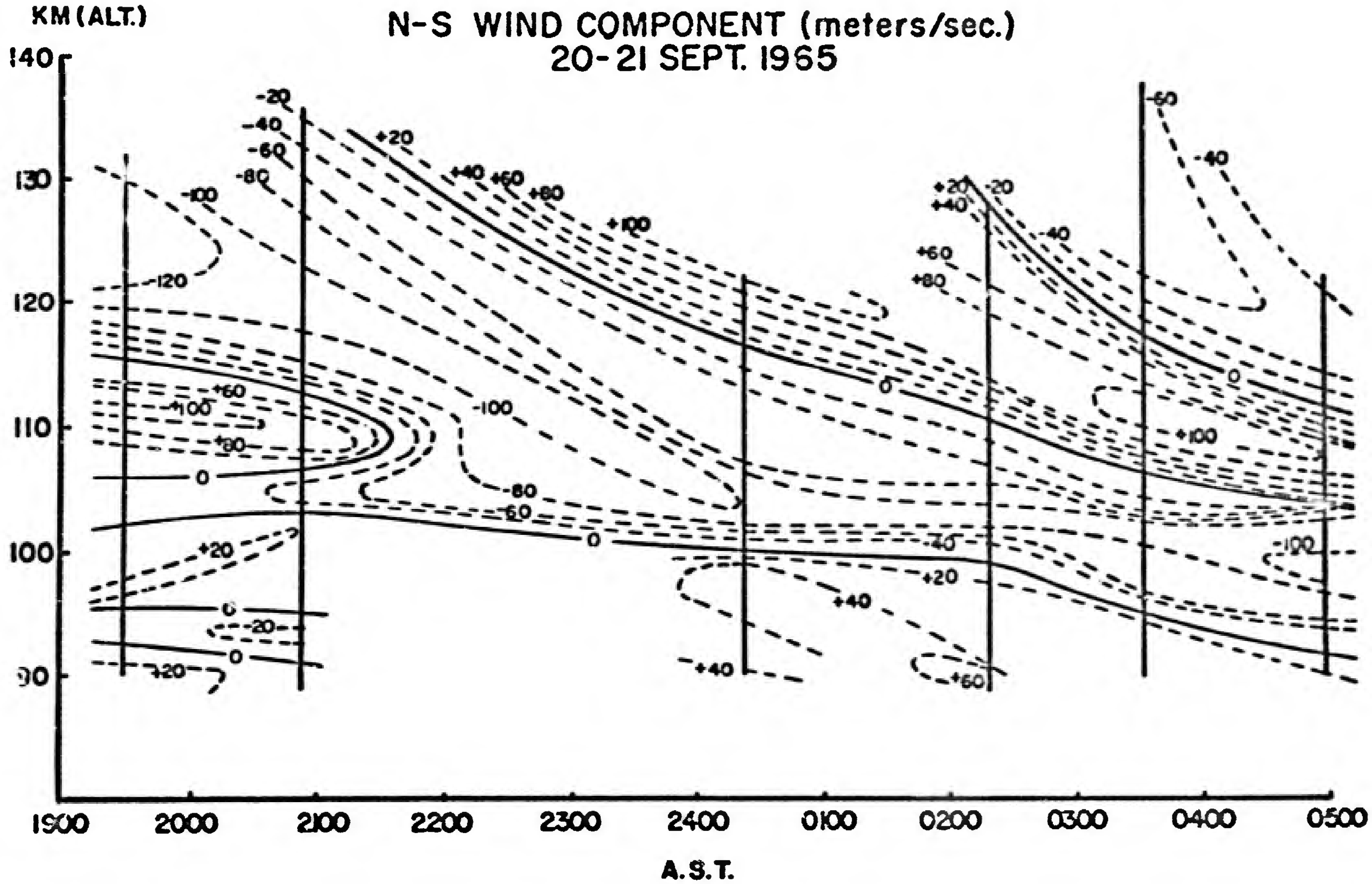


FIGURE 22

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Space Research Institute McGill University Montreal, P.Q., Canada	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP

3. REPORT TITLE
AEROSPACE APPLICATION OF GUN LAUNCHED PROJECTILES AND ROCKETS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

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Charles H. Murphy
Gerald V. Bull

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c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

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13. ABSTRACT

Project High Altitude Research Program (HARP) is directed toward the use of guns for scientific probing of the upper atmosphere. The attractive features of guns for this purpose are the basic economy of such a system and the high inherent accuracy of guns for placement at altitude as well as accuracy in ground impact. The basic liability for such an approach lies in the very high acceleration experienced by gun-launched payloads.

The guns used in Project HARP vary in size from 5-inch and 7-inch extended guns on mobile mounts to transportable fixed 16-inch guns. Altitude performance varies from 20 pound, 5-inch projectiles reaching 240,000 feet to 185-pound, 16-inch projectiles reaching 590,000 feet. Single and multiple stage rockets launched from the 16-inch gun have very promising predicted performance and are under development.

Scientific results to date are primarily wind profiles measured by radar chaff, aluminized balloons and parachutes, and tri-methyl-aluminum trails, although a number of successful 250 MHz and 1750 MHz telemetry flights have been made. Sun sensors, magnetometers, and temperature sensors have been flown and an electron density sensor was fired in early June. Development of other active sensors is continuing.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
HARP High Altitude Research Program Gun Boosted Rockets Gun Launched Projectiles Vertical Fired Gun Probe						