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NATIONAL RESEARCH COUNCIL OF CANADA
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BLACK BRANT ROCKET AMF-II-116
LAUNCHED AT CHURCHILL RESEARCH RANGE
22 APRIL 1968
Operations Requirement Number 258

OTTAWA
November 1968

ABSTRACT

This report deals with the engineering aspects of preparing the payload and launching Black Brant rocket AMF-II-116 on 22 April 1968 at Churchill Research Range at night, during sustained and distinct auroral activity. This vehicle carried recoverable experiments to provide photographic and photo-electric auroral analysis, vacuum ultraviolet and density measurements, together with a plasma probe, Wadsworth spectrograph, several photometers and an oxygen atom probe. AMF-II-116 malfunctioned, achieving an apogee of only 61,500 feet, resulting in failure of the experimental objectives.

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BLACK BRANT ROCKET AMF-II-116

LAUNCHED AT CHURCHILL RESEARCH RANGE 22 APRIL 1968

INTRODUCTION

The National Research Council of Canada is engaged in a sounding rocket program with various groups from Canadian universities, scientists in the Council and other government agencies who are interested in performing measurements in the upper atmosphere with particular reference to auroral activity.

The program is coordinated by the Associate Committee on Space Research of the National Research Council. Payload engineering, fabrication (except for the experimenters' own equipment) checkout and launching are arranged by the Space Research Facilities Branch through contracts to various agencies.

This report deals with the launching of Black Brant rocket AMF-II-116 at Churchill Research Range at night on 22 April 1968 during sustained and distinct auroral activity to carry out the launch objectives described below.

Payload engineering, fabrication and experiment integration were carried out by Bristol Aerospace Limited, Winnipeg, Manitoba under agreement with the Space Research Facilities Branch. Experiments were supplied by York University, the Defence Research Telecommunications Establishment, Defence Research Board and the Upper Atmosphere Research Section, Radio and Electrical Engineering Division, National Research Council.

OBJECTIVES

The launch objectives were: To photograph the auroral spectrum over the wavelength range $1000\text{\AA} - 3000\text{\AA}$, to measure relative intensities and to study the profile of selected auroral features with height. To measure the intensities of some of the major auroral emissions in the vacuum ultraviolet relative to visible emissions and incoming particle flux. To measure ionization density profiles and electron temperatures and to obtain measurements of height profiles of the oxygen atom concentration.

DESCRIPTION OF THE VEHICLE

AMF-II-116 was a single stage, solid propellant, fin stabilized sounding rocket. The vehicle used a 15KS25000 motor, manufactured by Bristol Aerospace Limited and was fitted with a Black Brant II/V igniter housing. The four fin Black Brant II stabilizer unit was manufactured and assembled at Canadair Limited, Montreal, with the fins set to obtain a stable roll rate of 0.65 r/s.

The forward section of the rocket consisted of a standard Black Brant II magnesium nose cone and a forward body section, plus a "Skylark" parachute-recovery unit. Forward and rear adaptor rings and manacle clamp rings were employed to attach the parachute recovery unit to the after end of the Black Brant II forward body and the forward end of the Black Brant V igniter housing. The nose cone was modified by Bristol Aerospace to a clamshell configuration with a pressure sealed bulkhead to seal the forward end of the Black Brant II forward body (figures 1 and 2).

The general data on the vehicle was as follows:

Length	349.39 in	
Diameter	17.2 in	
Launch weight	2930 lb	
Burnout weight	1144 lb	
Gross payload	520	(Gross payload included nose cone, igniter housing, forward launch lug and nose attachment hardware).
Discharge weight	1786 lb	
Propellant	Aluminized single grain polyurethane-ammonium perchlorate.	

VEHICLE PAYLOAD

The payload was designed to carry experiments to provide photographic and photo-electrical auroral analysis, vacuum ultraviolet, and ionization density measurements, and to obtain measurements of height profiles of the oxygen atom concentration in the upper atmosphere.

In addition, a separation and recovery system was fitted to allow the payload to be recovered. This was a standard "Skylark" type 4 Mk-1 parachute-recovery package manufactured by the British Aircraft Corporation, which was modified to fit onto a standard Bristol Aerospace Black Brant II/V igniter housing and to accept a Canadair Black Brant II forward body section.

Magnetometers and altitude switches were carried for vehicle attitude and performance evaluation purposes.

Holex cutters and Bellows actuator type pyrotechnic devices were also fitted to perform the following functions:

Clamshell deployment

Vacuum ultraviolet experiment door release

Closing the spectrograph flap, and extending the plasma probe

For ease in tracking, this vehicle was also equipped with a DPN-41 radar beacon.

The payload was ballasted to reduce peak altitude to within 10 kilometers of 110 kilometers for purposes of the experiments carried.

EXPERIMENTS

Auroral Spectrum Photography (Professor R. W. Nicholls, Dr. C. H. Dugan, Dr. F. J. Morgan and Dr. W. W. Duley, York University, Toronto, Ontario)

The purpose of this experiment was to photograph the auroral spectrum over the wavelength $1000\text{\AA} - 3000\text{\AA}$, and to measure the relative intensities and to study the profile of selected auroral features with height. A recoverable large aperture (f/6) photographic grating spectrograph (Wadsworth mounting) was employed. This package which had been assembled and laboratory tested during the past year was being flown for the first time on this vehicle.

