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U.S. ARMY ROCKET & GUIDED MISSILE AGENCY

OPERATION GASLIGHT IN AUSTRALIA

(January through July 1960)

BY

DR. DAVID D. WOODBRIDGE
Experimental Programs Branch
Requirements & Plans Division

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ARGMA REPORT NR.
EP-TR-1-60

ARMY ROCKET AND GUIDED MISSILE AGENCY

RESEARCH AND DEVELOPMENT OPERATIONS

OPERATION GASLIGHT IN AUSTRALIA

(January through July 1960)

BY

DR. DAVID D. WOODBRIDGE

EXPERIMENTAL PROGRAMS BRANCH
REQUIREMENTS & PLANS DIVISION

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SEMI-ANNUAL TECHNICAL SUMMARY REPORT NR 1

January - July 1960

ARPA ORDER NR	- 114-60
TITLE OF PROJECT	- Operation GASLIGHT (U)
CONTRACTOR	- Barnes Engineering Company
CONTRACT NR	- DA-19-020-ORD-5159
CONTRACT DATE	- 22 January 1960
CONTRACT EXPIRATION DATE	- 21 January 1961
CONTRACT AMOUNT	- $69,785
ARGMA PROJECT ENGINEER	- Dr. David D. Woodbridge Ext 876-0436
CONTRACTOR PROJECT ENGINEER	- Harold Yates

I. OBJECTIVE.

(C) The objective of this program is to obtain data concerning physical phenomena occurring during the flight of ballistic missiles with the object of seeking explanations of these phenomena.

The reasons for wishing to make measurements in Australia are: (a) The trajectory of Black Knight provides a unique opportunity of tracking from launch to impact from one location; (b) The Black Knight research program will include experiments with a variety of head materials and flight conditions not normally available on American missile ranges; (c) The trials conditions mandatory for Black Knight and other suitable firings in Australia provide better opportunity for optical observation than do firings on American ranges.

II. INTRODUCTION.

1. (C) In September 1959, a paper was given at the International Astronautics Congress in London, that presented the results obtained by Operation Gaslight during the re-entry of Ballistic Missiles on the Atlantic Missile Range. Following this conference, meetings were held at the Royal Radar Establishment (RAE) in Great Melbourne and at the Royal Aircraft Establishment in Farnborough. At these meetings, a common interest was discovered between the United States, United Kingdom (U.K.) and Australian representatives in relation to range measurements for Ballistic Missile Defense. As a result of these conferences, representatives of the United Kingdom contacted

representatives from Advanced Research Projects Agency (ARPA) to investigate the possibility of the utilization of the Operation Gaslight equipment on the Woomera Range in Australia.

2. (C) In November of 1959, Mr. A. J. Grobecker of ARPA and Dr. David D. Woodbridge of ABMA (now affiliated with ARGMA), had a conference with representatives of Royal Aircraft Establishment at Farnborough. The objectives of this conference were as follows:

a. Interchange the results of recent program measurements in the interest of ballistic missile defense research.

b. Determination of the potential contribution of the Weapons Research Establishment activities on the Woomera Range to the United States program on the range measurements of ballistic missile defense. Consideration was given to the instrumentation of the Woomera Range and the characteristics of the United States missile program.

c. A determination of potential use of United States equipment and personnel at Woomera, specifically, the possible use of Operation Gaslight equipment for observations of Black Knight missiles beginning in February 1960.

d. Determination of the interest of the United Kingdom in research for ballistic missile defense and this relationship to the Woomera Range missile program.

3. (C) Following the meetings at the Royal Aircraft Establishment in Farnborough, Mr. A. J. Grobecker and Dr. David D. Woodbridge were accompanied by Mr. J. R. Stretton and Dr. A. W. Lines from the Royal Aircraft Establishment to Salisbury, Australia, to meet with representatives from the Weapons Research Establishment (WRE) that operate the Woomera Range. While in Australia, meetings were also held with the Australian Department of Supply in Melbourne and the United States Embassy in Canberra. At that time a trip was made to the Woomera Range to inspect potential sites for the Operation Gaslight equipment.

4. (C) The meetings in England and Australia resulted in decisions by the representatives of Royal Aircraft Establishment, the Weapons Research Establishment of Department of Supply in Australia, and representatives from Advanced Research Projects Agency, that the Operation Gaslight equipment should be moved to Australia to make radiation measurements on the Black Knight missile and other available targets on the Woomera Range. Also at this time the Australians drew up a planning specification for Operation Gaslight work in Australia. This planning specification has become the agreement under which measurements have been made in Australia.

5. (S) The Advanced Research Projects Agency established ARPA Order 114-60 with the Army Ordnance Missile Command (AOMC) to carry

out the agreement established with the British and Australians, relative to measurements on the Woomera Range during calendar year 1960. This order provided $150,000 to accomplish the measuring program on the Woomera Range. Since the issuance of ARPA Order 114-60, firing delays of the Black Knight missile, and increase in the scope of work have resulted in ARPA supplementing the order by the amount of $52,000. The ARPA Order 114-60 stated that the responsibilities of AOMC shall include:

a. Providing the appropriate U. S. optical and infrared equipment necessary for the desired measurements.

b. Achieving agreement on implementation of the following anticipated arrangements for cooperative action by the three nations:

(1) U. S. equipment furnished will be mainly manned by personnel of Weapons Research Establishment, Australia, with minimum training by U. S. personnel.

(2) Equipment will be available for return to the United States by January 1961.

(3) Results of testing, both in the form of broad data and analytical results will be made available promptly to appropriate U. S., UK and Australian agencies.

(4) All plans made will be mutually acceptable to the U. S., UK and Australian governments.

III. WOOMERA RANGE.

1. (U) The Woomera Range head is located approximately 300 miles north of Adalaide, Australia. The entire range provides for 1250 mile trajectories (over land), but the actual land trajectory of the Black Knight missile is only 65 miles as the missile is fired almost vertically. A map of Woomera Range relative to Adalaide and the Australian site is shown in Figure 1. The climatic conditions on the Woomera Range are those of a desert. The average rainfall amounts to about seven (7) inches which often times may fall as low as one and one-half inches per year. Temperatures range from 85 to 103 degrees at Woomera in December, which is summer in the southern hemisphere, to temperatures of 50 to 70 degrees during their winter months. The atmospheric conditions are excellent for optical measurements with transmission in the visible region of the spectrum generally better than 85 percent. Stars are often seen at altitudes of less than one degree from the horizon.

2. (U) The town of Woomera has a population of more than 4,000 people, and is located about five miles from Pimba on the Trans-Australian Railway. A spur line runs from Pimba to Woomera.

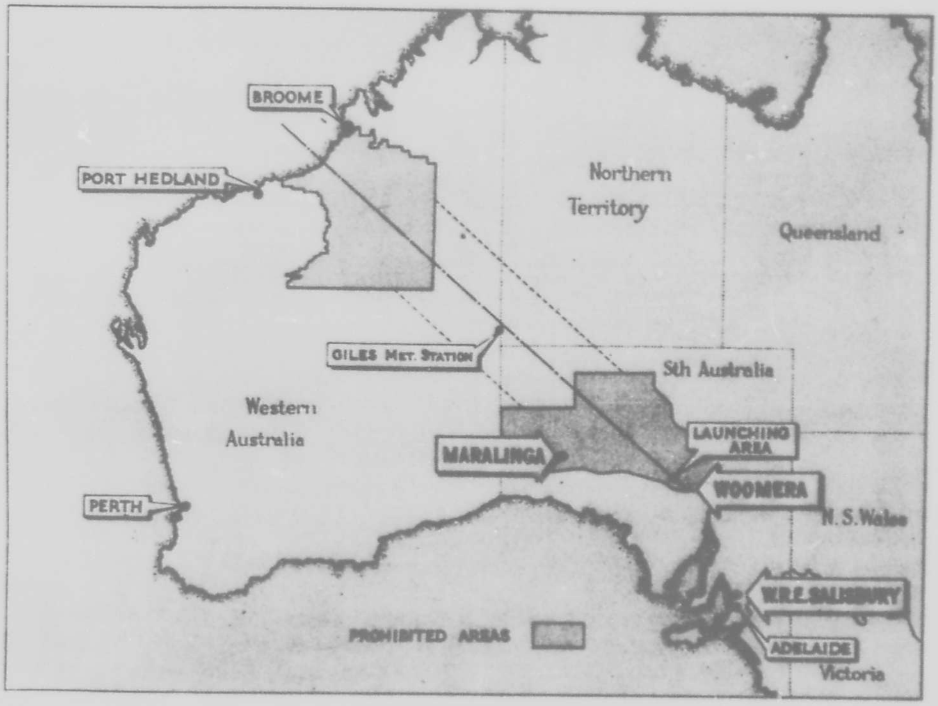


FIG. 1 MAP OF WOOMERA RANGE RELATIVE TO ADELAIDE AND WESTERN AUSTRALIA

3. (U) The Black Knight firing range is approximately 65 miles in horizontal length over a red sand desert. A typical scene over the range is shown in Figure 2. A map of the range used for the Black Knight firings is shown in Figure 3.

4. (C) Due to the favorable weather conditions over the Woomera Range, the British have placed considerable reliance on optical systems to take advantage of the much superior discrimination of optics over radio wavelength devices. Because of the preponderance of the optical devices, practically all of the Black Knight firings are planned to be during the hours of darkness. Prior to burn-out, the orthodox cinethedolite cameras are employed. For the accurate determination of the velocity and altitude after burn-out, ballistic cameras are used to photograph pyrotechnic or electronic flashes from the missile. Accurate timing of these flashes is determined by vehicle-borne and ground detector instruments located at several positions. During re-entry, optical tracking is again employed.

5. (C) In addition to the optical instruments on the range there also exists guidance radar which furnishes fairly good lateral data and launch data during the burning phase. Sound location stations are installed around the impact area to determine acoustically the point of re-entry into the atmosphere. To accomplish this accurately, demands a knowledge of the wind structure through the atmosphere as well as the temperature profile.

6. (C) Four-hundred and sixty-five (465) MC/S telemetry recorders are installed near the launching site on the Instrument Building. These are used to track the missile on ascent and during re-entry phase. For ascent, fixed antennae are used and for re-entry a series of narrow beam arrays are used. A four-hundred and sixty-five (465) MC/S receiver at Mt. Eba is also equipped to cover the re-entry phase. To cover from burn-out at 80 miles to apogee at 500 miles, two stations are employed at Salisbury, some 300 miles from the launcher and are equipped with automatic tracking horn antennae.

IV. BLACK KNIGHT MISSILE.

1. (C) The Black Knight Missile was developed by the British to enable their research and range establishements to perform applied research for the development of the military Blue Streak Missile. The missile was constructed such that its performance could be comparable with the weapon, but would be smaller and less expensive, enabling tests to be made under more flexible conditions and with greater economy than with the weapon itself.

2. (C) The scope of the experimental work planned for the Black Knight included problems of high speed aerodynamics, with special emphasis on the re-entry phase, control and guidance research, some aspects of propulsion, testing of systems and equipment in representative environments, the development of instrumentation and

FIGURE 2 TYPICAL DESERT SCENE OF WOOMERA RANGE

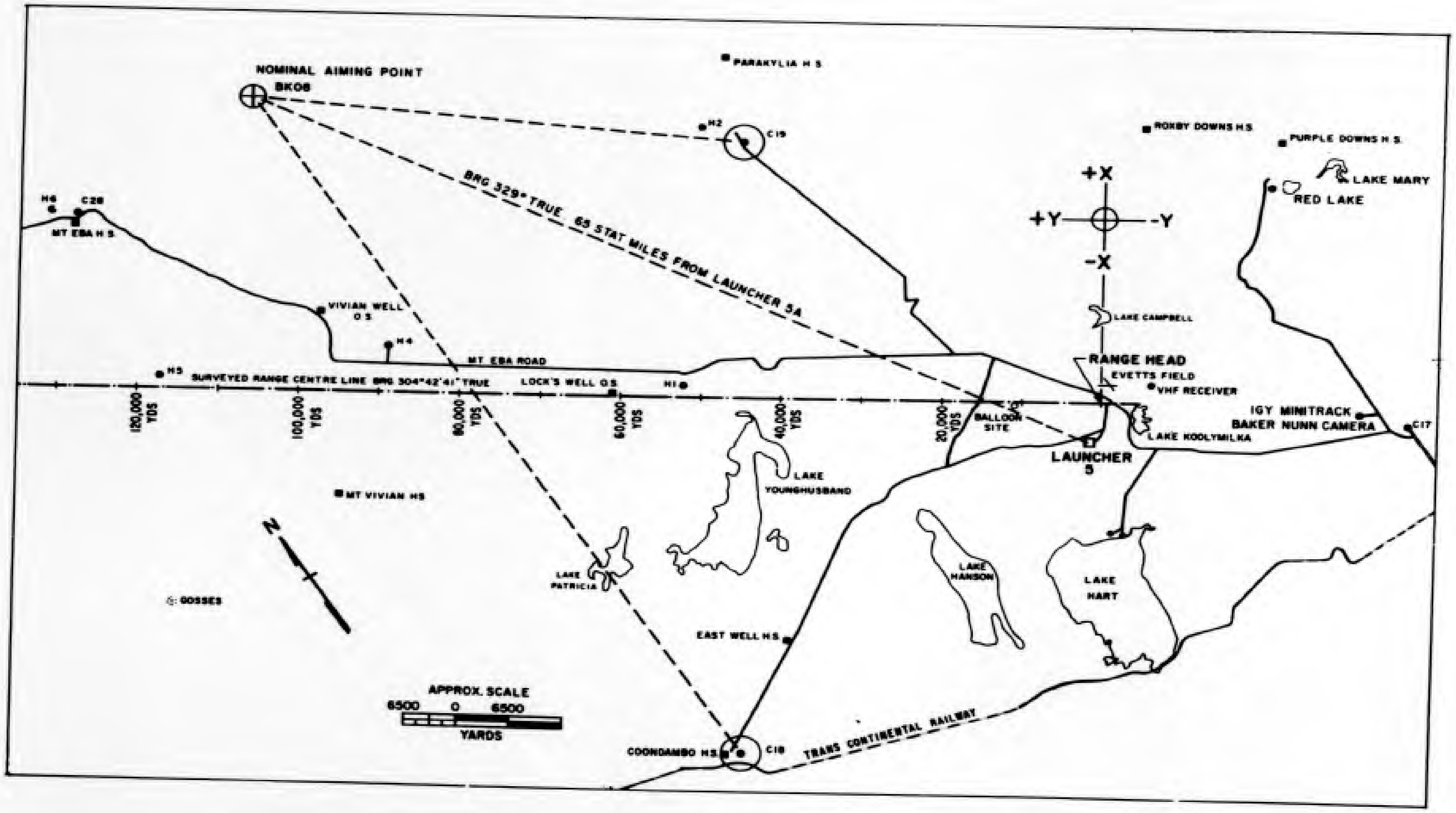


FIGURE 3 MAP OF WOOMERA RANGE USED FOR BLACK KNIGHT FIRINGS

range techniques, and the accumulation of designs and test experience in the high performance ballistic missile field. The re-entry velocities specified ranged from 10,000 to 18,000 feet per second, which was planned to be typical of the Blue Streak re-entry velocities.

3. (C) The British conducted a study program of all of their existing rocket engines to determine which of the available engines could produce the type of performance desired for the Black Knight missile. This study showed that their Gamma engine could be arranged to give burn-out velocities of 12,000 feet per second with a re-entry nose cone of 200 pounds and an instrumentation payload of 650 pounds. The instrumentation payload was carried for guidance system and component tests. For larger payloads, the 650 pounds instrumentation could be replaced by an additional solid propellant stage to provide re-entry speeds of about 17,000 feet per second for a 100 pound nose cone.

4. (C) The Gamma motor consists basically of two combustion chambers, each supplied by its own fuel and oxidant turbopumps. These pumps are driven by steam derived by catalytic decomposition of a fraction of the main hydrogen peroxide (H. T. P.) supply. Each chamber has a thrust of 4,000 pounds at sea level.

5. (C) The engine was designed for aircraft use so that its life-time was much in access of the ballistic missile requirement. The 16,000 pound thrust required to give the Black Knight the pre-described performance was obtained by the use of a four chamber design. A schematic diagram of the engine is shown in Figure 4. The weight breakdown of the missile is shown in Table I.

6. (C) The combustion chamber is re-regeneratively cooled by the oxidant which is an 85 percent concentration of hydrogen peroxide. The chamber is comprised of an outer jacket and an inner jacket, with filling pieces around the inner jacket to provide a controlled cooling gap. Before entering into the combustion chamber, the H. T. P. is decomposed into steam and oxygen in a catalyst pack at the top of the chamber. This pack is built up of silver plated nickel gauge discs. Kerosene is the fuel used and the engine is operated at a nominal oxidant/fuel mixture ratio of 8 to 1.

7. (C) The Royal Aircraft Establishment specified that the Gamma II engine should have a specific impulse of not less than 206 seconds using H. T. P. with a concentration of 85 percent and kerosene. The thrust was required to be maintained at 16,000 pounds (at sea level) to within + 5% to - 0%, while the vacuum pressure at the turbine inlets varied throughout the range estimated for the flight of the Black Knight. A requirement was made that the engine must have a life of 10 to 15 minutes at full operating thrust to cover initial calibration and static testing of the complete vehicle.

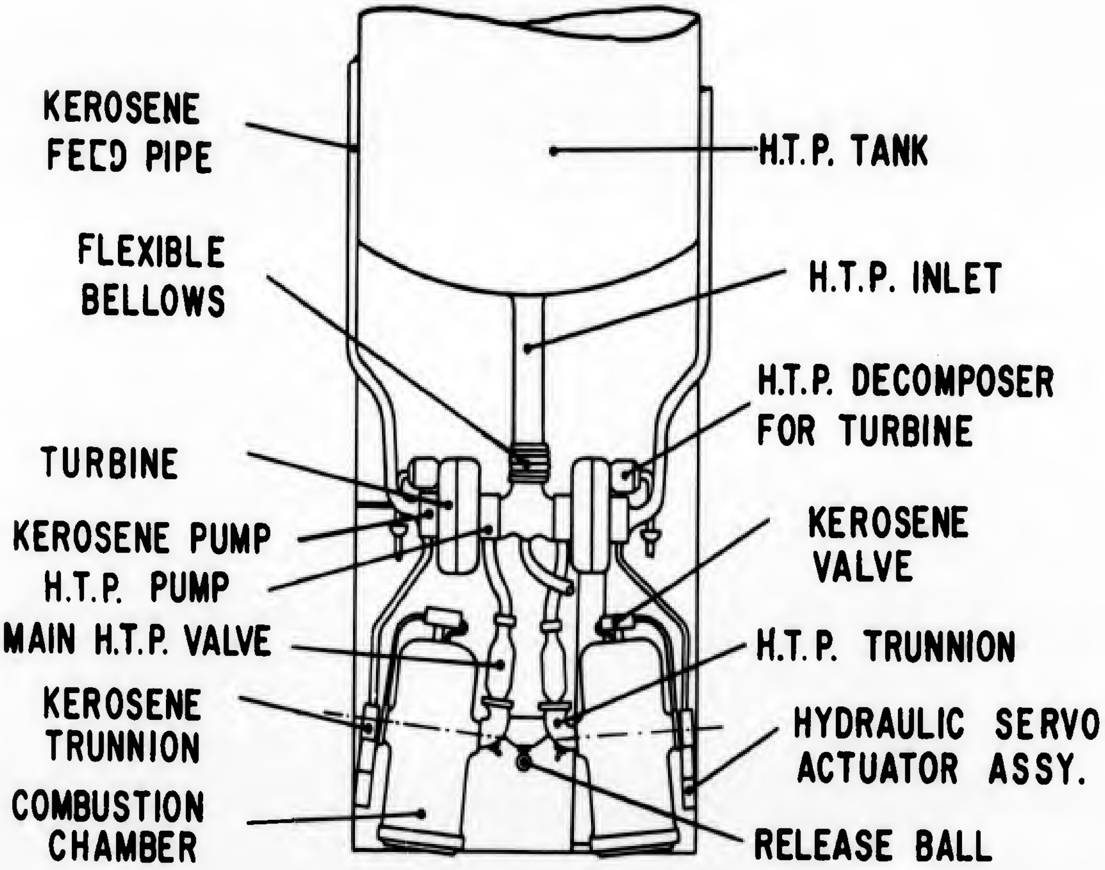


FIGURE 4 SCHEMATIC DIAGRAM OF GAMMA ENGINE

TABLE I

WEIGHT BREAKDOWN FOR SINGLE STAGE BLACK KNIGHT

STRUCTURE	
Tanks	150 lbs.
Propulsion Bay	51 lbs.
Head Ejection Bay	10 lbs.
TOTAL	211 lbs.
ENGINES	
Combustion Chambers and Trunnions	280 lbs.
Pumps, including steam generators and H. T. P. valves	160 lbs.
TOTAL	440 lbs.
FUEL SYSTEM	
Pipework and Pressurization Equipment	70 lbs.
CONTROL SYSTEM	
Oil pump and drive, valves and jacks, reservoir, accumulator, servo amplifiers and auto pilot gyros	65 lbs.
Electrical power supplies	25 lbs.
INSTRUMENTATION	
Main body telemetry, command break up receiver, radar transponder	58 lbs.
Unburnt propellants	50 lbs.
Head and Payload	200 lbs.
PROPELLANTS	
H. T. P.	9,938 lbs.
Kerosene	1,242 lbs.
TOTAL	11,180 lbs.
Take-off weight	12,299 lbs.
Weight at end of burning	1,119 lbs.

8. (C) The single stage Black Knight missile as it appears on the launching pad at Woomera is shown in Figure 5. A schematic diagram of the Black Knight Missile is shown in Figure 6. The vehicle is made up of the following units:

a. The main body assembly consisting of ejection bay, electronics bay, fuel tank, intertank bay and H. T. P. tank.

b. The propulsion bay.

c. Fins and fin pods.

d. Re-entry head, or second stage assembly.

The re-entry head on the single stage version is ejected at burn-out by circumferential row of springs after release of two explosive bolts.

9. (C) After initial testing, the Black Knight missile was assigned the task of gathering re-entry data. Four basic re-entry nose cones have been designed and constructed by the British.

a. A double nose cone designed for testing of erodible materials such as durestos and graphite.

b. A 40 degree conical head to provide techniques and a standard for later experiments.

c. A re-entry head to be used with the two-stage missile for re-entry velocities near 17,500 feet per second.

d. A heat-sink nose cone.

These nose cones are shown in Figure 7.

10. (C) The performance of the Black Knight was extended to be comparable with the Blue Streak missile by the design of a two-stage configuration. The two-stage configuration of the Black Knight is such that the Cuckoo motor consists of a solid propellant stage with a re-entry nose cone attached in an inverted position as is shown in Figure 8. The main characteristics of the Black Knight two-stage configuration is shown in Table II.

11. (C) The single-stage Black Knight has a maximum altitude of about 500 miles. Because of the increased weight of the second stage Cuckoo motor, the two-stage configuration has a maximum altitude of 350 miles. A typical vertical cross-section of a single-stage Black Knight missile trajectory is shown in Figure 9. It is worth noting that the flight time of the Black Knight missile is very similar to that of a U. S. IRBM missile. Because of the short horizontal range, it is possible to obtain both launch and re-entry data from the same

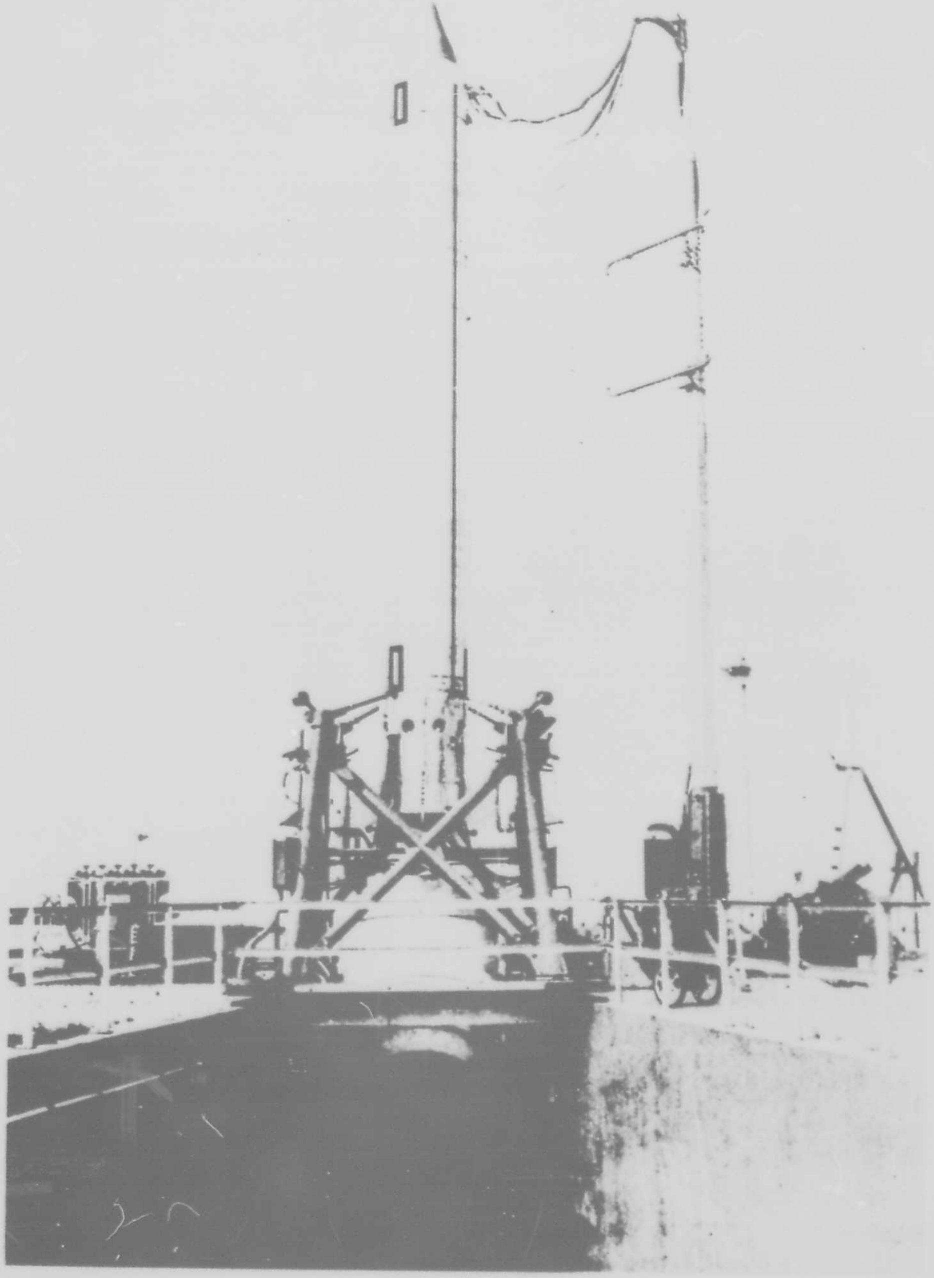


FIGURE 5 SINGLE STAGE BLACK KNIGHT MISSILE ON LAUNCHING PAD

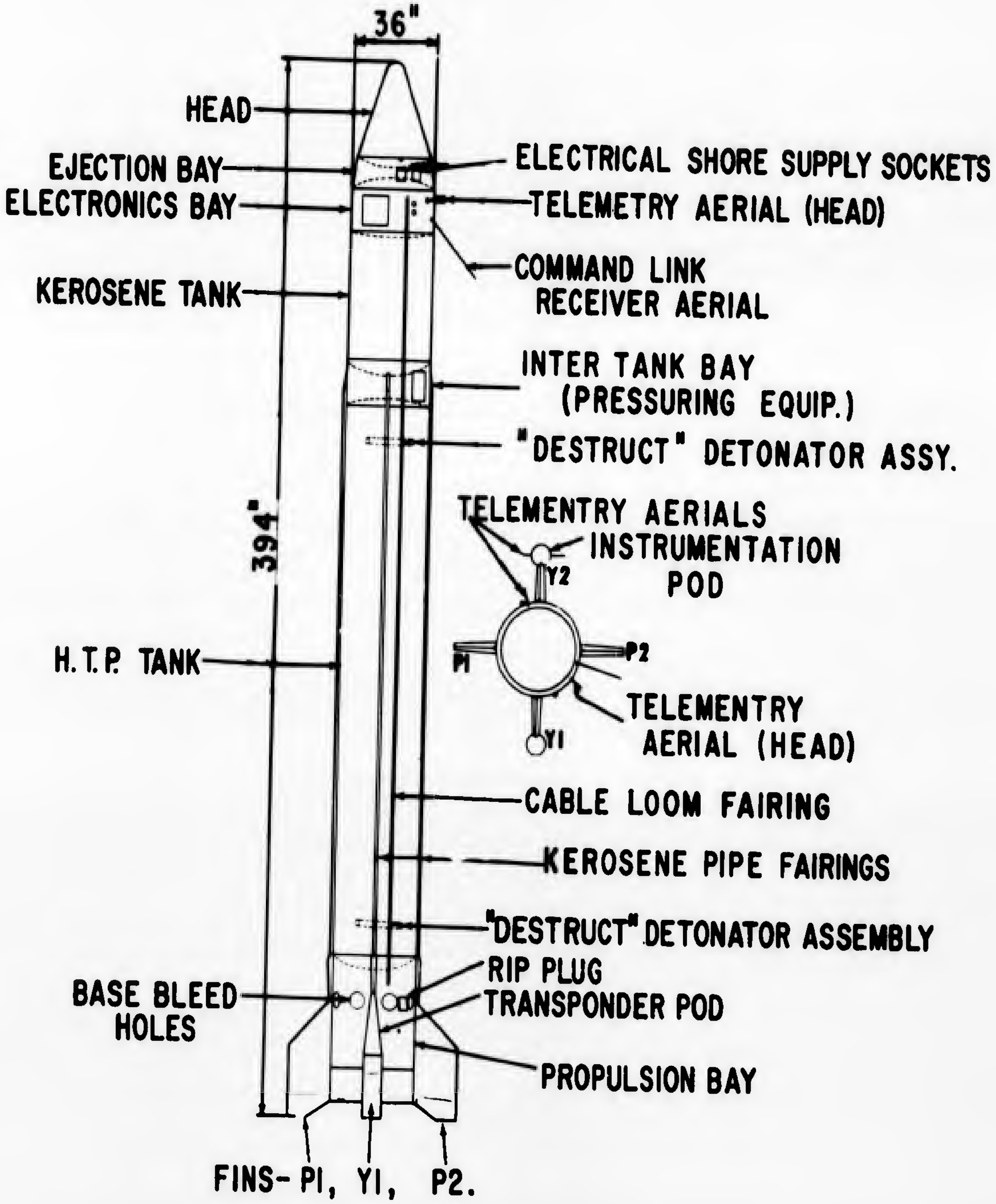


FIGURE 6 SCHEMATIC DRAWING OF SINGLE STAGE BLACK KNIGHT MISSILE

TABLE II

DRAG AND PERFORMANCE FOR A TWO-STAGE BLACK KNIGHT MISSILE

MAIN STAGE CHARACTERISTICS

Sea level thrust	16,150 lb
Take-off weight (all up)	12,750 lb
Burn-out weight, including second stage	1,919 lb
Burn-out velocity of first stage with heavier payload	9,000 ft/sec

CUCKOO MOTOR CHARACTERISTICS

Sea level S. I.	218 sec.
Charge weight	400 lb
Case venturi weight	124 lb
Vacuum S. I.	240 sec.

SECOND STAGE CHARACTERISTICS

Separation weight of second stage	624 lb
Payload weight of second stage (including separation equip. and instrumentation external to re-entry nose cone)	100 lb

TRAJECTORY

Burn-out altitude of first stage of propulsion	325,000 ft
Apogee (for 200 mile range)	315 miles
Ignition altitude of second stage	325,000 ft
Second stage burn-out velocity	17,480 ft/sec
Burn-out height	230,000 ft
Approximate flight time from launch to re-entry	770 sec.

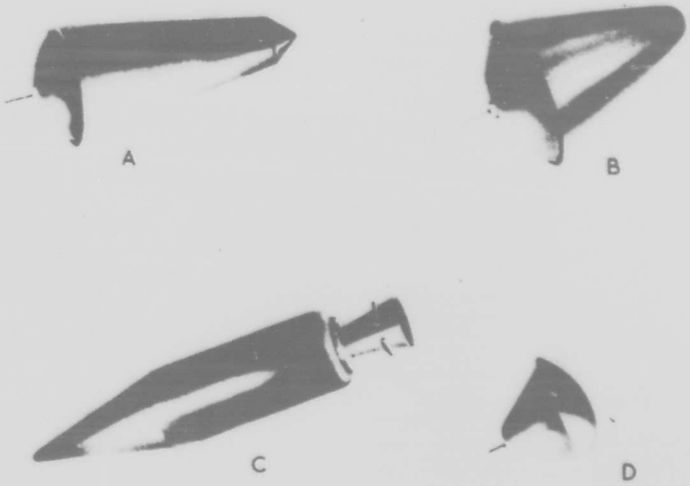


FIGURE 7 TYPICAL BLACK KNIGHT RE-ENTRY NOSE CONES

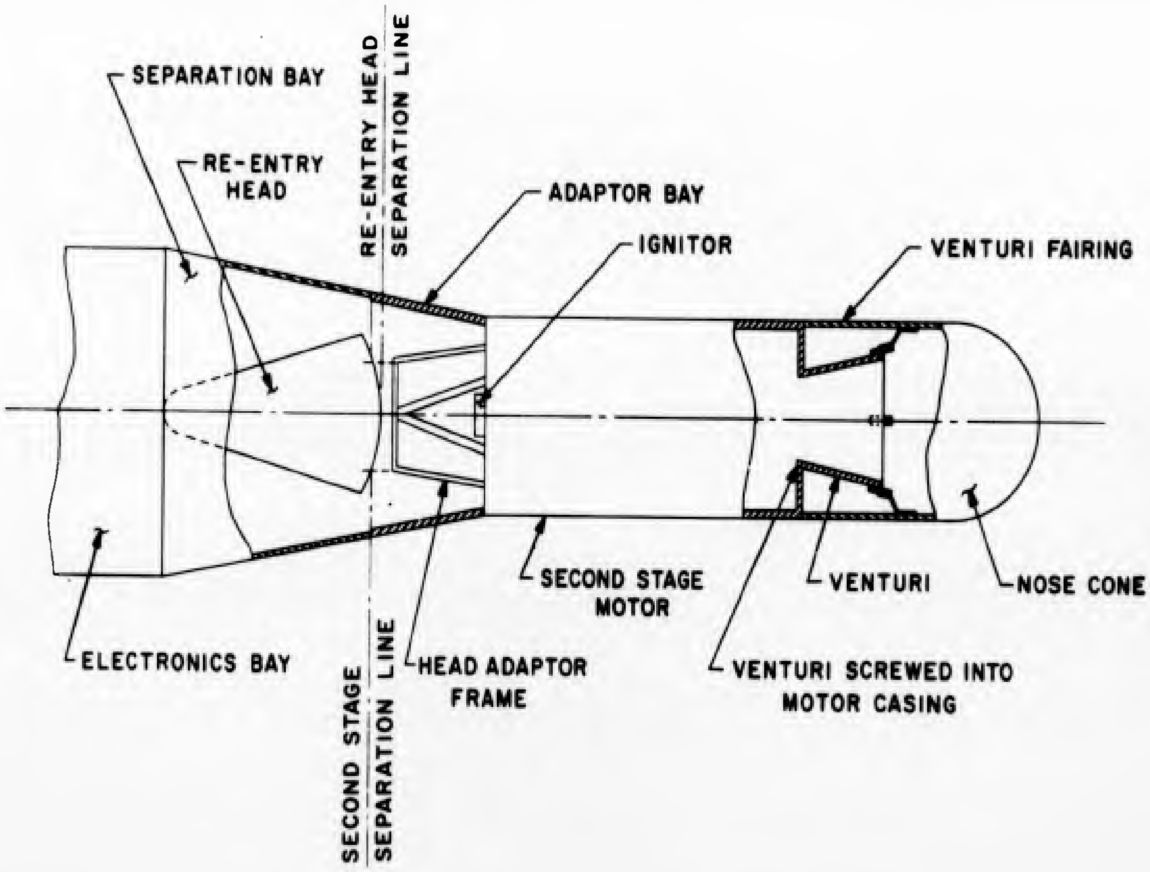
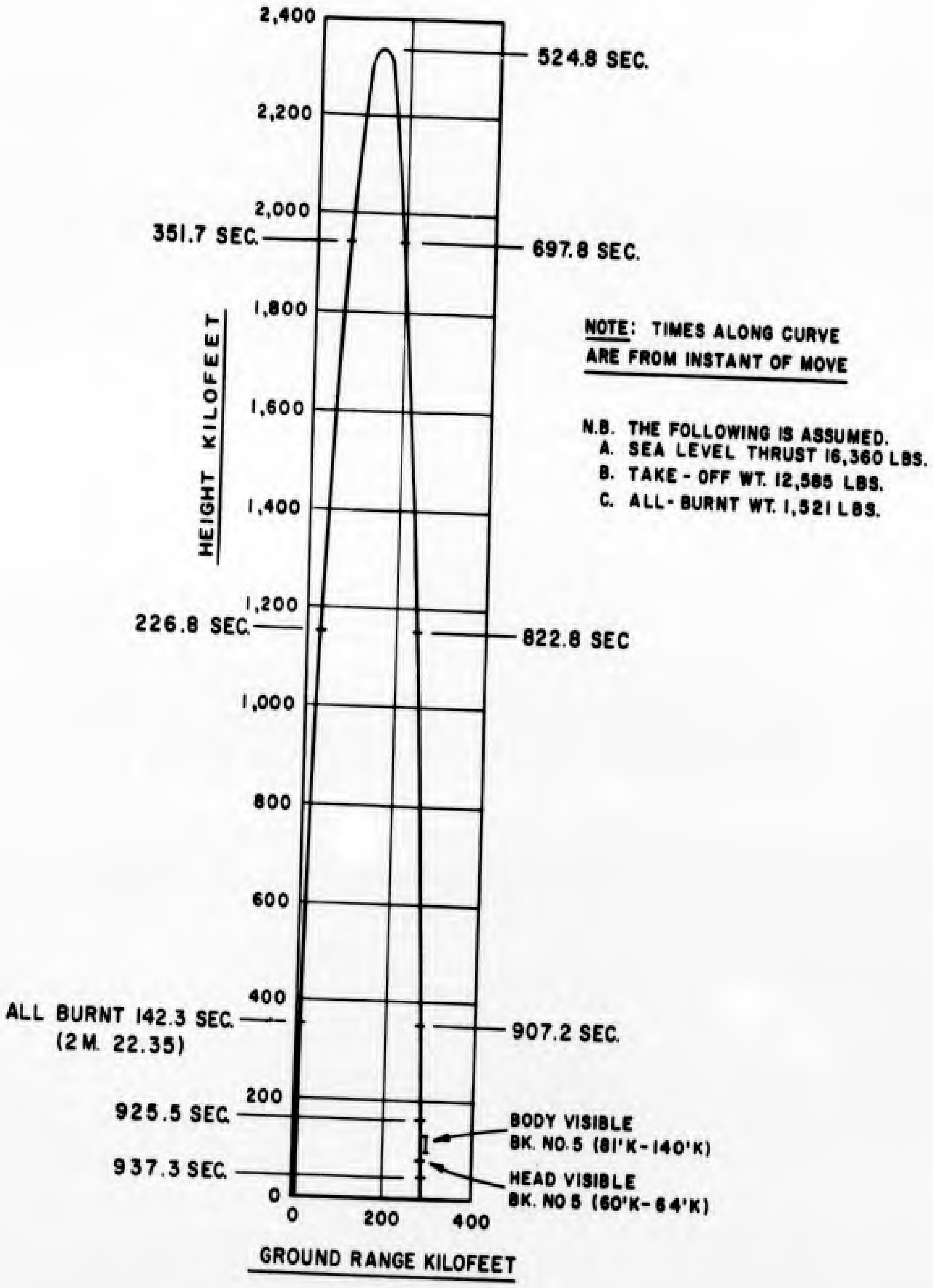


FIGURE 8 SECOND STAGE CUCKOO MOTOR AND RE-ENTRY HEAD ASSEMBLY



NOTE: TIMES ALONG CURVE ARE FROM INSTANT OF MOVE

N.B. THE FOLLOWING IS ASSUMED.
- A. SEA LEVEL THRUST 16,360 LBS.
- B. TAKE - OFF WT. 12,585 LBS.
- C. ALL - BURNT WT. 1,521 LBS.