Vacuum Ultraviolet Photometers (Dr. D. J. McEwen, Defence Research Telecommunications Establishment, Defence Research Board)

The photometer package was designed to measure the intensity of specific auroral radiations in the vacuum ultraviolet region of the spectrum in relation to visible emissions and incoming particle flux. It consisted of two ionization chambers and a photomultiplier detector, each with an electrometer amplifier and a feedback network which provided a logarithmic output with a dynamic range of about 10^4 . Emissions monitored were the atomic oxygen triplet at $1300\text{\AA}$, two bands of the Lyman-Birge-Hopfield system of nitrogen at 1450 and $1464\text{\AA}$, and the N_2^+ Band at the $3914\text{\AA}$. The possible application of these ultraviolet detectors for auroral intensity measurements was also to be investigated.

Ionization Density Measurements (Dr. A. G. McNamara, Upper Atmosphere Research Section, Radio and Electrical Engineering Division, National Research Council)

The purpose of this Langmuir type plasma probe experiment was to measure ionization density profiles and electron temperatures.

Oxygen Atom Probe (Dr. H. I. Schiff, York University, Toronto, Ontario)

An oxygen atom probe was carried to obtain measurements of height profiles of the oxygen atom concentration in the upper atmosphere. A very simple probe has been developed which shows promise of producing reliable quantitative results. It is based on the principle that atomic oxygen attacks silver with unit efficiency, i. e. every oxygen atom reaching the surface is converted to a silver oxide. This reaction results in the transformation of a conducting silver surface to a non-conducting silver oxide surface. The measurement then simply consists of following the resistance change of a silver film.

TELEMETRY

Data from the payload was transmitted by an FM/FM system operating at 240.2 MHz, with one watt nominal transmitted power. The antenna system consisted of two quadriloop radiators mounted 180° apart on the surface of the parallel section of the Black Brant II nose cone.

Four subcarrier oscillators were employed, using IRIG bands 15 through 18 inclusive, with modulation as described below:

Subcarrier Oscillator Allocations

<u>IRIG Band Numbering</u>	<u>Center Frequency kHz</u>	<u>Information</u>
15	30.0	Plasma probe channel number 3
16	40.0	Plasma probe channel number 2
17	52.5	Plasma probe channel number 1
18	70.0	10 x 30 commutator

Commutator channels are contained in Table 2.

Subcarrier oscillators were calibrated just prior to lift-off.

RANGE SUPPORT

In order to facilitate impact location during attempted recovery, the telemetry link number 1 frequency was changed from 219.5 to 240.2 MHz (Sarah receiver frequency) at the recommendation of the range.

Because this recovery flight required a launch azimuth of 170° , and the riometer was fixed at an azimuth of $110^\circ \pm 20^\circ$, the request of the project scientist for the launch site riometer to be directed along expected trajectory could not be met.

Due to lack of equipment, the request for photometer and spectrometer coverage from the ground in the $1000\text{\AA}$ to $3500\text{\AA}$ wavelength region could not be met. Coverage of the shortest wavelength available was therefore arranged.

70 mm all-sky camera photographs were to be provided prior to T-90 seconds at four frames per minute, and after resumption of the count at T-90 seconds at 20 frames per minute until T+10 minutes.

The three component fluxgate magnetometer was to be manned for the night of the launching.

Auroral height finding data was to be taken as rapidly as possible from T-0 to T+10 minutes. Four ionosonde sweeps per minute were required from T-0 to T+10 minutes. Auroral activity predictions were to be provided, with verbal reports of visual aurora during countdown and flight also to be given.

Real time lines from telemetry were arranged at the work bench in the operations building. A digital countdown display was installed in the user area of the operations building near the real time patch panel. Arrangements for helium and dry ice experimental requirements were agreed with and provided by the range.

A rawinsonde balloon (winds only) was to be released as close to launch T-0 as possible.

Tracking

Radar tracking only was required, with plotting board data of H vs R and X vs Y requested with one data point per second on the up and down legs of the trajectory, and one data point every five seconds over apogee. A copy of the real time plotting board data was required for each radar with valid track. A magnetic tape of metric data and IRIG B timing waveform was also required.

Telemetry Requirements

All telemetry requirements were to be met by the primary telemetry station, with the backup station duplicating the primary as much as possible.

Recordings

Magnetic tape recordings were required for approximately three minutes during horizontal instrumentation checks, from T-2 minutes to loss of telemetry and for a

short period following vehicle impact for post-flight calibration.

Telemetry recordings were to be made as follows:

<u>Tape Track</u> <u>IRIG Numbering</u>	<u>Information</u>
1	Voice
2	Receiver number 1 video
3	Receiver number 2 video
4	Speed control and compensation (17 and 100 kHz)
5	Timing signal IRIG B
6	Multiplex
7	Timing signal IRIG C

LAUNCH PREPARATIONS

The launch crew from Bristol Aerospace Limited, together with the scientists from York University arrived at the range on 15 April by chartered aircraft. The same flight carried vehicle payloads and test equipment.

A pre-flight conference was held on 16 April, and it was agreed that the first launch attempt would be made on 18 April, with a window from 2130 to 0130.

Under Operations Requirement Number 258, two vehicles (AMF-II-116 and 117) were to be launched, one in early April, and the other later in the same month.

The universal launcher was to be employed, with an effective elevation angle of approximately 85° and an azimuth which was to ensure impact of the payload in the recovery area. The requirement for a peak altitude of 110 kilometers ± 10 , resulted in the selection of a Q. E. of 86.0°.