FIGURE 9
TYPICAL VERTICAL CROSS SECTION OF SINGLE STAGE BLACK KNIGHT MISSILE TRAJECTORY

instrumentation site. This type of trajectory also provides the opportunity to make radiation measurements during mid-course of the missile's flight.

12. (C) The second stage Cuckoo motor is fired just prior to re-entry of the nose cone. Ignition just before re-entry, produces the same maximum re-entry speed as would be obtained by igniting the stage on ascent soon after the first stage burn-out, but has the great advantage of limiting range, height, and dispersion. A higher velocity can be obtained by igniting the Cuckoo motor just prior to re-entry than at apogee. This fact can be shown as follows.

13. (U) Consider case one in which the Cuckoo motor is fired at apogee.

Let

M_1 = mass of ejected gases during burning phase

U_1 = velocity of ejected gases

M_2 = mass of nose cone plus Cuckoo Motor

U_2 = velocity of nose cone and Cuckoo Motor due to ejected gases

From the conservation of momentum

$$M_1U_1 = M_2U_2$$

The total kinetic energy produced by the propellant is:

$$1/2\ M_1U_1^2 + 1/2\ M_2U_2^2$$

First consider the Cuckoo Motor fired at apogee.

The velocity of any object in free fall is given by:

$$v^2 = v_0^2 + 2gs$$

where

v = velocity at any given height

v_0 = velocity at some initial height

g = acceleration due to gravity

s = distance between the height of v and the height of v_0

The velocity of M_2 at re-entry altitudes will be given by:

$$\mathcal{V}_2 = (U_2^2 + 2\ gs)^{1/2}$$

This assumes that velocity U_2 is provided nearly instantaneously at apogee. The velocity of the ejected gases at this height can be expressed as:

$$\mathcal{V}_1 = (U_1^2 + 2\ g\ s)^{1/2}$$

14. In the second case, if the Cuckoo motor is fired just prior to re-entry the total mass of the nose cone, Cuckoo motor, and propellant will have the velocity of:

$$\mathcal{V}_3 = (2\ gs)^{1/2}$$

before the Cuckoo motor is fired. Additional velocities of U_1, and U_2 are then given to M_1 and M_2 so that they then would have:

$$\mathcal{V}_1 = (2\ gs)^{1/2} + U_1$$

and $$\mathcal{V}_2 = (2\ gs)^{1/2} + U_2$$

Now

$$(2gs)^{1/2} + U_2 > (2gs + U_2^2)^{1/2}$$

So greater velocities will be obtained by firing the Cuckoo Motor as close to re-entry as possible.

The total kinetic energy in both cases are the same.

Case I:

$$\text{Total KE} = 1/2\ M_1(U_1^2 + 2gs) + 1/2M_2(U_2^2 + 2gs)$$

$$\text{or KE} = 1/2\ M_1U_1^2 + 1/2\ M_2U_2^2 + (M_1 + M_2)\ gs$$

Case II:

$$\text{Total KE} = 1/2\ M_1 \left[(2gs)^{1/2} - U_1\right]^2 + 1/2M_2 \left[(2gs)^{1/2} + U_2\right]^2$$

$$\text{or}\quad \text{KE} = (M_1 + M_2)\ gs + 1/2M_1U_1^2 + 1/2\ M_2U_2^2 - M_1U_1(2gs)^{1/2} + M_2U_2(2gs)^{1/2}$$

From the conservation of momentum:

$$M_1U_1 = M_2U_2$$

So

$$KE = (M_1 \quad M_2)\ gs \quad 1/2M_1U_1^2 \quad 1/2\ M_2U_2^2$$

which is the same as given in Case I.

15. (U) A comparison of the British Black Knight Missile with a number of the American missiles is shown in Table III.

V OPERATION GASLIGHT EQUIPMENT.

1. (C) In March of 1960, the equipment generated under Operation Gaslight by Barnes Engineering Company was shipped to Sidney, Australia and thence to Woomera. The equipment was then split between the observation sights of Coondambo (C18) and Parakylia (C19) according to the planning specifications drawn up by the Weapons Research Establishment at Salisbury. These stations are shown in Figure 3. The equipment at Coondambo was as follows:

a. One 4RK1 radiometer with a lead sulphide detector package and a reticle chopper to obtain data in the 1.8 to 2.7 micron region of the electromagnetic spectrum.

b. One 35mm Eyemo camera with a transmission grating in front of the lens and using TRI/X film.

c. One 16mm GSAP camera used as a bore-sight camera.

d. Two spectroballistic cameras with Bausch and Lomb transmission gratings having 300 lines per mm blazed for 6,000 Å in the first order and using high speed infrared film.

2. (C) At Parakylia the following equipment was installed:

a. One 4RK1 radiometer with a lead sulphide detector package and with a reticle chopper to obtain data on the 1.8 to 2.7 micron region.

b. One 35mm Eyemo camera with a wedge in front of the lens to give multiple image TRI/X on the film. The purpose of this camera was to eliminate the loss of data of film due to halation.

c. One 16 mm GSAP camera used as a bore-sight camera.

d. One four-barrel photometer with the following characteristics:

Channel	RCA Tube	Filter	Width
1	6217	5850 Å	99 Å

Channel	RCA Tube	Filter	Width
2	7102	7915 Å	105 Å
3	6217	6825 Å	105 Å
4	6903	4205 Å	99 Å

e. Four spectroballistic cameras with Bausch and Lomb transmission gratings of 300 lines per milimeter blazed for 6,000 Å in the first order and using TRI/X film.

3. (C) Appropriate timing and recording equipment was located at each of the sites. Figure 10 shows the Parakylia observation site. The Gaslight equipment and the caravan, which was supplied by the Australians to house the timing and recording gear, are located in the center of the picture nearest the location of the camera. The dome shaped structure to the right and above the Gaslight equipment is the housing for a BC-4 Ballistic Camera. A number of similar KC-3 Ballistic Cameras can be seen around the housing for the BC-4 camera. The caravans to the left and above the Gaslight equipment hold several Hulcher cameras. The caravans just behind the Gaslight equipment are the power, communication and telemetry receiving vans. The station is approximately 45 miles from the launch point and about 30 miles from the impact area. Figure 11 shows the Gaslight equipment in position for a re-entry experiment. The Australians had laid a cement pad for the instrumentation caravan and for the Mark 51 Gun Director. Figure 12 shows a close-up view of four of the spectral ballistic cameras. The blade type structure in the picture is a chopper so designed as to give relative time on the resulting images. The BC-4 camera housing and the KF-3 ballistic cameras can be observed above the ballistic cameras. The caravan directly above the ballistic camera with the door open is a portable dark room. Figure 13 shows the equipment on the Mark 51 Gun Director. A small camera on the left hand side of the picture is a bore-sight GSAP. The radiometer is next to the right. The radiometer is designed such that either a lead sulphide or thermistor detector package can be inserted. The next scope to the right is the tracking scope of the Mark 51 Gun Director. The next camera is a 35mm Eyemo with a wedge in front of the lens. This wedge causes multiple images of reduced intensity to be simultaneously focused on the film. The four-barrell photometer is located farthest to the right on the Mark 51 Gun Director. Figure 14 shows the instrument inside the caravan. These include the timing apparatus recording gear and a tape recorder.

TABLE III

CHARACTERISTICS OF BALLISTIC MISSILES AVAILABLE FOR U. S. BALLISTIC MISSILE DEFENSE STUDY

Missile	Range NM	Max Altitude NM	Nose Cone		Re-Entry Velocity fps	Impact Area	Time
			Dia Ft	Material			
JUPITER IRBM	1500	350	6	Ablative	14,000	Antigua	CY 60
THOR IRBM	1500	350	6	Heat Sink	14,000	Antigua	CY 60
POLARIS IRBM	900/ 1200	300	2	Heat Sink	12,000	AMR	CY 60
ATLAS & TITAN ICBM	5500	800	10	Ablative	24,000	Ascension Eniwetok	CY 60
NASA D-58 (5" Sphere)	100	200	5"	Sphere Various metals	14,000 24,000	Wallops Island	CY 60
BLACK KNIGHT	65	500	3 1.5	Heat Sink & Ablative	11,000 20,000	Woomera	CY 60/61

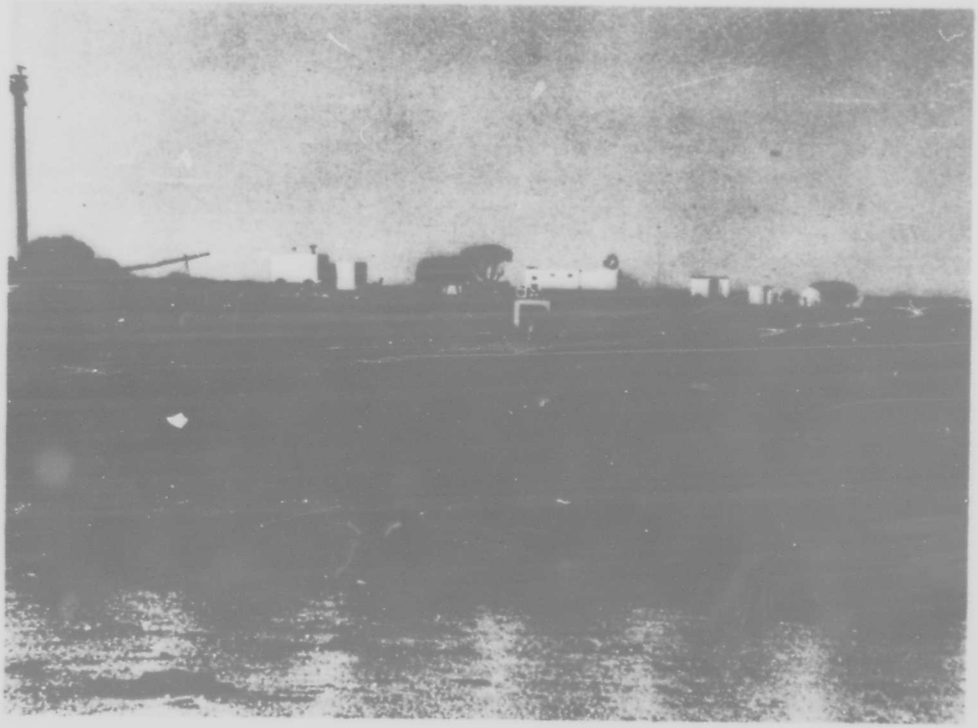


FIGURE 10 PARAKYLIA INSTRUMENTATION SITE

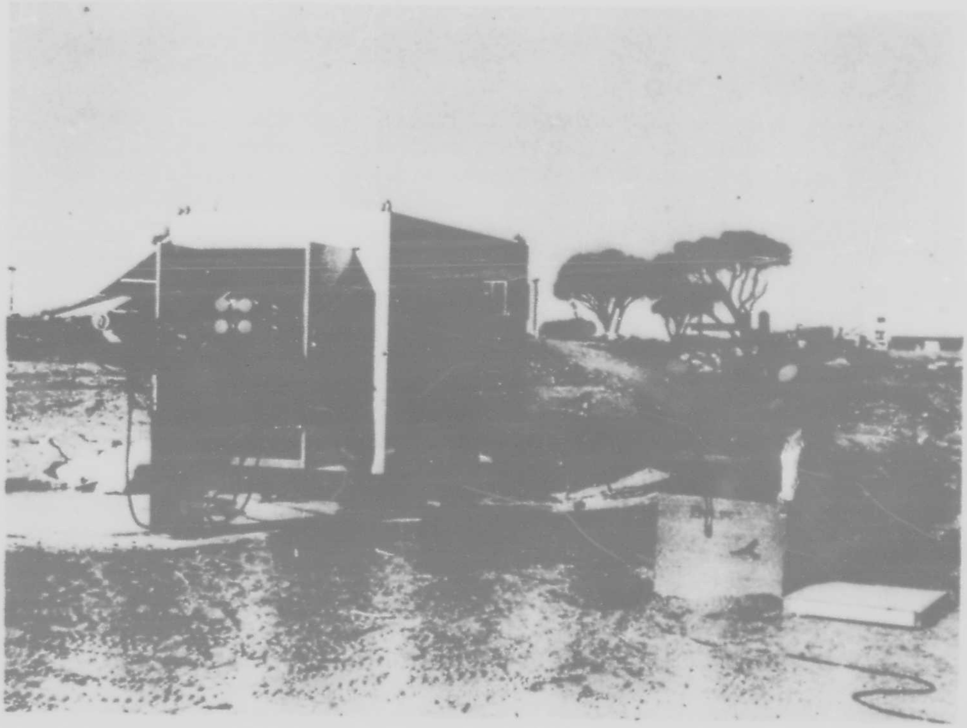


FIGURE 11 GASLIGHT EQUIPMENT IN POSITION AT PARAKYLIA

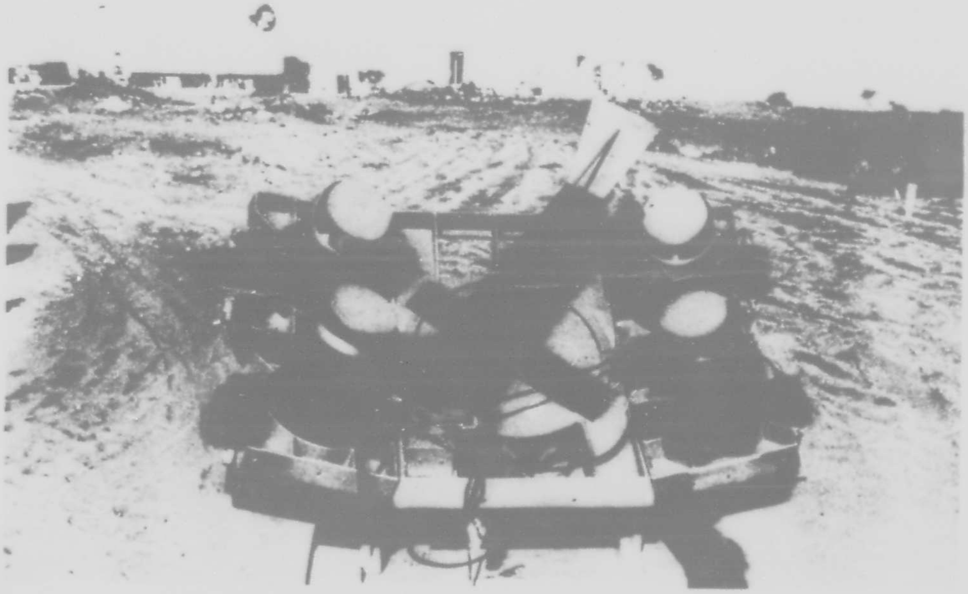


FIGURE 12 SPECTRA BALLISTIC CAMERAS AT PARAKYLIA

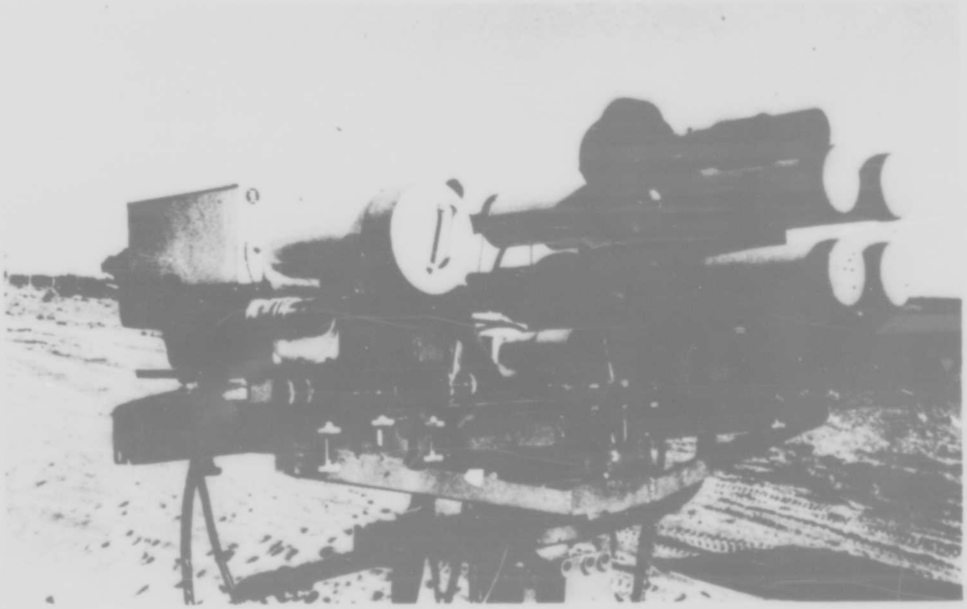


FIGURE 13 GASLIGHT EQUIPMENT ON MARK 51 GUN DIRECTOR AT PARAKYLIA

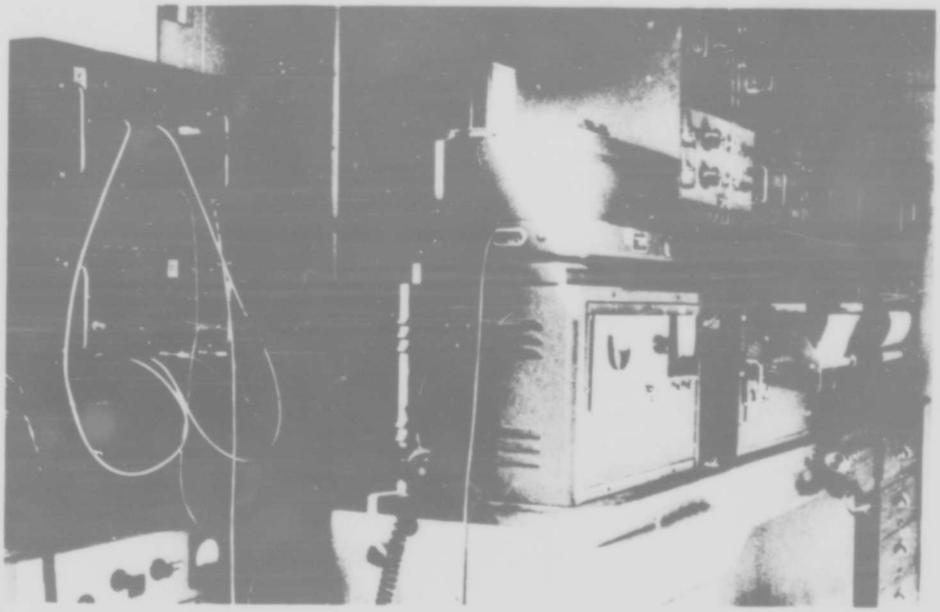


FIG. 14 RECORDING AND TIMING INSTRUMENTATION IN CARAVAN AT PARAKYLIA

4. (U) Dr. Peter Crosby of the Weapons Research Establishment, Salisbury, Australia, has calibrated the Gaslight equipment on the Woomera Range and has constructed a series of nomographs such that it is possible to estimate the apparent temperature of an object measured by the equipment. Figure 15 shows his calculations of the radiance emitted by a black body in watts per angstrom per centimeter for temperatures in the re-entry range for various wavelengths. It is most interesting to note that for objects with a temperature in the range of 500 degrees kelvin, the radiance in the 5.0 micron to 10.0 micron region, is of the order of magnitude of the radiance of 0.4 microns for a body of 2,000 degrees kelvin.

5. (C) Figure 16 shows the results of Dr. Crosby's calculations on the ability of the unaided eye, a 10 power binocular and a Baker Nunn camera to observe the re-entry of a body at various temperatures. The horizontal line represents the threshold of the various instruments. This is based upon an object with an emissivity of 0.5 and a surface area of about 7,000 square centimeters. These calculations also are assuming a range distance of approximately 40 miles from the observing instrument to the re-entering object. This is the approximate distance from the Parakylia instrument site to the re-entry point. It should be noted that while the 40 miles is the actual distance from the equipment located at Parakylia, the Baker Nunn camera which is located at the I. G. Y. minitrack station, has an actual distance of approximately 80 miles to the re-entry point. Because of this fact, the actual observability curve of the Baker Nunn camera would be moved to the right on Figure 16. This would mean that the Baker Nunn camera should certainly observe a re-entering object when it reaches the temperature of slightly more than 1,100 degrees kelvin, at a range of about 80 miles. This corresponds to the Baker Nunn ability to observe an eleventh magnitude star. The threshold line on the nomograph can easily be adjusted for various surface areas, emissivity and relative performance above or below those assumed. No reduction in the irradiance due to atmospheric attenuation was used in the calculations.

6. (C) Dr. Crosby has performed similar calculations for the radiometers, photometers, and spectroballistic cameras located at Parakylia. Figure 17 shows the nomograph for the radiometers at Parakylia and at Coondambo. The lead sulphide detector in each of the instruments, has been found to be of different sensitivity. The distance from the instruments to the re-entry object has again been assumed to be 40 miles. The horizontal line in the center of the graph on Figure 17 is set to represent the energy received by the radiometers to cause a two (2) milimeter deflection on a 50 micro-volt per centimeter scale. It is interesting to note that if the radiometer at Coondambo were located at the Parakylia, it should be able to detect the re-entry object of the prescribed emissivity and surface area at about 950 degrees kelvin. The actual radiometer at Parakylia would not detect the same object until it reached 1,200 degrees kelvin.

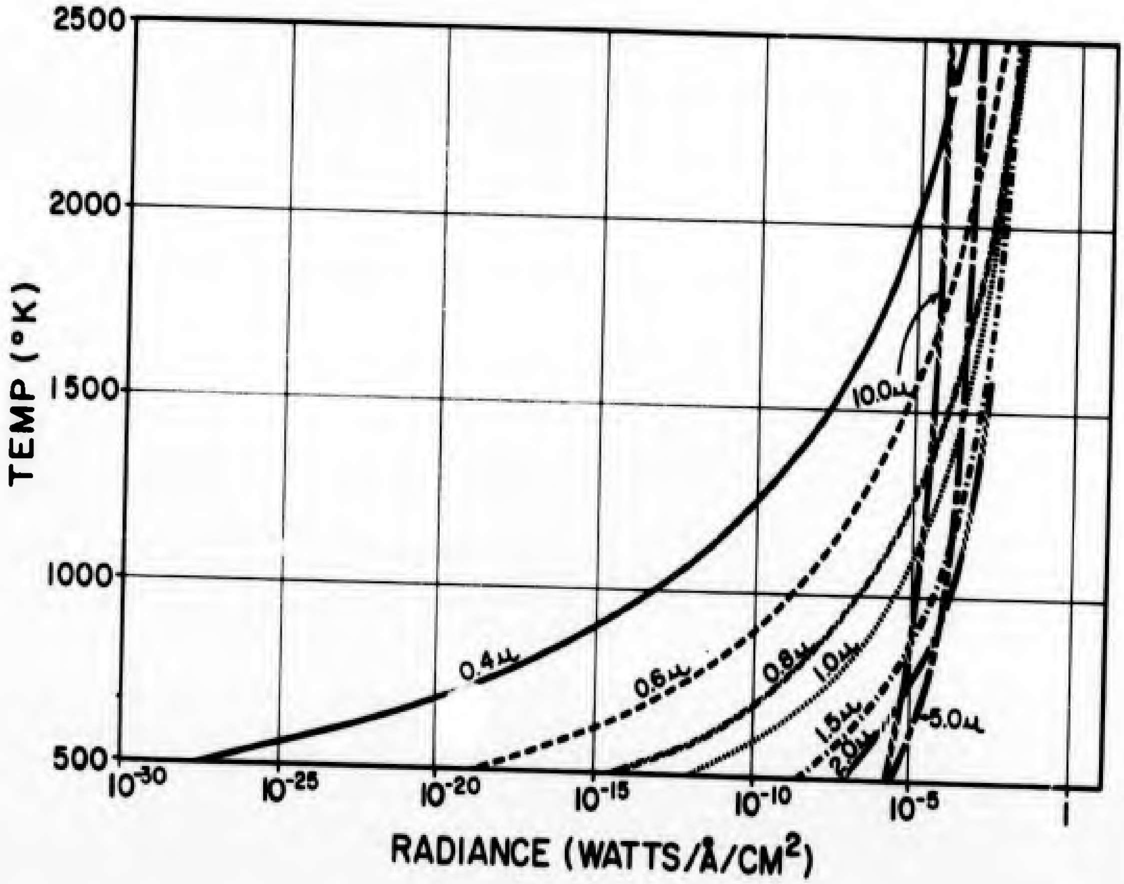


FIGURE 15 BLACK BODY RADIANT INTENSITY CURVES

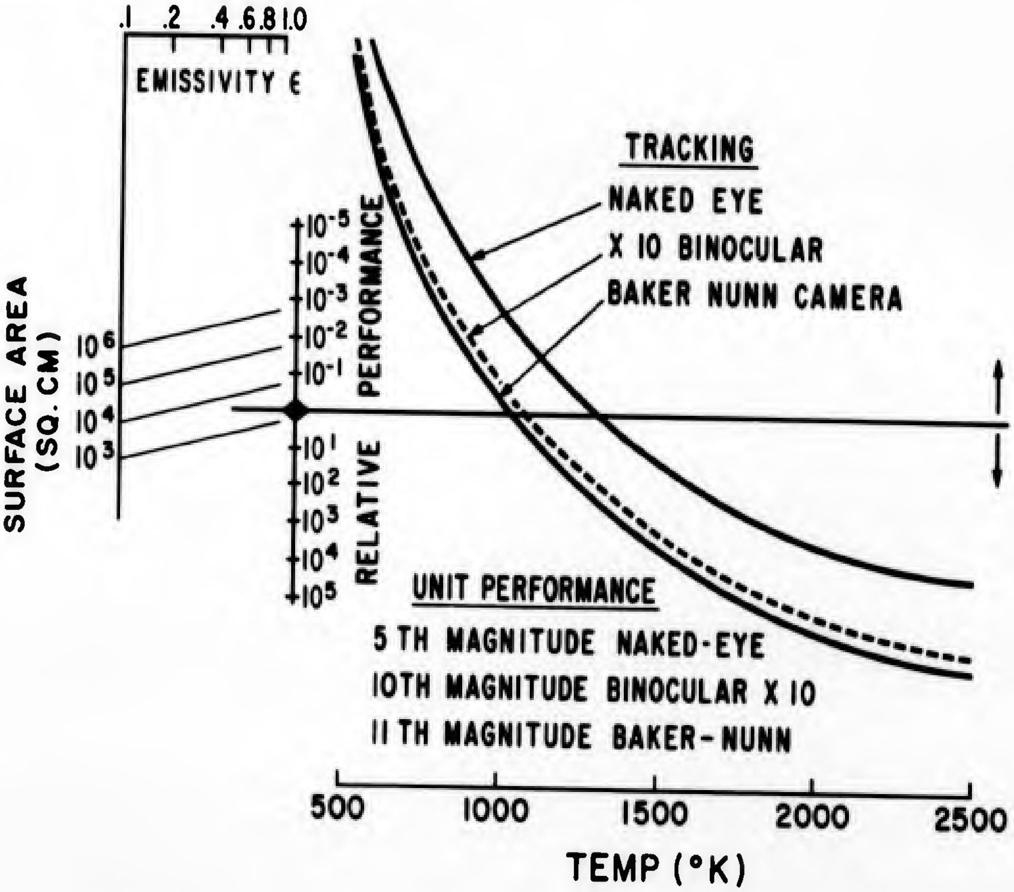


FIGURE 16 RELATIVE PERFORMANCE CURVES FOR THE NAKED EYE

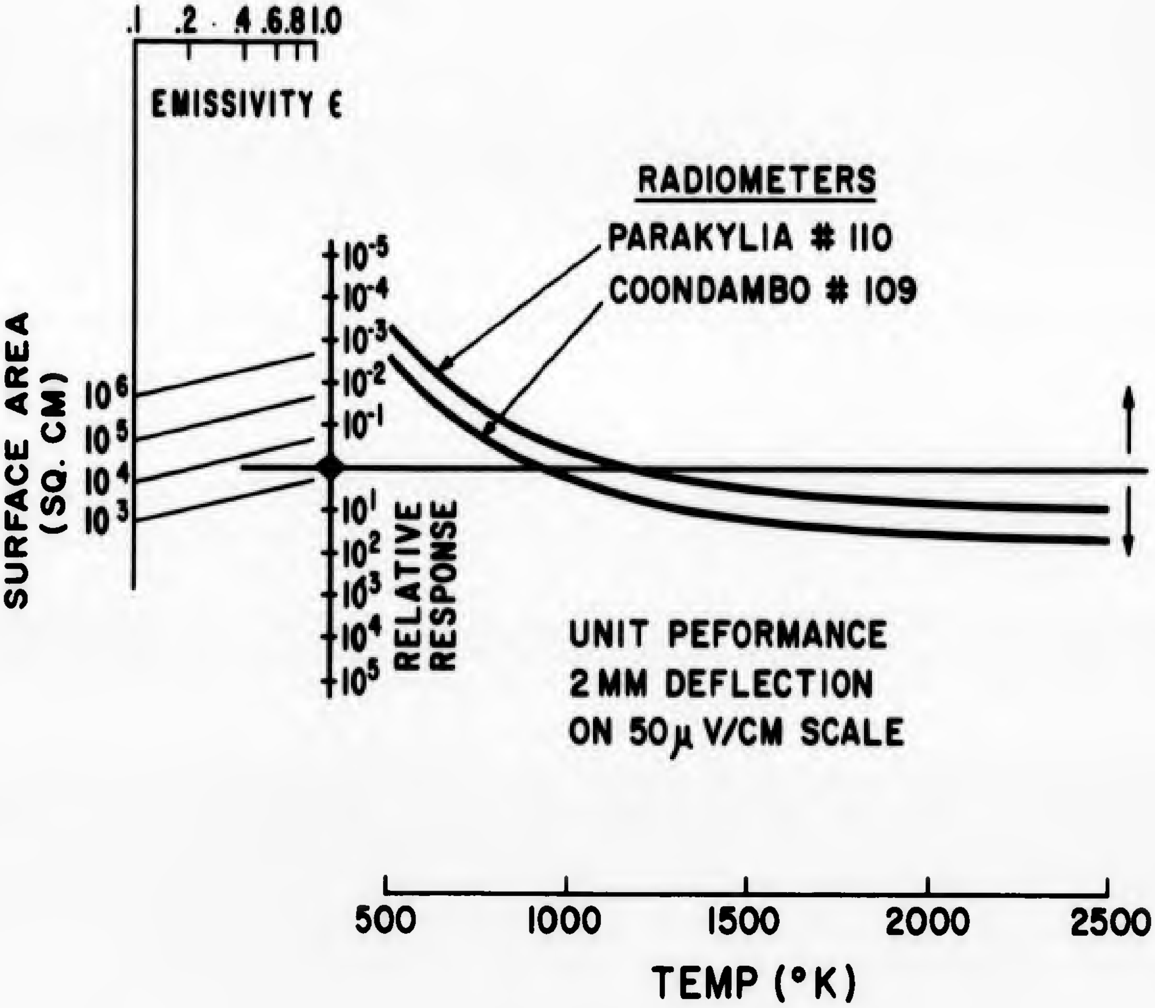


FIGURE 17 RELATIVE PERFORMANCE FOR GASLIGHT RADIOMETERS

Data cannot be recorded before the re-entering object attains a temperature of 1,300 degrees as shown in Figure 16 because of restrictions imposed by visual acquisition and manual tracking. If a Lumicon wide-field type of system were used for acquisition and tracking, there is a possibility of acquiring data much earlier in the re-entry history with the lead sulphide radiometers. Similar calculations for the photometers at Parakylia and for the spectrographs are shown in Figures 18 and 19.

VI. MISSILE BK08.

1. (S) The British Black Knight Missile BK08 was a two-stage missile with the second stage approximately as shown in Figure 8. The missile was fired at Woomera, Australia on the 24th of May, 1960. The radiation from the motor flame was first recorded by the lead sulfide radiometer located at Coondambo at + 18 seconds, and continued to record signals until + 148 seconds. This is the same burn-out time for the missile as recorded by telemetry. The missile had been programmed such that burn-out of the first stage was to occur at + 137 seconds, thus, extra burning time was experienced by BK08. The tape recording of the operator's comments and timing from Parakylia indicates that the motor flame was visible until approximately + 150 seconds from that site. No record was obtained with the lead sulfide radiometer at Parakylia on this flight. The visible radiation from the motor did not produce sufficient energy to be recorded by the photometers at Parakylia. Figure 20 shows the radiant intensity for the launch phase of BK08 as a function of height as calculated from the irradiance received at Coondambo. The radiant intensity is plotted on a log scale while the altitude is on a linear scale.

2. (C) Figure 21 shows a plot of both altitude and slant range from Coondambo and Parakylia as a function of range time for the launch phase of BK08. Eighteen ionic flashes were programmed for the mid course flight of BK08. These flashes were recorded by the three photometers at Parakylia. The responses of the radiometers at Coondambo and Parakylia were too slow to detect these flashes. Table IV presents the time of these flashes, the attenuation factor and the signal strength in watts per angstrom per cm^2 at the photometer.

3. (S) The re-entry was first recorded at Parakylia at + 831.9 seconds. The first recording on the radiometer at Coondambo was at + 832.5 seconds. Radiometer records from both locations terminated by recording a strong impulse at + 839.6 seconds. The missile was programmed for the second stage to ignite at + 744 seconds and for re-entry to occur at + 752 seconds. The delay in the occurrence of the re-entry phenomena of 79.9 seconds was due to two factors.

   a. The eleven seconds longer burning time of the first stage motor.

   b. The failure for the second stage (Cuckoo) motor and nose cone to separate from the first stage propellant unit.