The following sequence of experimental events was planned:

<u>Altitude</u>	<u>Action</u>
40 kilometers	Exposure of vacuum ultraviolet detectors by pyrotechnic release of the door.
60 kilometers	Extension of the plasma probe.

70 kilometers

Ejection of clamshells, exposure of Wadsworth spectrograph and the extension of oxygen atom probe.

Wadsworth Spectrograph Atmosphere Requirements

It was necessary to make special arrangements to ensure that the Wadsworth spectrograph was surrounded by a non-contaminated atmosphere until clamshell ejection in the vacuum of space. In this regard, it was first necessary to evacuate the sealed spectrograph compartment to 10^{-3} torr for approximately fifteen minutes, and then pressurize with helium. Connections for vacuum and helium supply lines were made through a small port in the Black Brant II forward body section, and evacuation and pressurizing were carried out with the vehicle on the universal launcher. Plate 2 shows vacuum pumping arrangement.

LAUNCH REQUIREMENTS

These launch requirements were to cover the launching of two vehicles, one in early April, and the second in late April 1968. Both vehicles were to be fired at night during periods of sustained and distinct auroral activity. In order to meet the desired atmospheric and auroral activity requirements, day to day rescheduling might be necessary.

LAUNCHING AMF-II-116

Payload build up and check out was started on 16 April, and proceeded smoothly, with the payload being ready for fitting to the motor assembly by 18 April without any problems.

The first launch attempt was made during the evening of 18 April, assembly of the vehicle having been completed in the early afternoon. AMF-II-116 was installed on the universal launcher by 1600, and horizontal instrumentation checks were carried out between 1940 and 2022. Range countdown was commenced at 2030 as scheduled. Payload checking and arming, and checking of the separation and recovery unit were started at 2031, but had not been completed by 2120 and the countdown was therefore held at T-40 minutes. It was ascertained that the push rod which operated the parachute arming microswitch was too short to be actuated by the igniter housing bulkhead, and efforts to lengthen the rod were started immediately. This launch attempt was aborted at 2206. The microswitch problem was not resolved until 0130.

The second attempt was made on the evening of 19 April. The weather was predicted as overcast, with layers at 600 and 1200 feet. However, large holes in the cloud cover permitted the project scientist to look for aurora, and Belcher out station had clear skies from about 2330. This launch attempt was aborted at 0200 because of lack of sufficient auroral activity.

The range was not scheduled on Saturday and Sunday 20 and 21 April, and the third attempt was therefore made on the evening of 22 April, in a double count with a Nike Tomahawk.

Because of the possible requirement to maintain a slight helium flow to the payload, AMF-II-116 was not elevated to the vertical position on completion of arming. However, at 2132, due to indications of aurora build-up, the count was picked up, and the vehicle elevated. At 2200, with the launcher on final settings, the count was jumped to T-3.5 minutes and holding; and jumped again to T-90 seconds as auroral activity continued to build up. The count was picked up at 2238, but returned to T-90 seconds and holding at 2239. At 2245 the final count was requested, and lift-off occurred at 2247 central standard time April 22, 1968.

LAUNCH RESULTS

General

Vehicle lift-off appeared normal at first, and telemetry reported a good signal. However, both telemetry signal strength and radar apogee data indicated a vehicle malfunction with premature separation occurring at T+15.5 seconds. This resulted in a low peak altitude and failure to deploy the parachute correctly. Instrumentation performance was good until T+16 seconds.

Radar Performance

Two type FPQ-11 radars were employed during the flight of this vehicle, number one in an automatic beacon tracking mode, the second automatic skin tracking. A MK 51 type optical tracker was also used as an acquisition aid. Radar number 1 acquired the rocket at T+4 seconds at a height of 1620 feet, and lost contact at T+209 seconds at 1400 feet. The second radar acquired the target at T+12 seconds at an altitude of 22,260 feet, lost contact at T+14 seconds at a height of 30,900 feet, reacquired at T+54 seconds at 61500 feet, and finally lost track of the vehicle at T+209 seconds at 600 feet.

Trajectory

From the radar plots furnished by the range, it was determined that AMF-II-116 attained an altitude of 61,500 feet (11.6 statute miles) at approximately T+45 seconds. Effective elevation angle was 84.6° at a flight azimuth of 159°. Total flight time was 210 seconds, which was confirmed by the loss of telemetry at that time, with vehicle impact range of 2,778 yards. Vehicle spin rate was 0.7 r/s. Vehicle height with respect to time is shown in Figure 3.

Telemetry

Telemetry was received for a total of 206.9 seconds, with the operations of primary and back-up stations indicated as excellent. At T+16 seconds, telemetry reported a major reduction in signal strength. Thereafter signals were reported as very weak, and at T+206.9 seconds the signal was finally lost.

EXPERIMENT RESULTS

No experimental results were obtained because of the low apogee attained by AMF-II-116. This was unfortunate, for had the rocket performed the payload would have passed through a 75 kilorayleigh aurora.

Plasma Probe

Probe telemetry signals were received throughout the flight, although the telemetry was extremely noisy at times.

The battered probe and electronics package were subsequently recovered from the wreckage and returned to the laboratory. The probe had not extended from its chute. The fact that the probe was jammed in its chute and the squib actuator had fired, confirms that the mechanical damage occurred early in the flight.

The electronics box was badly damaged and scorched. However, when the package was plugged into a laboratory power source, all output signals were found to be operating and their voltage leads were normal. This rather severe environmental test at least proved the efficacy of the foamed circuit board method of construction.