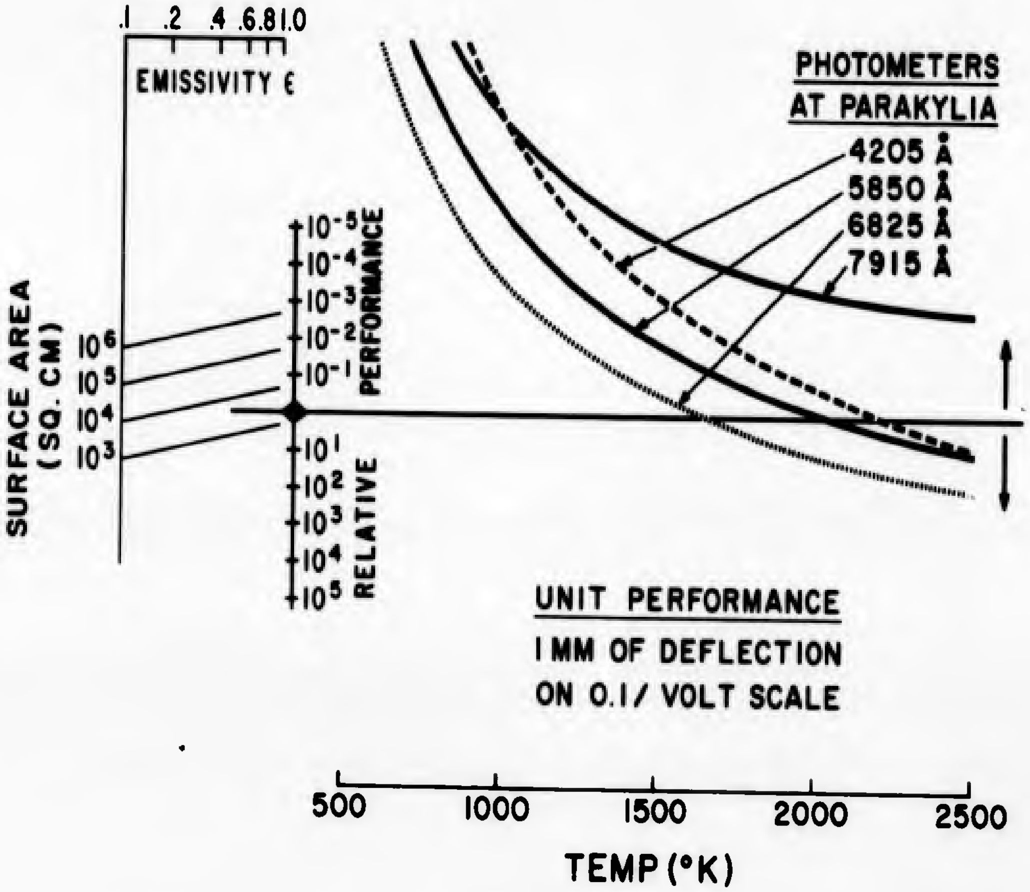


FIGURE 18 RELATIVE CURVE FOR THE PHOTOMETERS AT PARAKYLIA

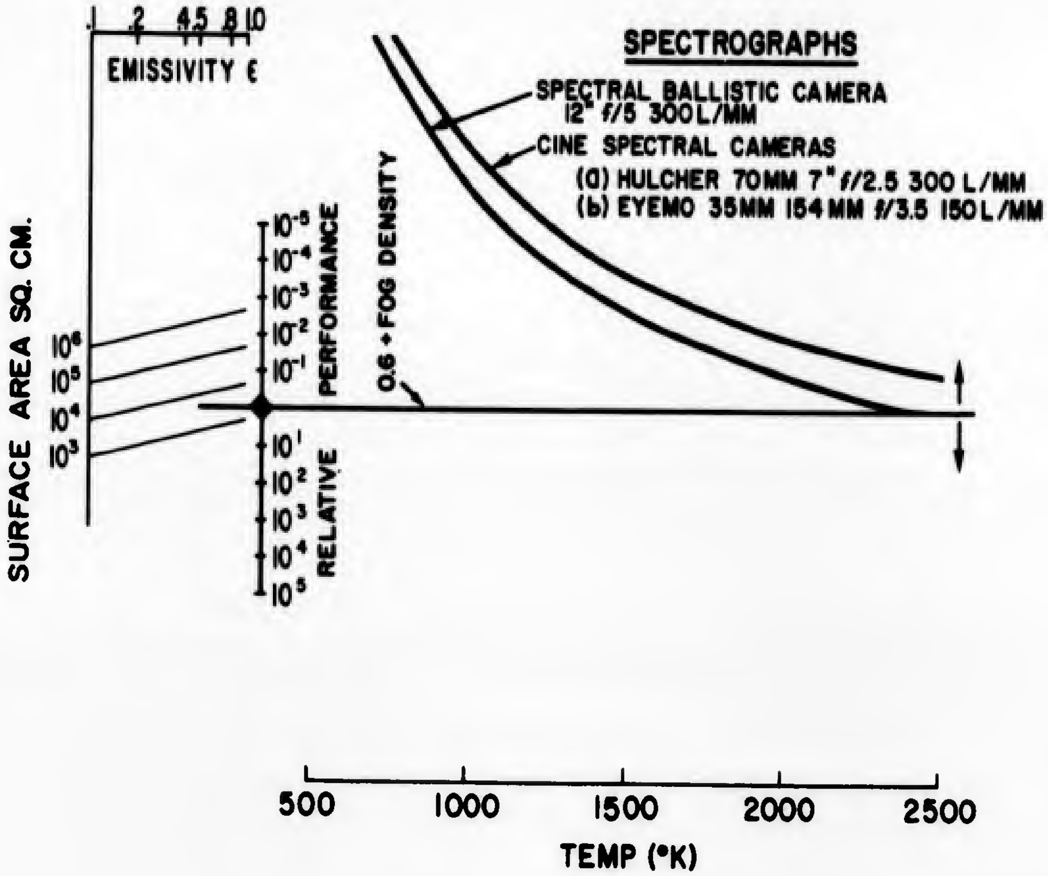


FIGURE 19 RELATIVE PERFORMANCE CURVES FOR THE SPECTROGRAPHS AT PARAKYLIA

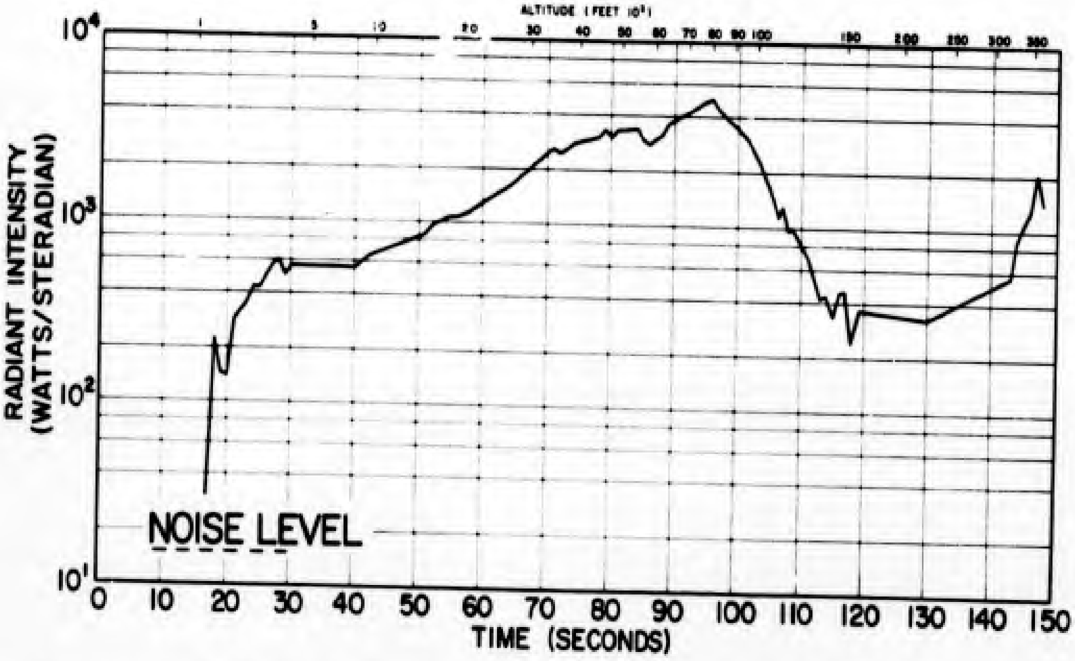


FIGURE 20 RADIANT INTENSITY IN Pb.S. REGION DURING LAUNCH OF BK08

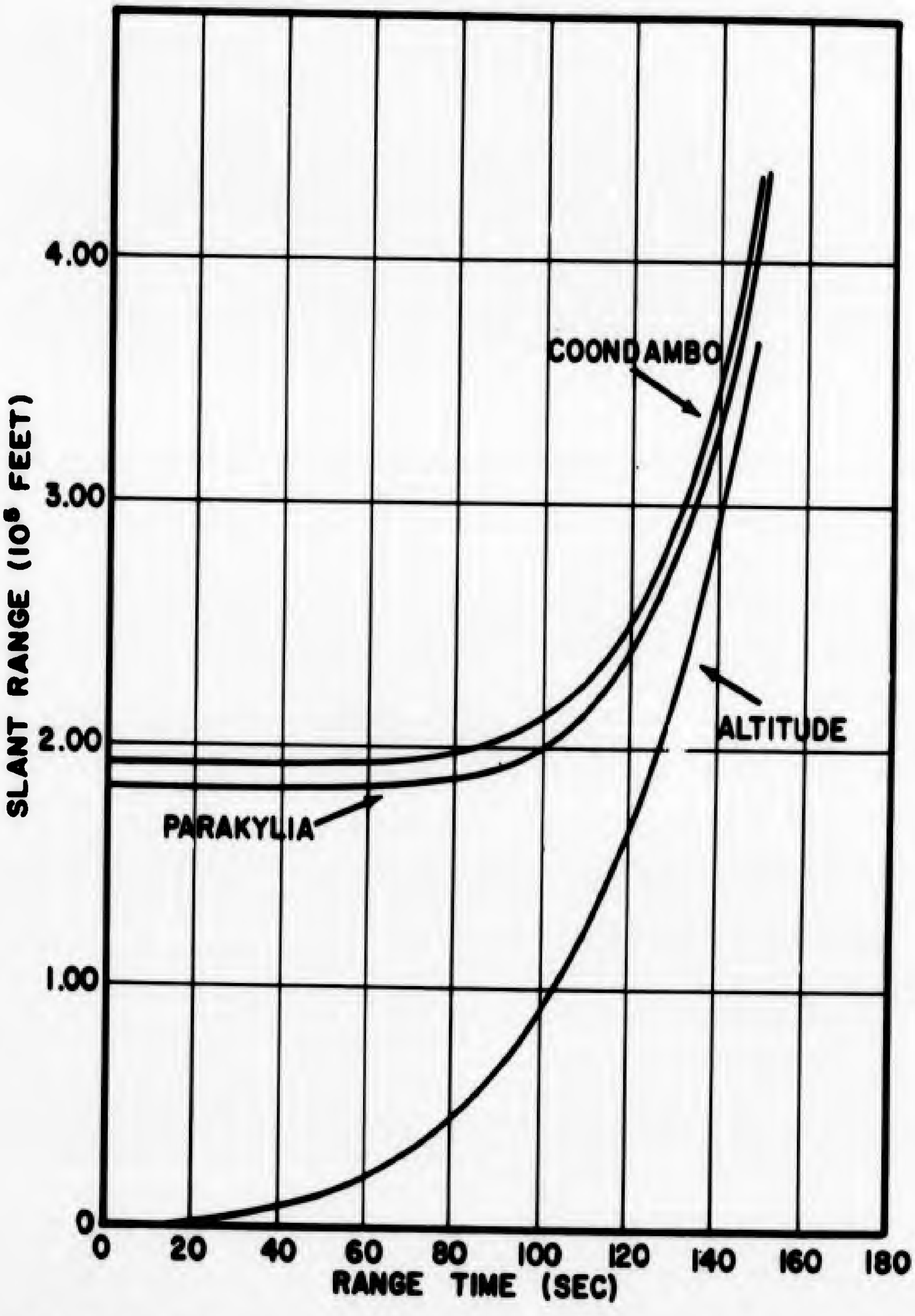


FIGURE 21 ALTITUDE AND SLANT RANGE DURING LAUNCH OF MISSILE BK08

TABLE IV. PHOTOMETER RECORD ELECTRONIC FLASHES ON BK08

Nr.	Secs.	Parakylia 5850 Å / 50 Å Photometer 1			Parakylia 6825 Å / 53 Å Photometer 3			Parakylia 4205 Å / 50 Å Photometer 4		
	IME	Deflection MMS	Alt. Volts/ CMS	W	Deflection MMS	Alt. Volts/ CMS	W	Deflection MMS	Alt. Volts/ CMS	W
1	119.9	8.5	0.1	0.25	5.1	0.1	0.40	32.0	0.1	0.19
2	130.6	9.0	0.1	0.27	7.3	0.1	0.57	34.3	0.1	0.20
3	136.0	8.0	0.1	0.24	4.8	0.1	0.37	17.5	0.1	0.10
4	141.2	5.5	0.1	0.16	4.8	0.1	0.37	23.0	0.1	0.13
5	146.8	8.9	0.1	0.26	6.1	0.1	0.48	19.1	0.1	0.11
6	152.05	9.0	0.1	0.27	6.1	0.1	0.48	21.0	0.1	0.12
7	157.5	5.0	0.1	0.15	2.2	0.1	0.17	19.5	0.1	0.11
8	162.8	7.1	0.1	0.21	1.6	0.1	0.13	11.7	0.1	0.07
9	168.2	2.0	0.1	0.06	1.7	0.1	0.13	10.8	0.1	0.06
10	179.0	4.4	0.1	0.13	1.0	0.1	0.08	6.1	0.1	0.04
11	184.2	2.6	0.1	0.08	0.9	0.1	0.07	7.0	0.1	0.04
12	189.6	2.3	0.1	0.07	1.4	0.1	0.11	10.0	0.1	0.06
13	205.6	1.5	0.1	0.04	1.1	0.1	0.09	5.0	0.1	0.03
14	211.0	1.5	0.1	0.04	0	0.1	0	6.8	0.1	0.04
15	216.3	-	0.1	-	-	0.1	-	6.5	0.1	0.04
16	221.8	-	0.1	-	-	0.1	-	6.8	0.1	0.04
17	227.1	1.3	0.1	0.04	0	0.1	0	4.5	0.1	0.03
18	232.5	1.3	0.1	0.04	0	0.1	0	5.0	0.1	0.03

NOTE: "W" is given in watts/Å/CMS^2 x 10^{14}

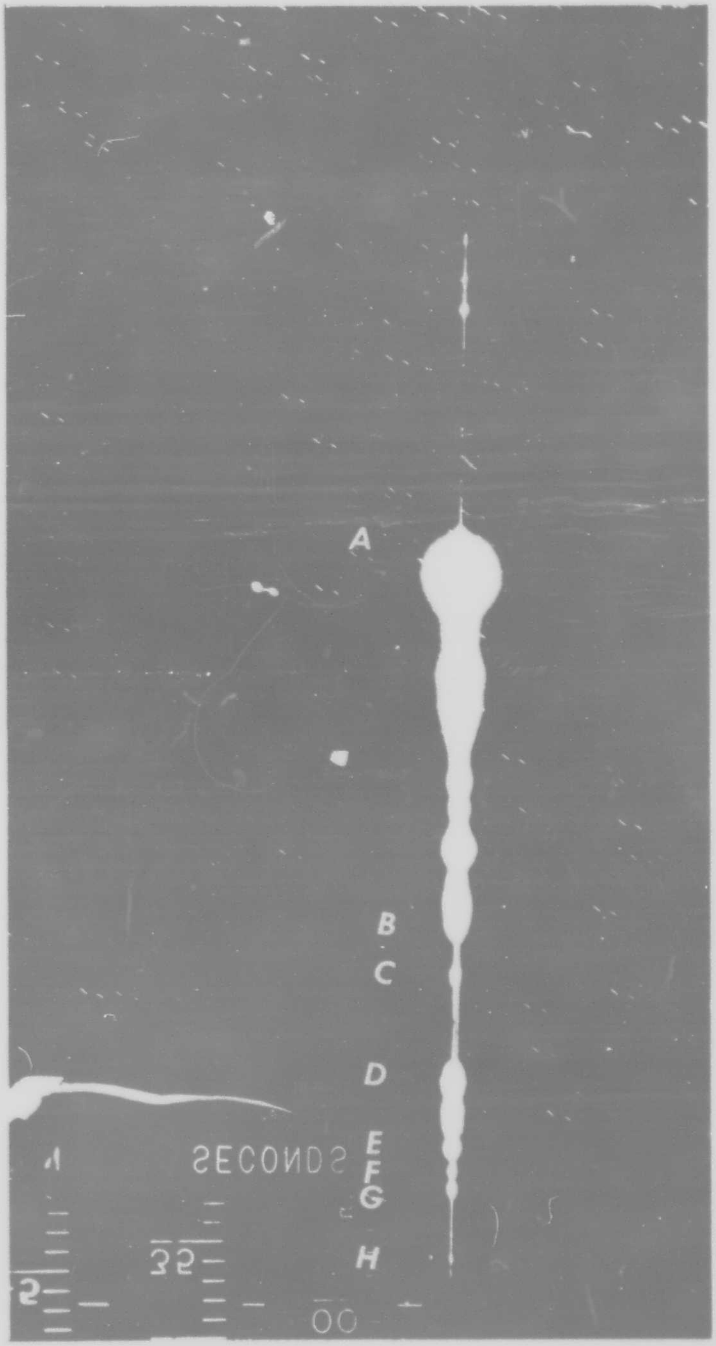


FIGURE 22 BAKER NUNN PHOTOGRAPH OF RE-ENTRY BK08

As a result of the failure to separate, the second stage did not ignite and the complete missile re-entered as a single unit. The failure of the second stage motor to ignite also resulted in the re-entry velocity being much less than the desired 17,000 feet per second. The actual re-entry velocity of BK08 was about 13,000 feet per second.

4. (S) The re-entry phenomena as observed by the Baker Nunn camera at the I. G. Y. Minitrack station is shown in Figure 22. The phenomena first recorded by the instruments at Parakylia and Coondambo was the brightest flash recorded on the film at A. The upper part of the re-entry trace recorded by the Baker Nunn camera was too faint for the eye to detect as was shown in Figure 16. From the curves of Figure 16, it has been estimated that the temperature of the re-entering missile was about 1200 degrees kelvin during the time it created the faintest part of the trace on Figure 22. It is also evident from the Baker Nunn picture that there occurred considerable fluctuations in the visible radiation at these reduced temperatures and high altitudes. From the trace between points B and D on the Black Knight picture and from reports of observers, it is evident that the Cuckoo motor and nose cone separated from the main part of the missile at the beginning of visible re-entry. When the two traces, observable in the lower part of the Baker Nunn picture, are extended back, through the brighter part of the re-entry glow, they intersect at the point of brightest glow. Based upon this picture it is assumed that separation took place at the point of the brightest flash. From the detail of the Baker Nunn picture it is also possible to associate sudden increase in radiometer and photometer readings with particular parts of the re-entry picture.

5. (S) At point A where the missile was first observed visually, the missile was at an altitude of 135,250 feet and was travelling with a velocity of about 13,000 feet per second. At point H where the last glow was observed from the nose cone, the velocity was about 9,000 feet per second and at an altitude of about 81,000 feet. Table V presents the range times, altitude and velocities for the points noted on Figure 22.

TABLE V

POINT	RANGE TIME (Sec)	ALTITUDE (Ft)	VELOCITY (Ft/Sec)
A	831.6	136,000	13,200
B	833.2	117,200	12,000
C	833.7	111,300	11,580
D	834.8	99,500	10,660
E	835.6	90,700	10,100
F	835.9	87,800	9,820
G	836.1	86,000	9,460
H	836.6	81,400	9,110

6. (C) Figure 23 is a plot of the altitude and slant range versus time, for the re-entry of BK08.

7. (S) A plot of the radiant intensity as calculated from the recordings of the lead sulfide radiometer at Coondambo as a function of altitude for BK08, is shown in Figure 24. Figures 25, 26, and 27, show the radiant intensity as calculated from the recordings of the photometers stationed at Parakylia.

8. (S) A cine-spectrograph (Figure 28) was obtained of the BK08 re-entry at the point where the Cuckoo motor separated from the main stage of the missile. This spectrograph indicates radiation conditions when the missile was at an altitude of 136,000 ft and had a velocity of 13,200 ft/sec, which corresponds to point A in Figure 22. A densitometer trace through the spectra is shown in Figure 29. The aluminum oxide bonds are characteristic of the missile booster as shown by previous Gaslight measurements on Jupiter missile (1 - 8).