SUMMARY

At T+11 seconds the manacle ring attaching the motor to the nose assembly was prematurely released. Consequently, the nose assembly separated from the motor at burnout (approximately T+15.5 seconds) and due to the sudden change in attitude, the clamshells were released. Total flight time was 208.6 seconds, with an apogee of 61,500 feet, and an impact range of 2,778 yards.

The payload was recovered, damaged due to the high impact velocity. The main parachute had been deployed but the drogue chute was missing and some of the parachute lanyards were severed.

Sufficient data was obtained from telemetry to follow the chain of events during the flight to conclude that the payload was prematurely separated from the motor due

to failure of the solenoid.

Failure of the recovery bay was due to heat damage to the nylon components of the parachute system. It is considered that this was caused by a collision of the payload and motor after separation. This punctured the heat shield and allowed an inrush of high temperature air.

Due to the malfunction of this vehicle, the second launching was postponed pending analysis. AMF-II-117 has since been rescheduled for launching in February 1969.

BIBLIOGRAPHY

- McNamara, A. G. Rocket measurements of auroral plasma
Bulletin of the Radio and Electrical Engineering Division,
National Research Council of Canada,
Volume 15, Number 2, April/June 1965.
- McEwen, D. J. Auroral radiations below 2000A°
Oral presentation at Congress of Canadian Association of
Physicists, June 1968. (Paper yet to be published)

TABLE 1

METEOROLOGICAL/IMPACT PREDICTION TEST SUMMARY AMF-II-116

1. Test Number 109.8B22583L Support of NRC, York University, DRTE
DRB.
2. Date 22 April 1968 Scheduled Time Launch Time 2247 CST
3. Vehicle Type Black Brant IIA Objective To photograph auroral spectrum
1000 to 3000A°, and measure intensities and
study profile of selected features with height.
To measure intensities of some major auroral
emissions in vacuum ultra violet and ioniza-
tion density profiles and electron tempera-
tures. An oxygen atom probe was also
carried.
4. Sustainer (motor) BAW-MT-90 Weight 241.0 lb Length
Payload serial number AMF-II-116 Payload weight 520 lb Total vehicle weight
2930 lb
5. Surface Weather Observation
Surface winds 282 degrees 14 knots
200 foot winds 287 degrees 20 knots
Temp +11.0 degrees F pressure 1,15.7 mbs
Sky clear visibility 15 miles.
6. Supporting rawinsonde
7. Supporting pibal
8. Vehicle Performance Predicted
Sustainer impact azimuth 160° Range 46,400 yds Time T+314 seconds
Apogee altitude 369,000 ft Range 23,200 yds Time T+155 seconds
9. Vehicle Performance Actual
Sustainer impact azimuth 130.5° Range 4,500 yds Time T+209 seconds
Apogee altitude 61,500 ft Range 2,778 yds Time T+45 seconds

TABLE 2

AMF-II-116 COMMUTATOR CHANNELS

<u>Channel #</u>	<u>Information</u>
1	Zero volts calibration
2	+5.00 volts calibration
3	Vacuum ultraviolet photometer # 1
4	Vacuum ultraviolet photometer # 2
5	Vacuum ultraviolet photometer # 3
6	50 and 70 K feet altitude switch
7	Y-Axis magnetometer
8	Clamshell monitors
9	Plasma probe extension monitor and spectrometer flap
10	Oxygen atom probe detector channel 1
11	Diaphragm release monitors and payload/motor separation
12	Payload heatsink temperature
13	X-Axis magnetometer
14	Plasma channel 1
15	Plasma channel 2
16	Plasma channel 3
17	Y-Axis magnetometer
18	Vacuum ultraviolet photometer # 1
19	Vacuum ultraviolet photometer # 2
20	Vacuum ultraviolet photometer # 3
21	Spectrometer flap monitor and plasma extension monitor
22	Radiation temperature
23	
24	Clamshell pressure gauge

TABLE 2 (contd)

<u>Channel #</u>	<u>Information</u>
25	Oxygen atom probe detector channel 2
26	Vacuum ultraviolet photometer door and solenoid limit switch monitors
27	Y-Axis magnetometer
28	X-Axis magnetometer
29	Master pulse for synchronization
30	

AMF-II-116/117 CONFIGURATION

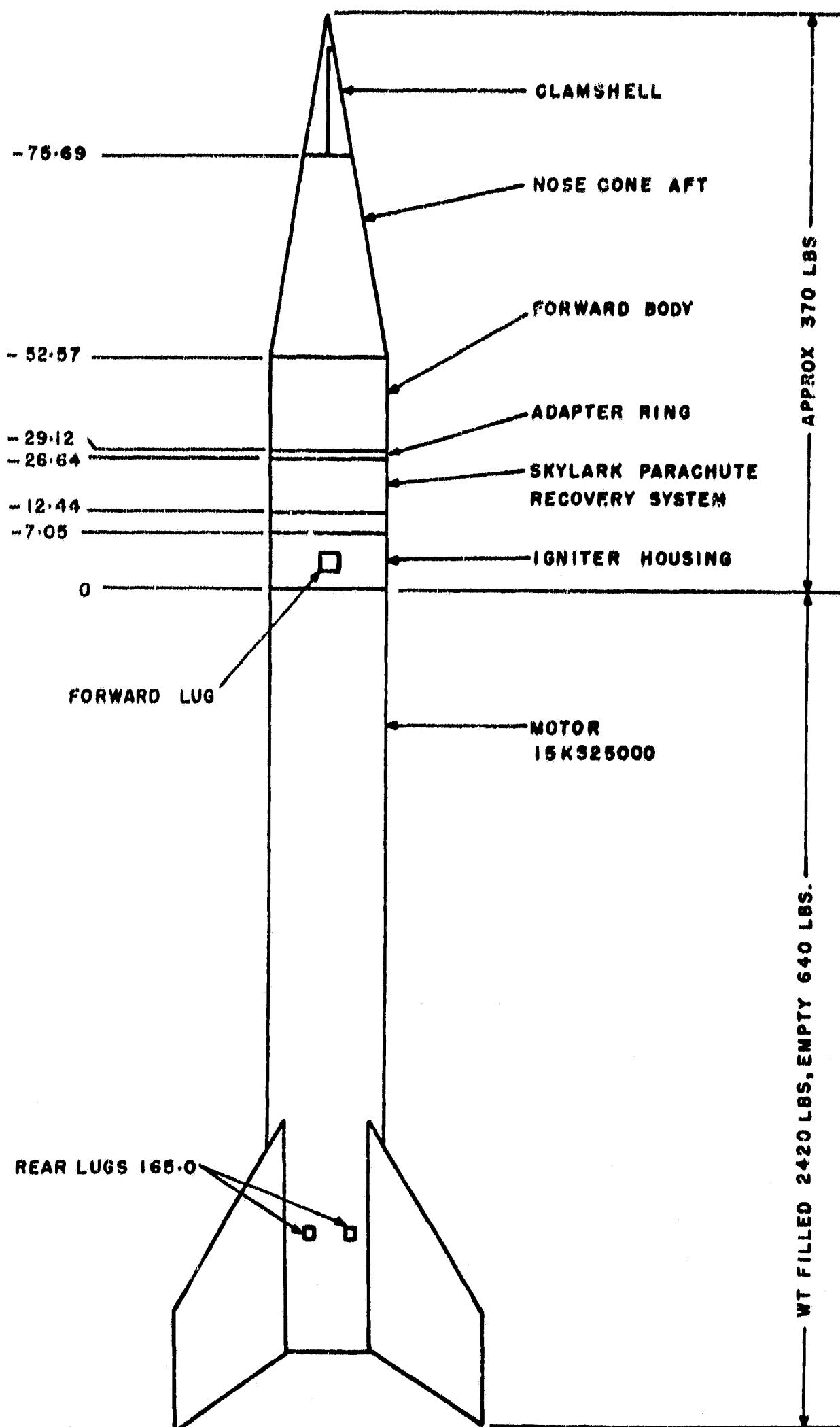


FIGURE 1

AMF-11-116/117 NOSE CONE LAYOUTS

STA:

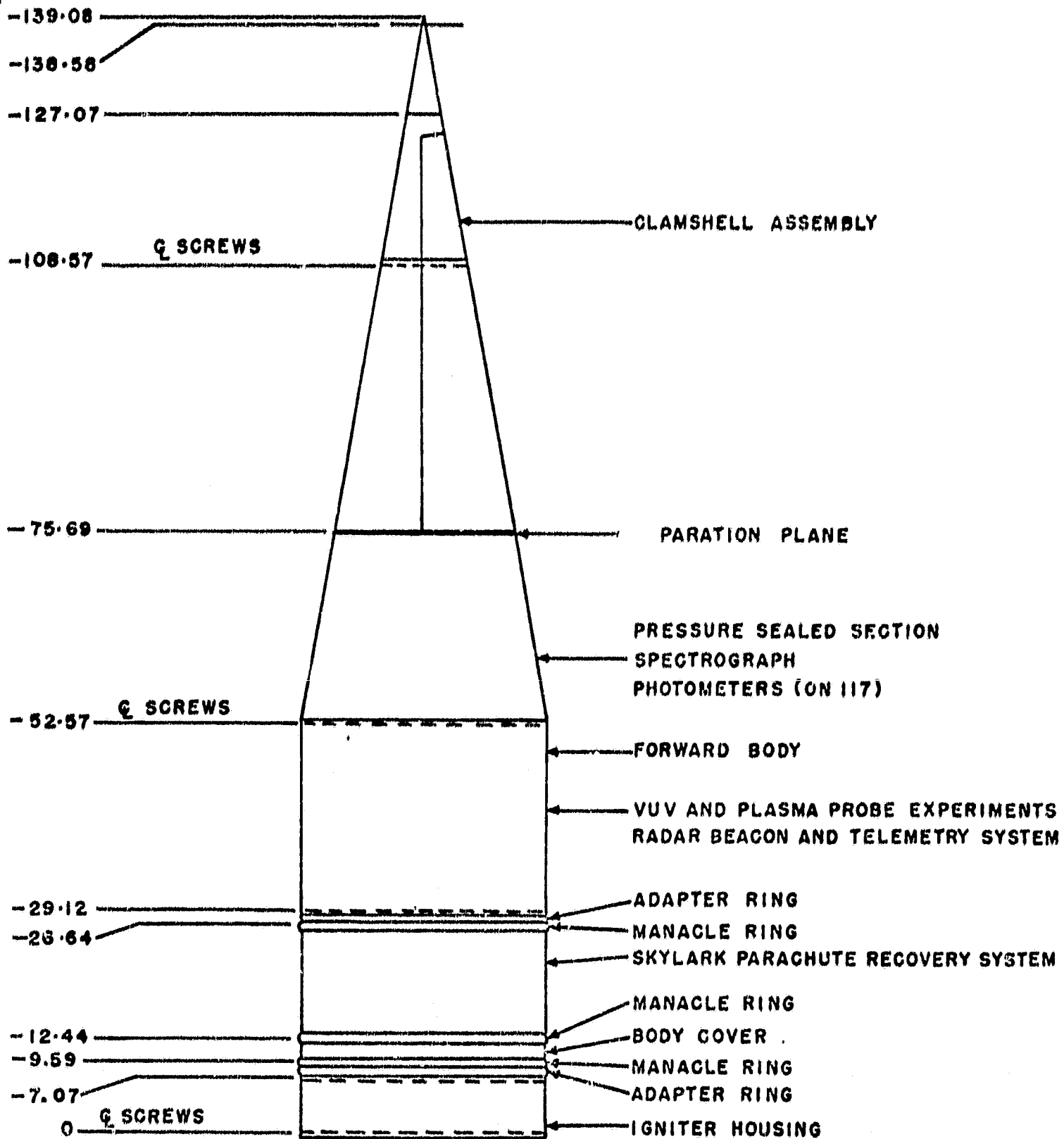


FIGURE 2

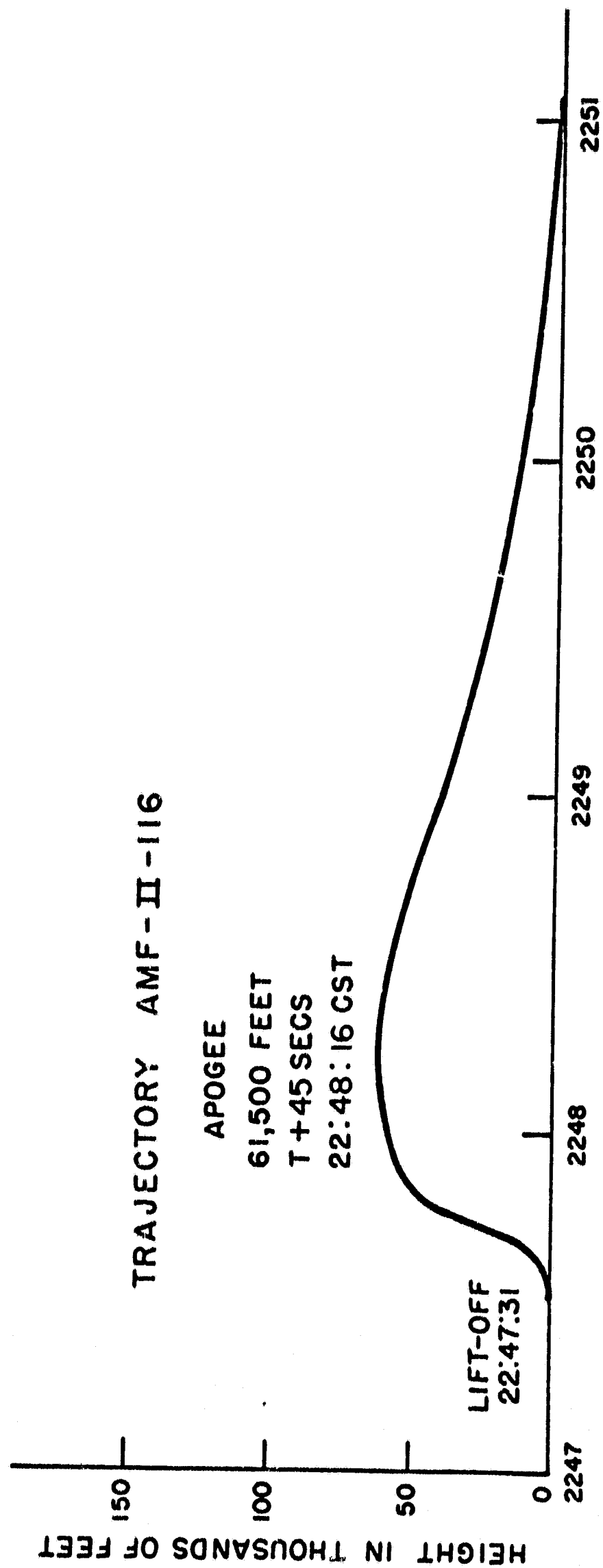


FIGURE 3

NOSE CONE AND FORWARD