9. (U) Just prior to the firing of BK08, a virtual temperature profile up to 120,000 feet was obtained. The profile shows the tropopause to be located at about 43,000 feet with a minimum temperature of about -65 degrees. This temperature profile is shown in Figure 30. Unfortunately, humidity measurements were not made at this time. At the time the missile was fired, the temperature at the ground was 49.7 degrees C with a relative humidity of 67 percent and a pressure of 1,007.8 mbs. There were a few fine isolated clouds at about 5,000 feet. Very good visibility and a wind of about five feet per second from the South, Southeast. The temperature profile for the firing of BK08 is quite typical of the conditions on the Woomera Range. As a comparison, Figure 31 shows the temperature profile for the firing of BK06 which occurred in October of 1959. In this case, the tropopause is at 55,000 feet. The high altitude of the tropopause appears to be more common over the Woomera Range. At the time of this profile ground temperature was 73.9 degrees F, with a relative humidity of 36 percent and a pressure of 995.9 mbs.

VII. MISSILE BK09.

1. (C) The Black Knight Missile, BK09 was similar to BK08 except in minor modifications to the nose cone. The nose cone of BK09 had the durestos applied in sheets to the side rather than being machined out of solid durestos blocks.

2. (C) The missile was fired at Woomera, Australia, on the 21st day of June, 1960. All aspects of this flight were essentially as had been planned and the first and second separations occurred according to the program. The Cuckoo motor ignited at approximately 380,000 feet which provided a re-entry velocity for the nose cone of about 15,600 feet per second.

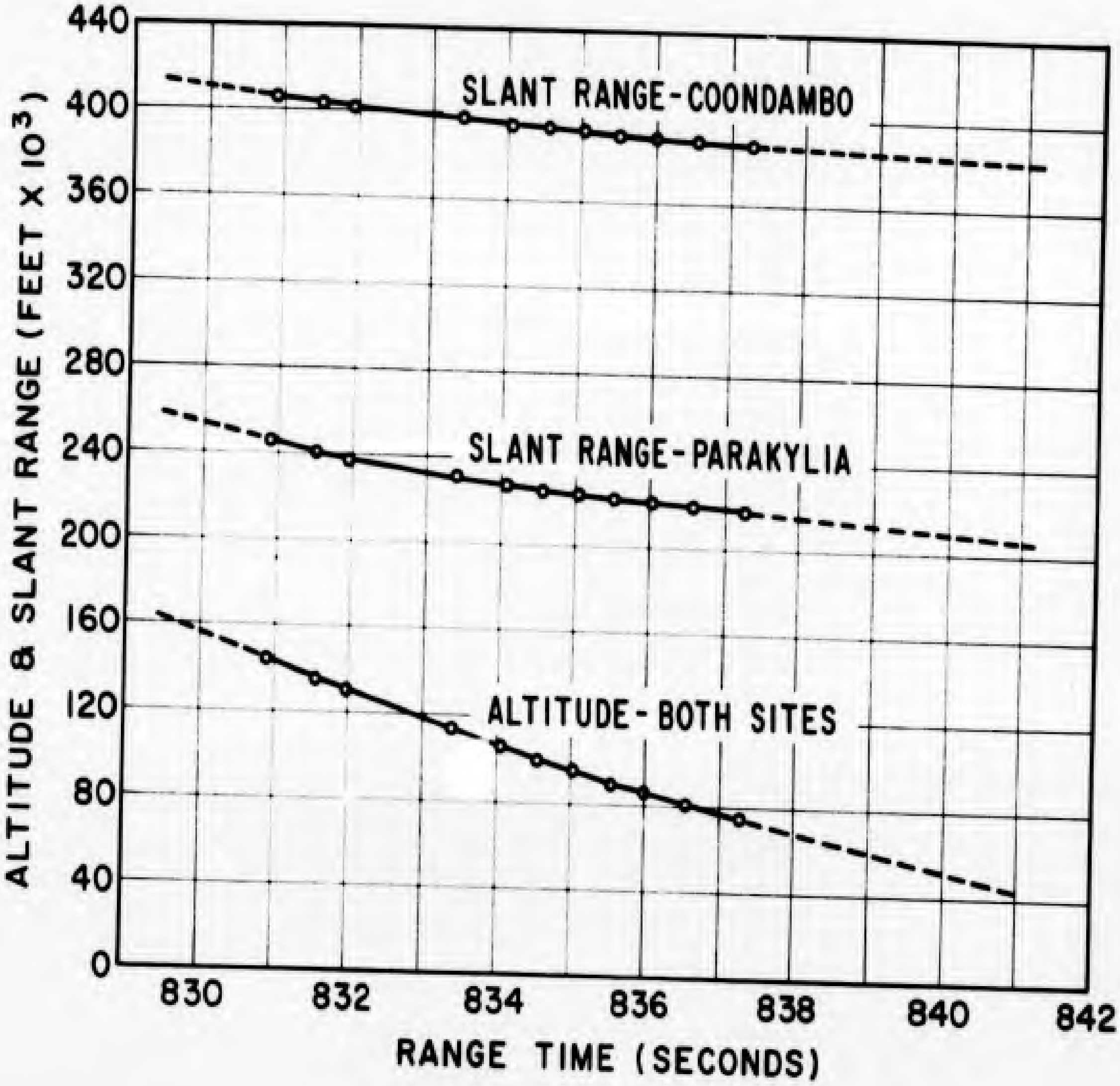


FIGURE 23 ALTITUDE AND SLANT RANGE FOR RE-ENTRY BK08

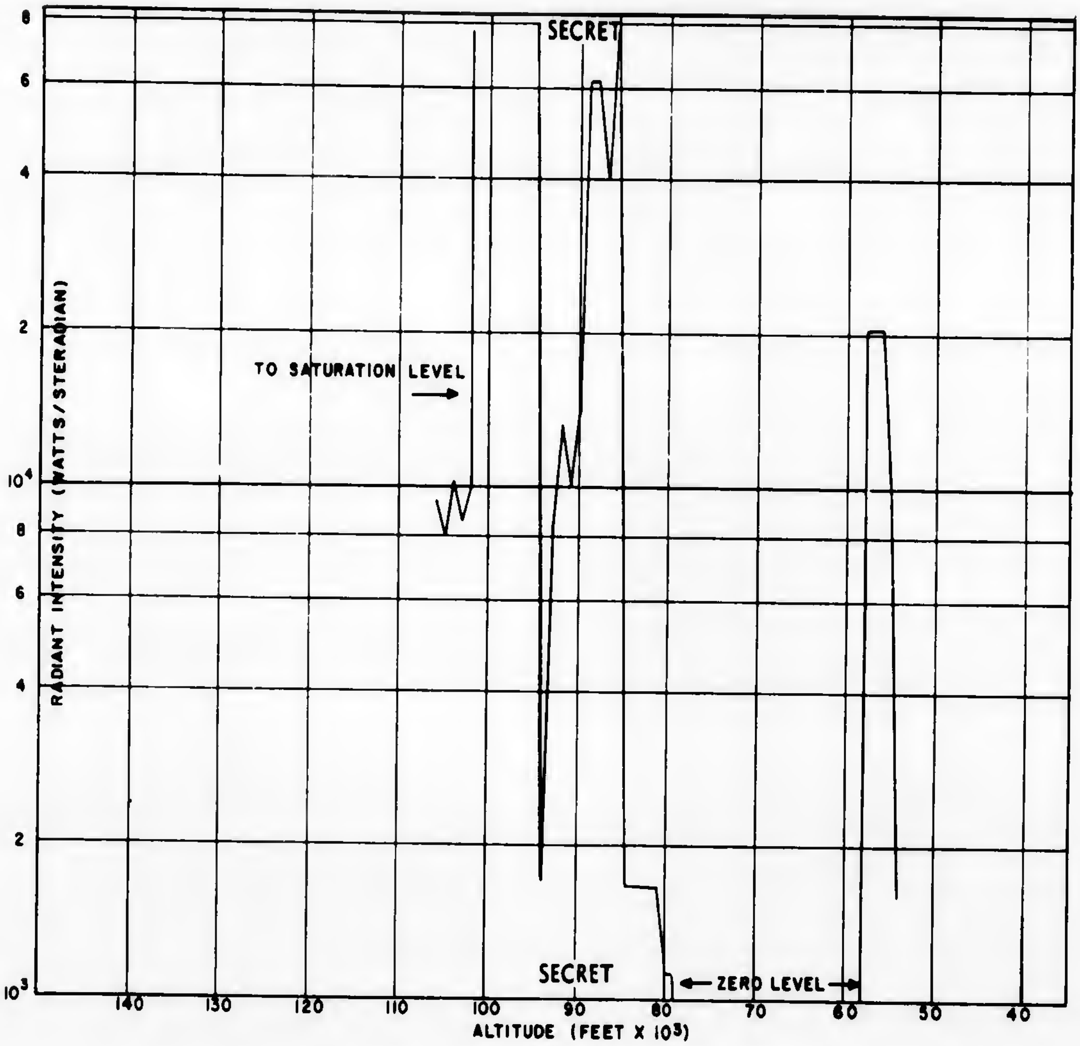


FIGURE 24 BK08 Pb.S. RADIANT INTENSITY DURING RE-ENTRY

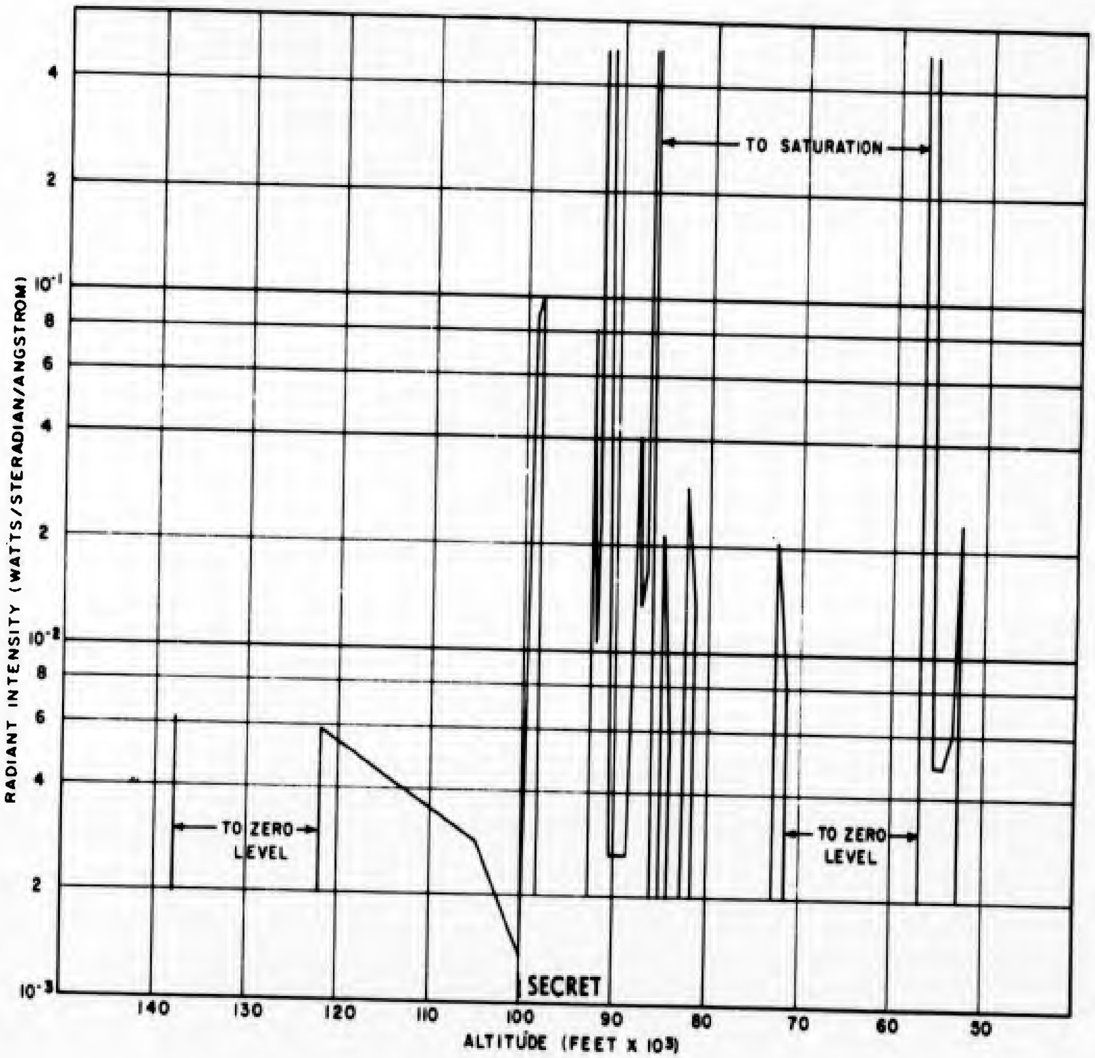


FIGURE 25 BK08 RADIANT INTENSITY DURING RE-ENTRY (4205 Å)

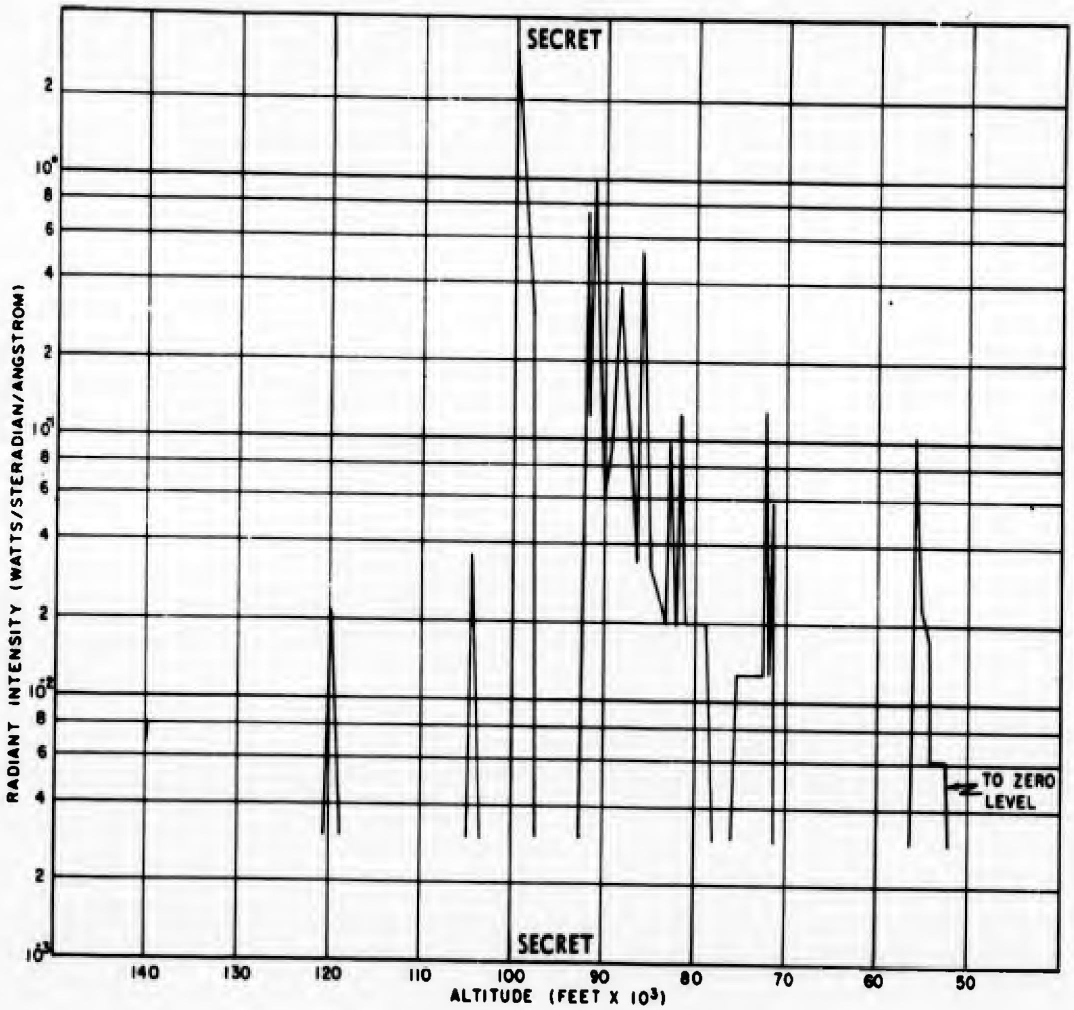


FIGURE 26 BK08 RADIANT INTENSITY DURING RE-ENTRY (5850 Å)

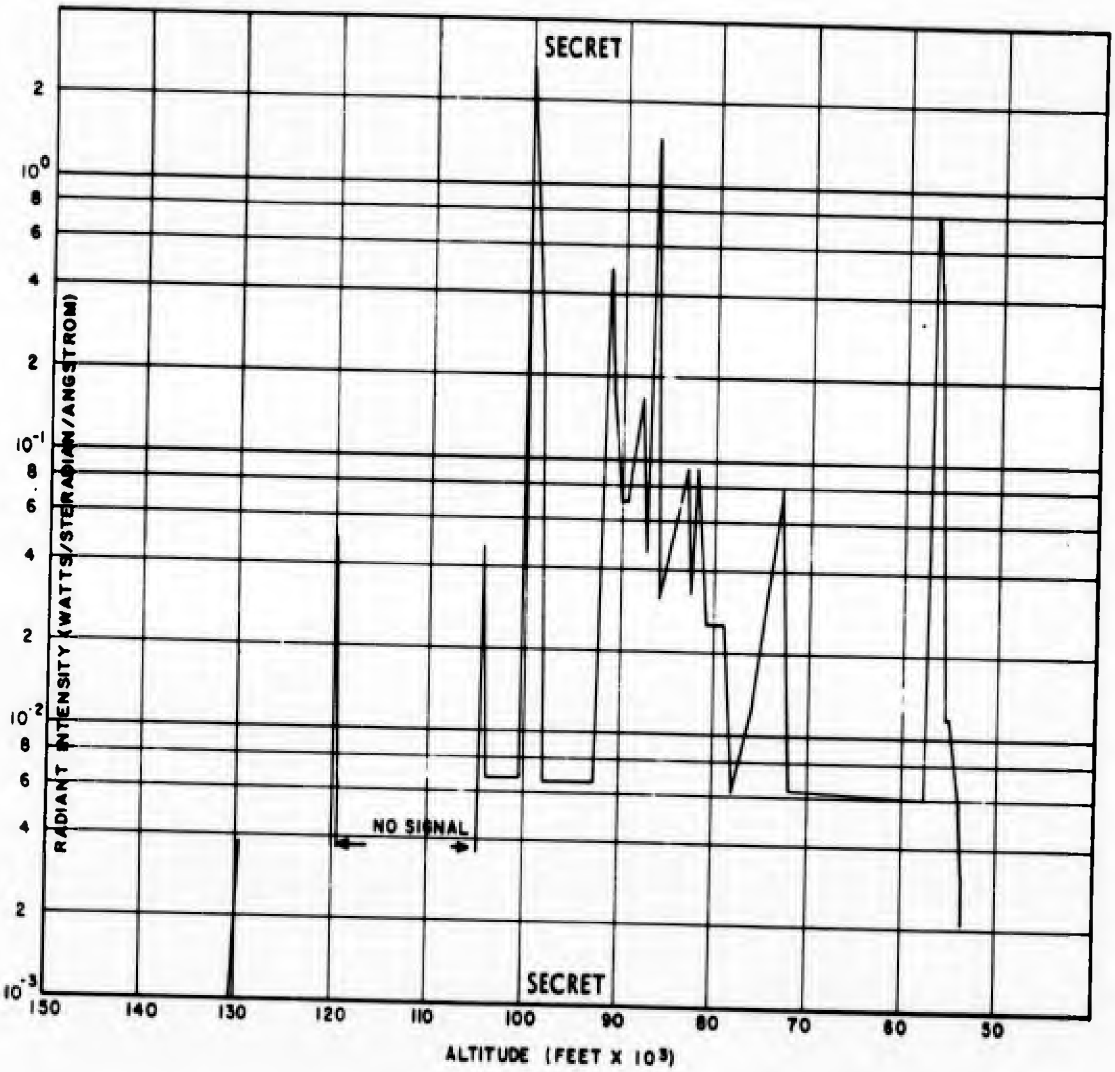


FIGURE 27 BK08 RADIANT INTENSITY FURING RE-ENTRY (6825 Å)