BODY, SHOWING MANACLE RINGS, AMF-II-116

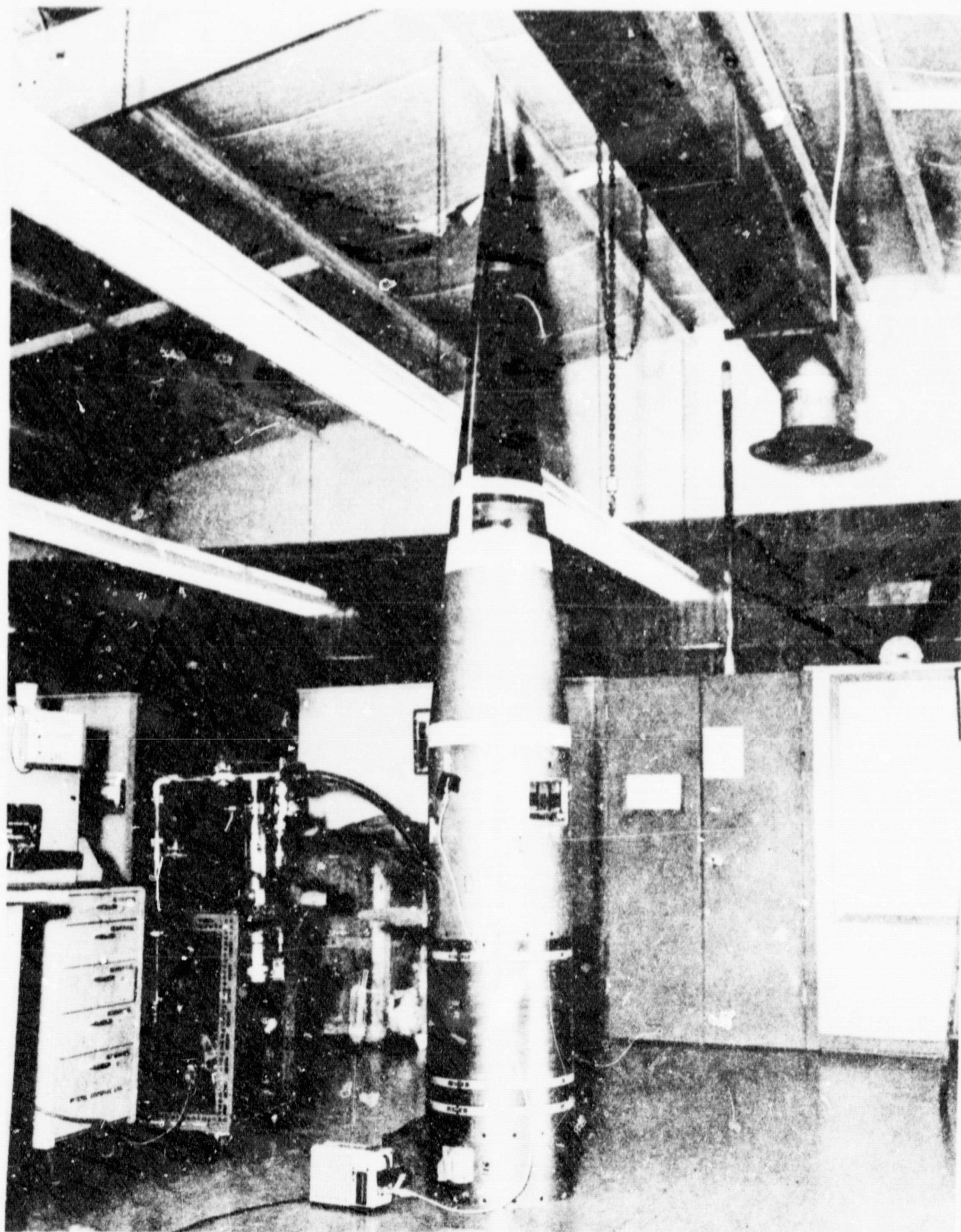


PLATE I

VACUUM PUMP ATTACHED TO PAYLOAD, AMF-II-116