FIGURE 28 CINESPECTRAGRAPH BK08 RE-ENTRY at 136,000 FEET

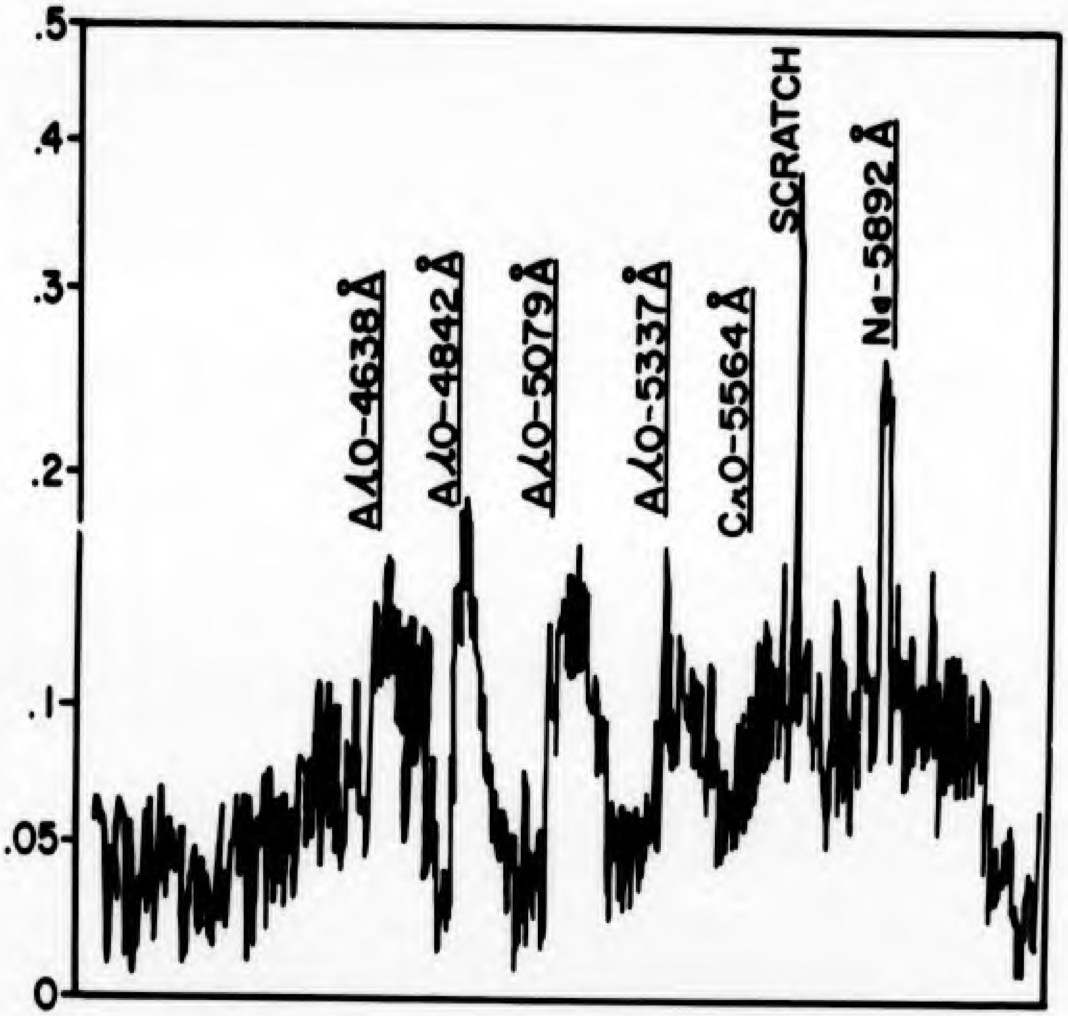


FIGURE 29 DENSITOMETER TRACE THROUGH CINESPECTROGRAPH

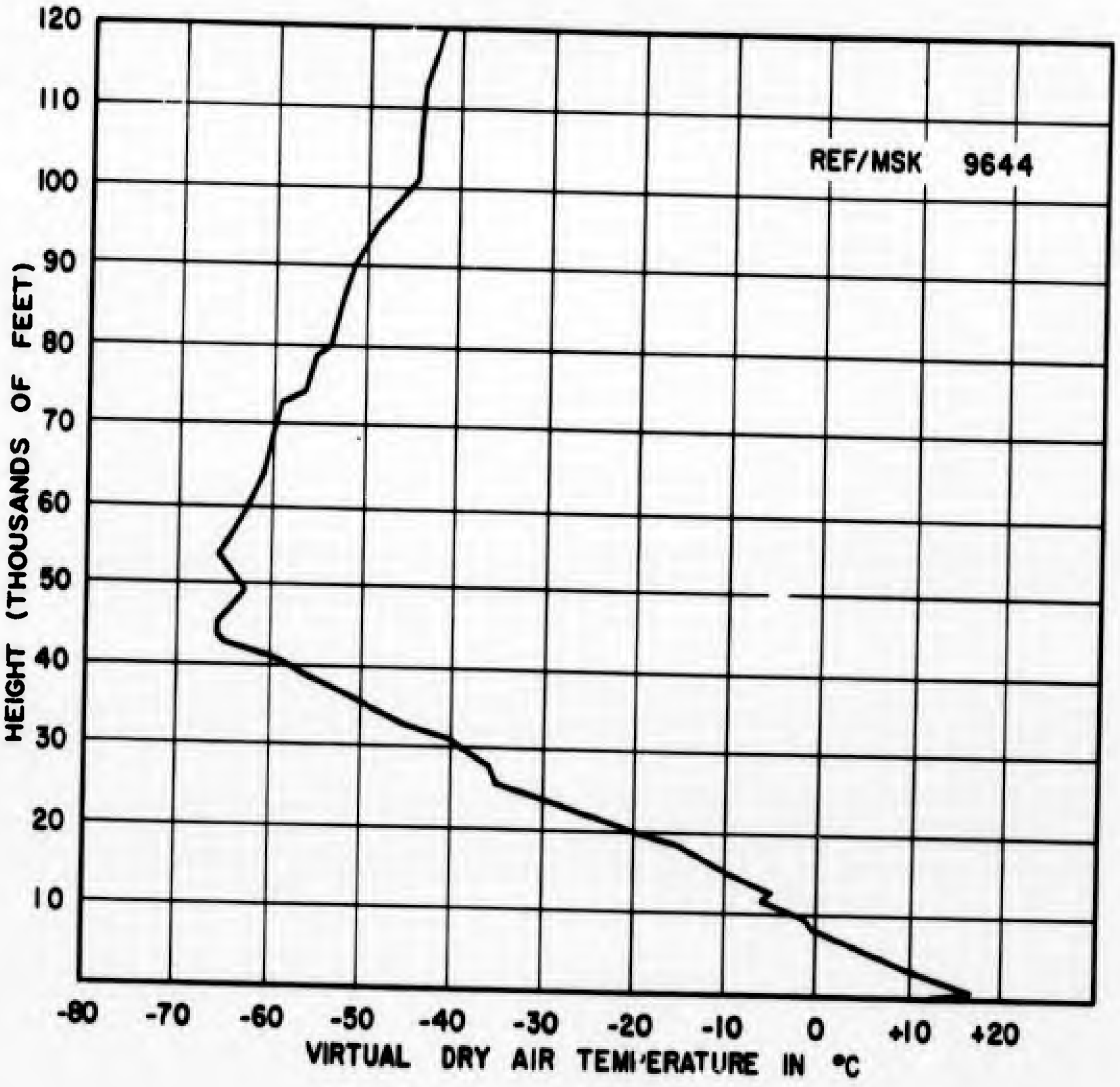


FIGURE 30 VIRTUAL TEMPERATURE PROFILE PRIOR TO FIRING BK08

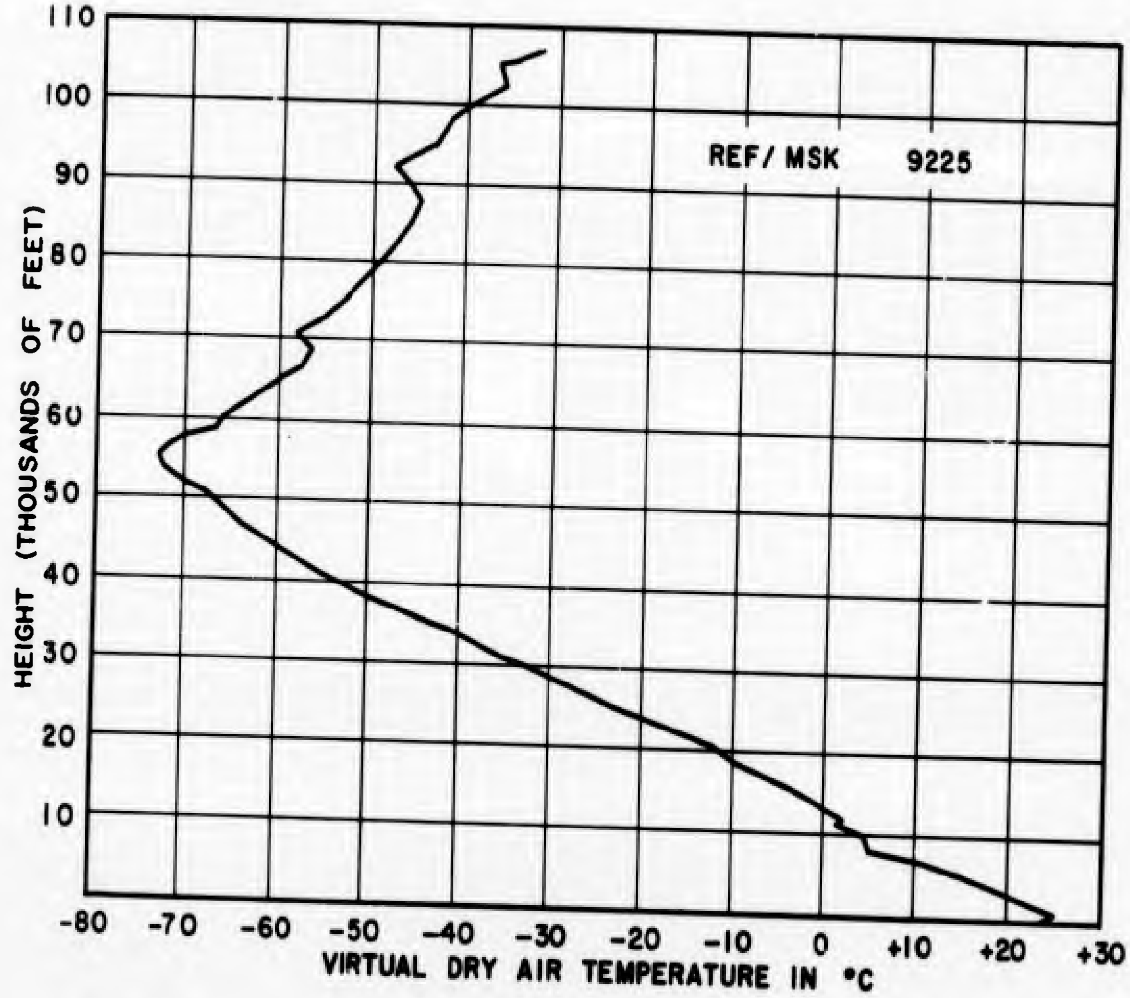


FIGURE 31 VIRTUAL TEMPERATURE PROFILE PRIOR TO FIRING BK06

3. (S) The lead sulfide radiometer at Coondambo acquired the motor flame at + 20 seconds and continued to track the missile during the ascent until about + 120 seconds. The motor burned out at approximately 175,000 feet. The radiant intensity in the 1.8 to 2.7 micron region as obtained from the radiometer at Coondambo for the launch phase of BK09 is shown in Figure 32. A comparison of the BK09 results with the BK08 results shows that the two missiles performed nearly identically except for the very end of the launch phase. Each missile shows an increasing radiation during the last 50 seconds of burning time. A maximum radiation of about 5×10^3 watts/steradian in the 1.8 to 2.7 micron region was observed at about 80,000 feet for both missiles. In the past great variations have been recorded in the radiant intensity emitted from similar missiles fired at different times. In the Black Knight firings observed, the consistency in the two records is of utmost importance. A plot of the altitude and slant range from Coondambo and Parakylia during the launch phase as a function of range time for BK09 is shown in Figure 33.

4. (S) Shortly after the main stage motor burned out, first separation occurred. The Cuckoo motor and re-entry nose cone had been placed on the missile as was shown in Figure 8. The separation of the second stage is effected by explosive bolts which break the connections and then a pyrotechnic impulse ignites, and applies a torque, which gives an angular velocity of about twenty (20) radians per second to the second stage. This impulse also produces a small separation velocity by a slight off-set of the nozzles.

5. (S) The Cuckoo motor ignited at about + 773 seconds which placed the nose cone and second stage motor at 380,000 feet. The path of the second stage Cuckoo motor was clearly visible to all observers on the range as a long persisting trail was formed during the burning phase. The Cuckoo motor and nose cone re-entry became luminous to the eye at about 215,000 feet. Separation of the two re-entering objects did not occur until they reached an altitude of 131,000 feet. Figure 34 shows the Baker Nunn picture of the re-entry of BK09. A number of the events are lettered in this picture with explanation given in Table VI. In order to differentiate the multiple traces and also to put rough timing on the record, the camera was moved through a small azimuthal angle on six different occasions during the re-entry phenomena. The persistent glow from the Cuckoo motor reported by observers is evident in the first part of the record shown at point F. At this point the camera was moved to one side and then almost immediately it was returned about halfway. At each stop there was sufficient after-glow to expose the flame in the new position and give a repeated trace of the trajectory. During the longer exposure after the camera had been returned to about the halfway point of its original position, the lower part and less luminous part of the after trail was recorded. The persistent after-glow was not evident at any of the succeeding camera shifts. It seems thus, that this persistent glow at an altitude of about 350,000 feet may probably be associated with chemical luminescence