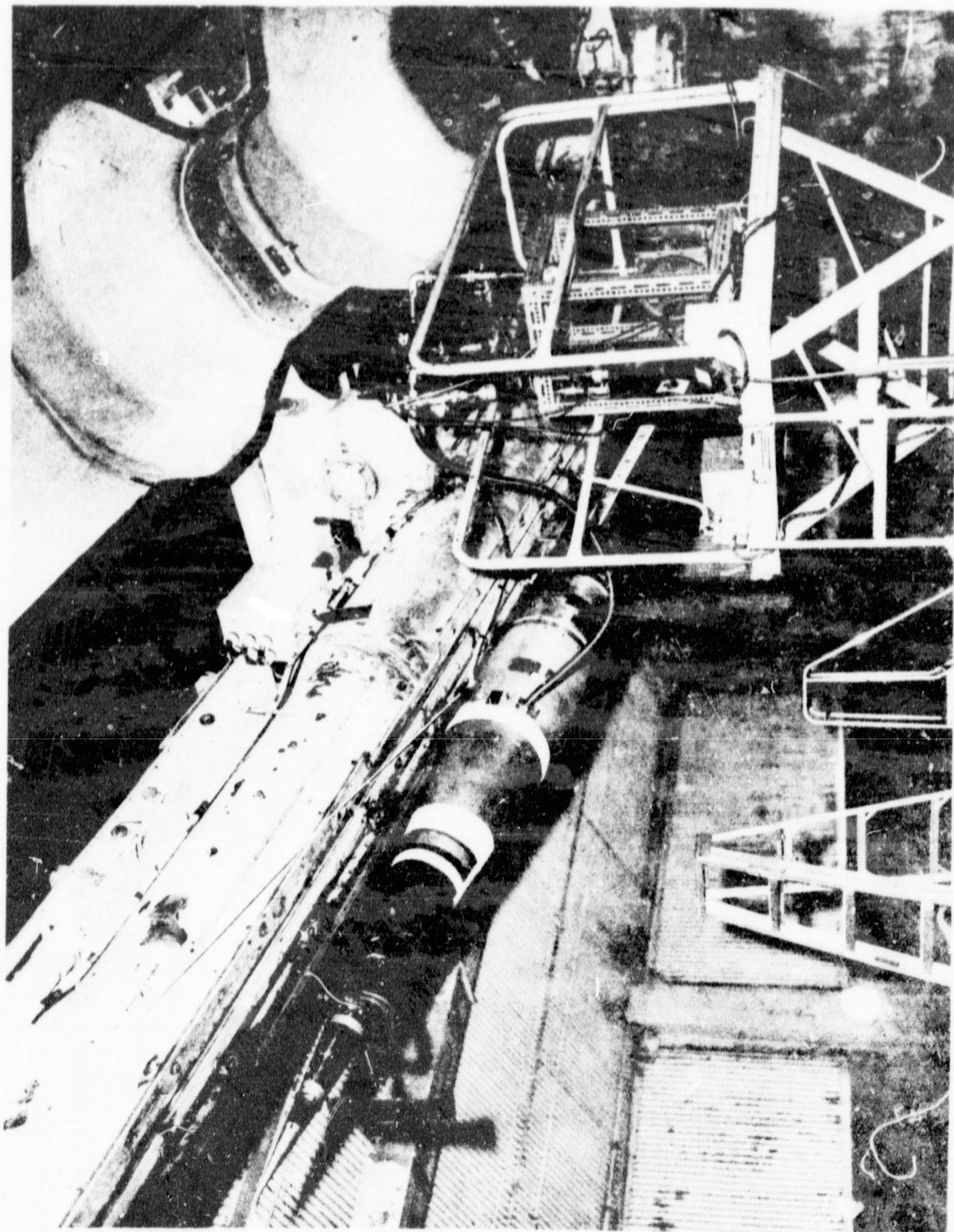


PLATE 2

AMF-II-116 ON THE LAUNCHER

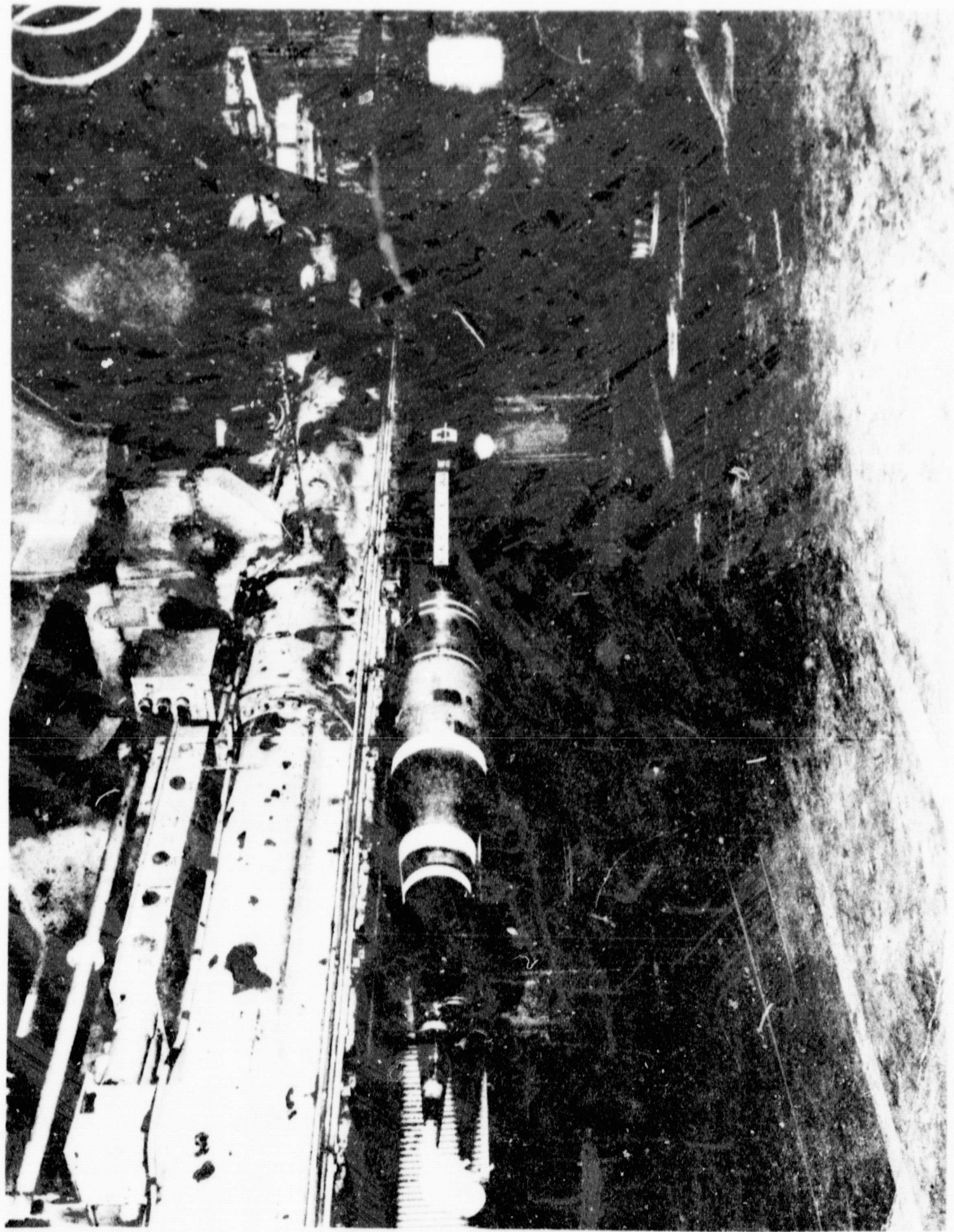


PLATE 3