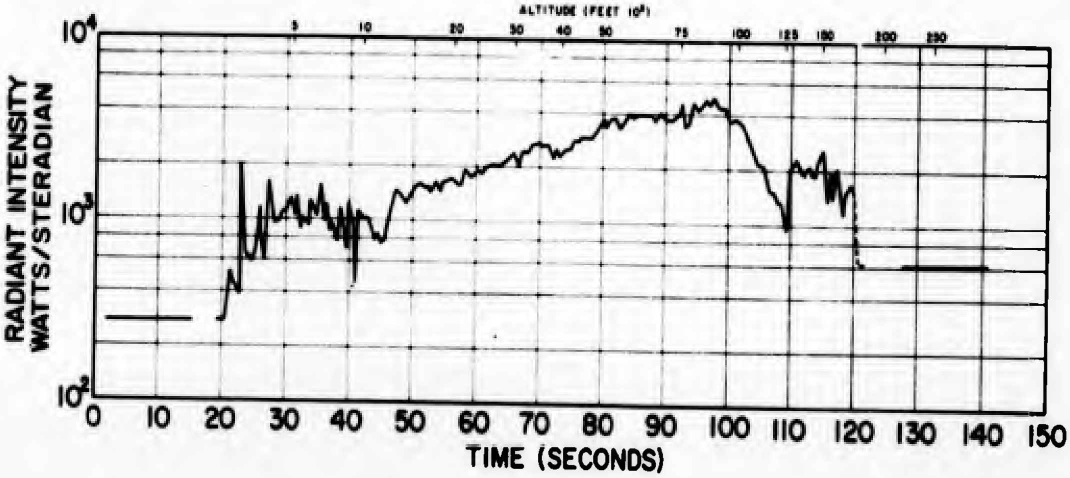


FIGURE 32 BK09 Pb.S. RADIANT INTENSITY DURING LAUNCH

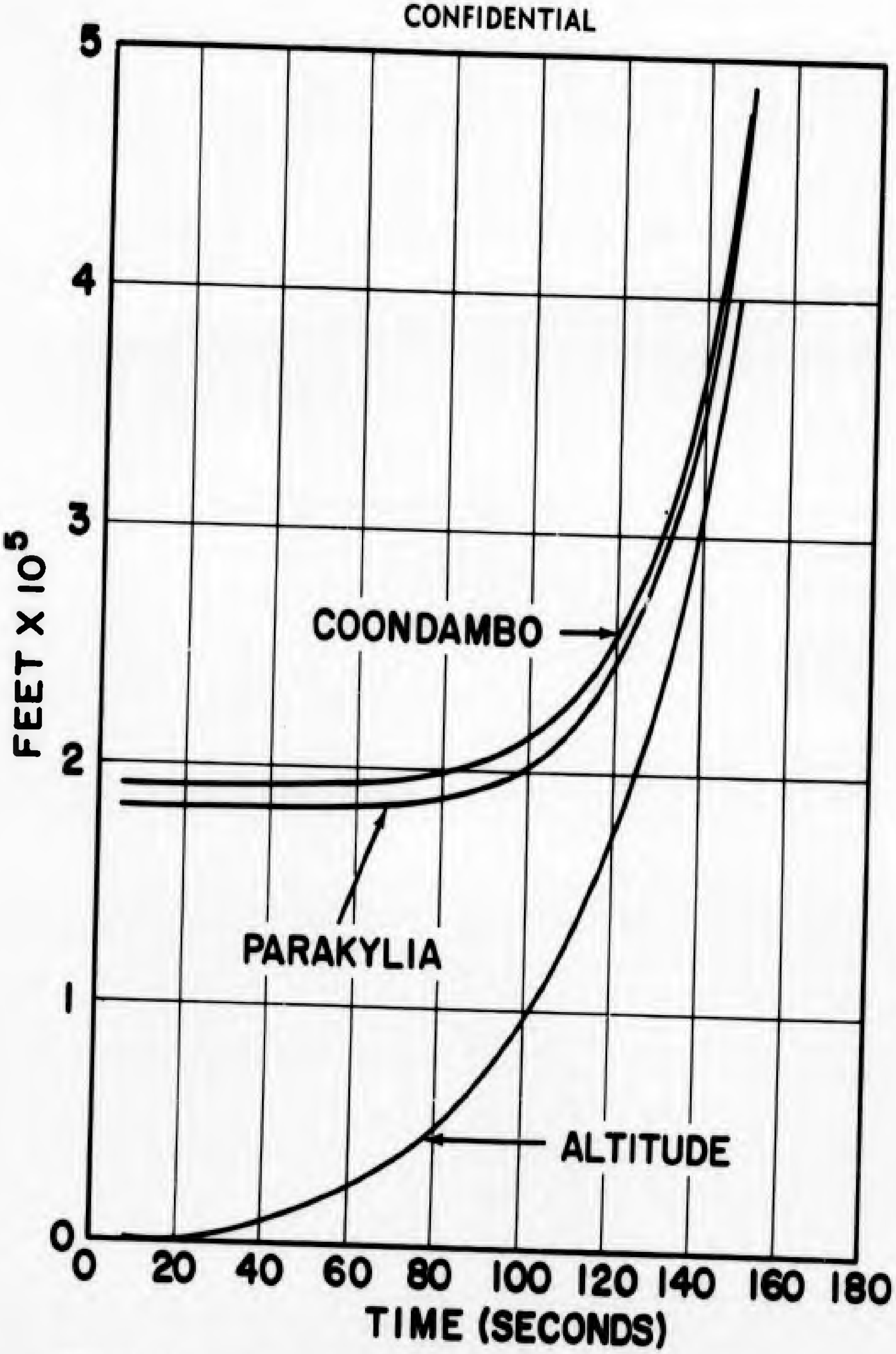


FIGURE 33 ALTITUDE AND SLANT RANGE OF BK09 DURING LAUNCH

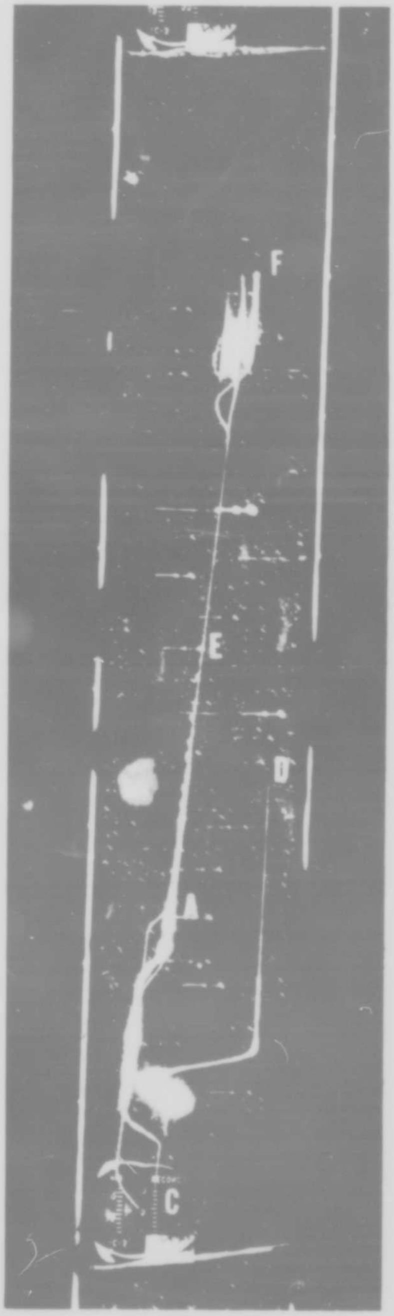


FIGURE 34 BAKER NUNN PHOTOGRAPH OF RE-ENTRY OF BK09

from atomic oxygen. A close inspection of the three traces at F shows a marked drift at an altitude about 320,000 feet. This drift can be considered as evidence of horizontal winds at these altitudes.

TABLE VI

DESIGNATION	PROBABLE EVENT	HEIGHT (Ft)	TIME (Sec)
A	Separation of Nose Cone and Second Stage	131,000	765
B	Nose Cone Break Up	28,000	772.5
C	Second Stage Disappears	70,000	771
D	First Stage Appears	149,000	773
E	Second Stage Glow Appears	215,000	---
F	Second Stage Ignition	380,000	752

6. (S) The re-entry glow apparently began at point E, where the altitude is about 215,000 feet. The Baker Nunn camera shows a definite recorded trace below the trace of the after-glows of the Cuckoo motor and the start of the re-entry glow. From Dr. Crosby's curves shown in Figure 16, the temperature of the Cuckoo motor and nose cone during this part of its flight can be estimated to be between 1100 to 1300 degrees kelvin. The question arises as to whether this temperature was due to the re-entry process or was a residue temperature from the burning of the Cuckoo motor.

7. (S) The trace of the nose cone can easily be identified in Figure 34 because of its greater velocity than the other re-entering components. This increase in velocity is evident by a greater slope of the trace on the Baker-Nunn film when the camera was shifted in azimuth. A small piece that can be seen to be separate from the main glow of the Cuckoo motor above point A, can not be the nose cone as it does not show this greater slope when the camera was shifted. The nose cone was tracked down to a height of 28,000 feet at which time it broke up and became invisible. Figures 35 and 36 show prints from the film obtained by two KF-3 ballistic cameras located at Coondambo. Unfortunately, lettering the points shown in these pictures were added to the negative so that they do not read conveniently. Certain stars have also been identified using the notation in Norton's Star Atlas. Figure 35 shows the upper portion of the re-entry trajection whereas Figure 36 shows the lower portion. The shutters of the cameras are open for a time exposure after re-entry, to obtain the star calibration

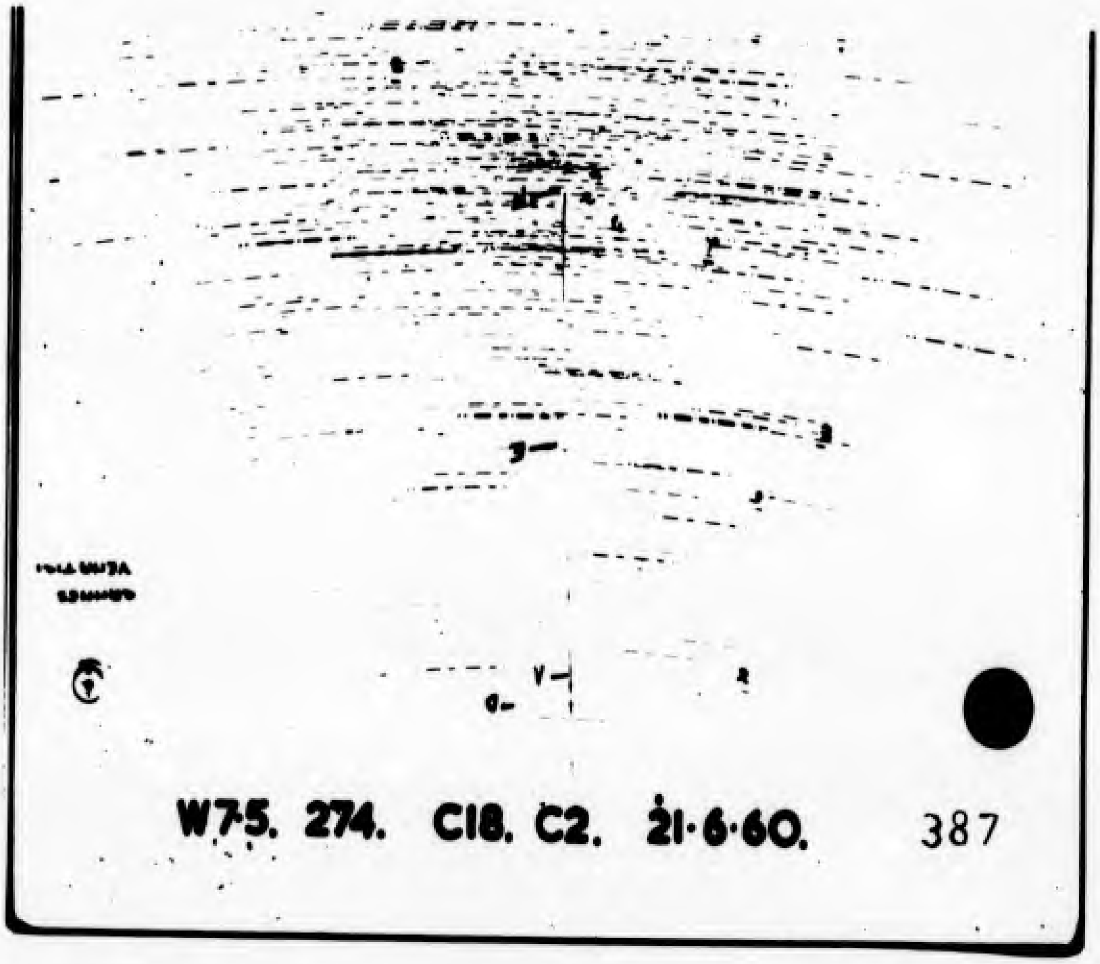


FIGURE 35 KF3 BALLISTIC CAMERA PHOTOGRAPH OF RE-ENTRY OF BK09

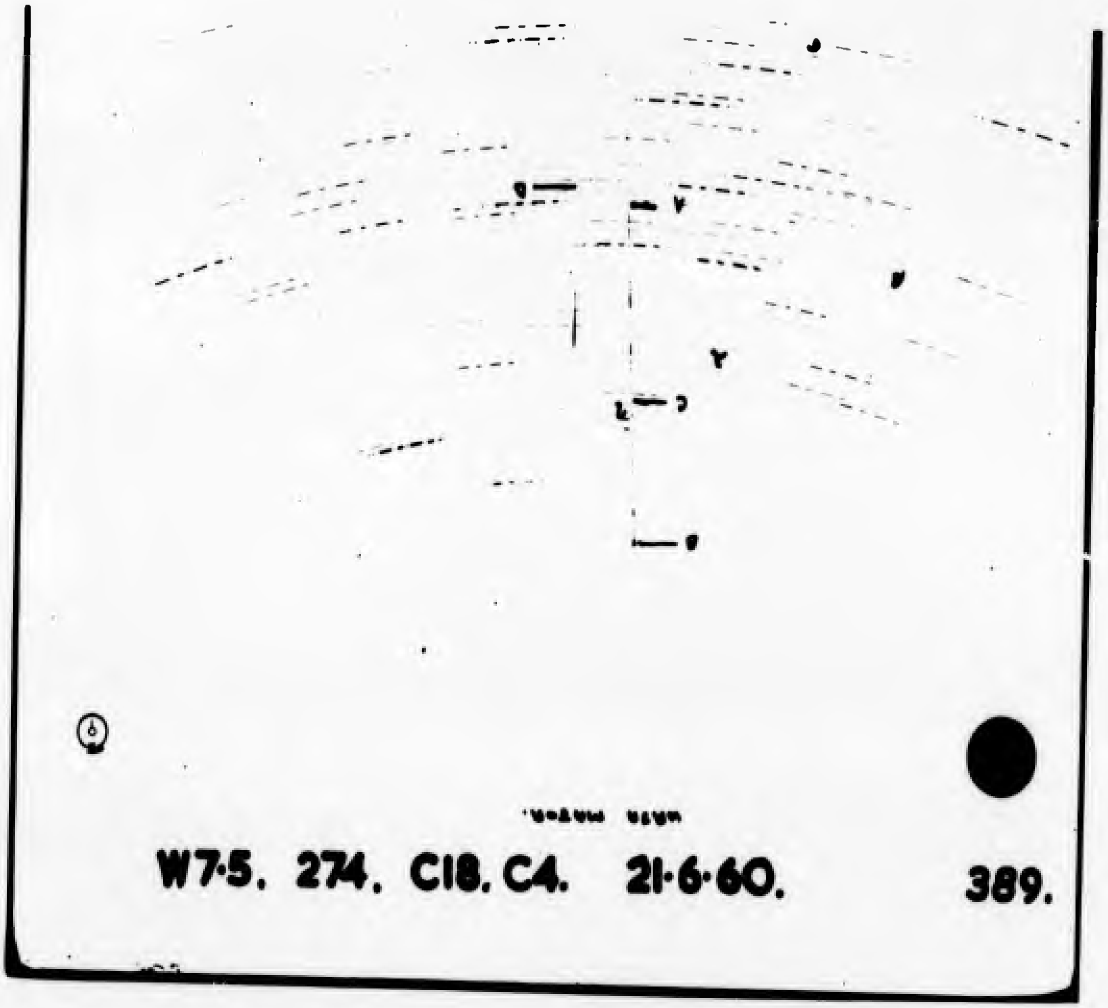


FIGURE 36 KF3 BALLISTIC CAMERA PHOTOGRAPH OF RE-ENTRY OF BK09

indicated. A light chopper interrupted the traces at periodic intervals in Figure 36, whereas the camera used for the other Figure did not have a chopper. The gaps in the record were made by operating the camera shutter in order to impress known times on the traces. The main stage of BK09 re-entered much later than the Cuckoo motor and nose cone. It was also not in line with the other re-entering bodies which can be easily distinguished on Figures 34, 35, and 36.

8. (S) Figures 37 and 38 show tracings of the re-entry phenomena as obtained from the ballistic camera prints at Coondambo and Parakylia. These tracings show various portions of the re-entry phenomena as a function of azimuth elevation and altitude from each of the sights. The sequence as shown in the preceeding figures indicate that the glows occurred at the following altitudes:

1st Stage	150,000 to 90,000 feet
2nd Stage	320,000 to 80,000 feet
Nose Cone	150,000 to 30,000 feet.

From the ballistic camera records that were made at Woomera, the re-entries were compared to traces of stars with the following results:

a. First stage approximately - 1st magnitude

b. Second stage approximately + 3rd magnitude

c. Nose cone approximately + 1st to + 4th magnitude.

9. (C) Figure 39 shows a graph of the altitude and the slant range of the missile from Coondambo and Parakylia. The use of this data enables Barnes Engineering Company to reduce the irradiance data received by the radiometers and photometers to radiant intensity data as a function of altitude. Unfortunately, no measurements were made on the Woomera range of the relative humidity as a function of altitude. Thus, no correction has been made for the continuation due to atmospheric absorption.

10. (S) Data was obtained on each of the individual parts of missile BK09 during re-entry. Figure 40 shows the radiant intensity in watts per steradian in the 1.8 to 2.7 micron region as a function of altitude for the nose cone. The decrease in intensity through the altitude range of 106,000 to 94,000 feet was due to the gradual pulling away of the nose cone from the Cuckoo motor. For the altitude range of 94,000 to 50,000 feet, an excellent radiation history in the 1.8 to 2.7 micron region was obtained. At an altitude of 50,000 feet, the nose cone began to break up and fragmented in a final burst of energy at an altitude of 36,000 feet. This effect appears very similar to the phenomena of the fragmentation of JUPITER nose cone AM-21 which had been fabricated very similar to that of the British BK09.

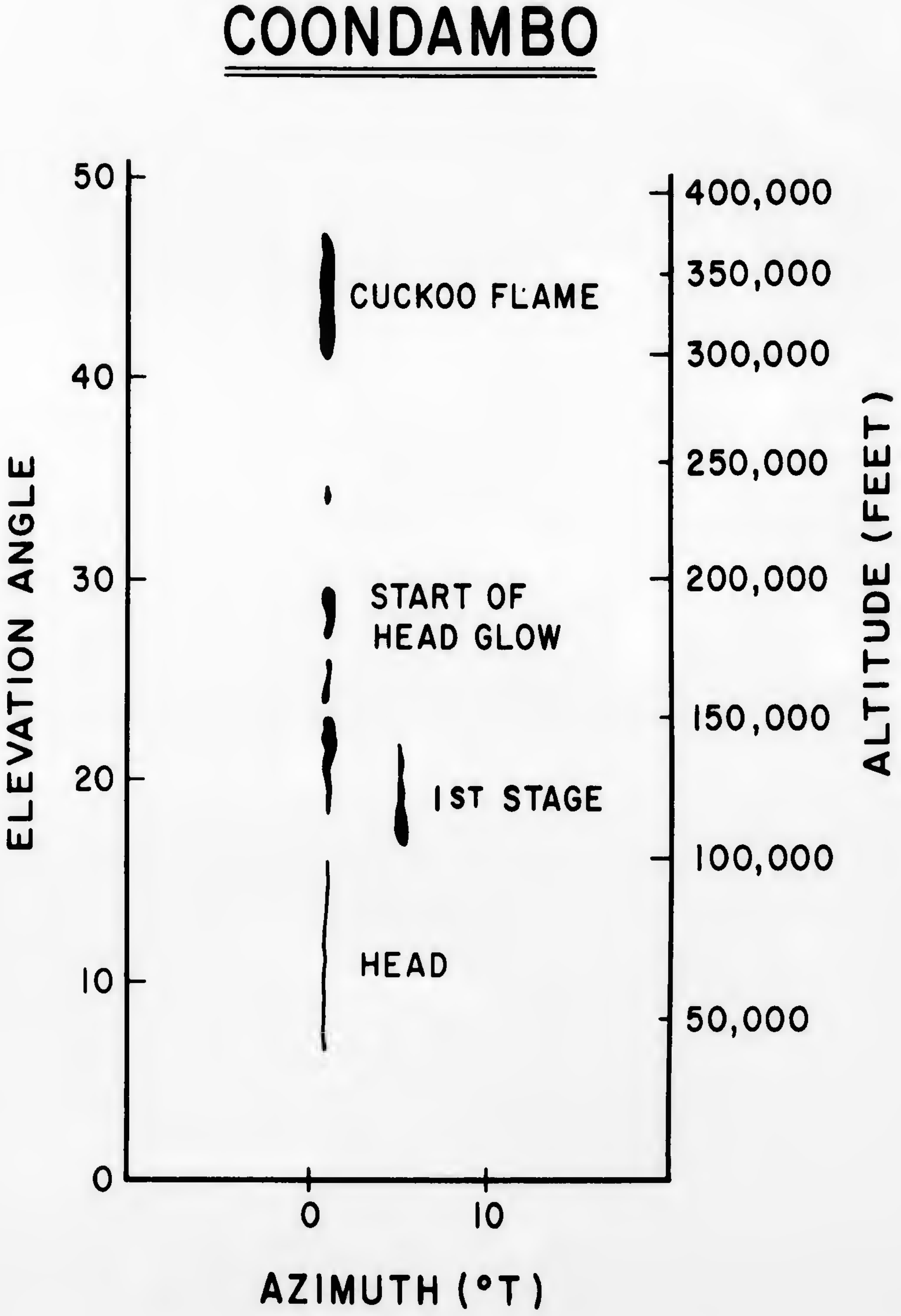


FIGURE 37 TRACINGS OF RE-ENTRY PHENOMENA AS OBSERVED FROM COONDAMBO

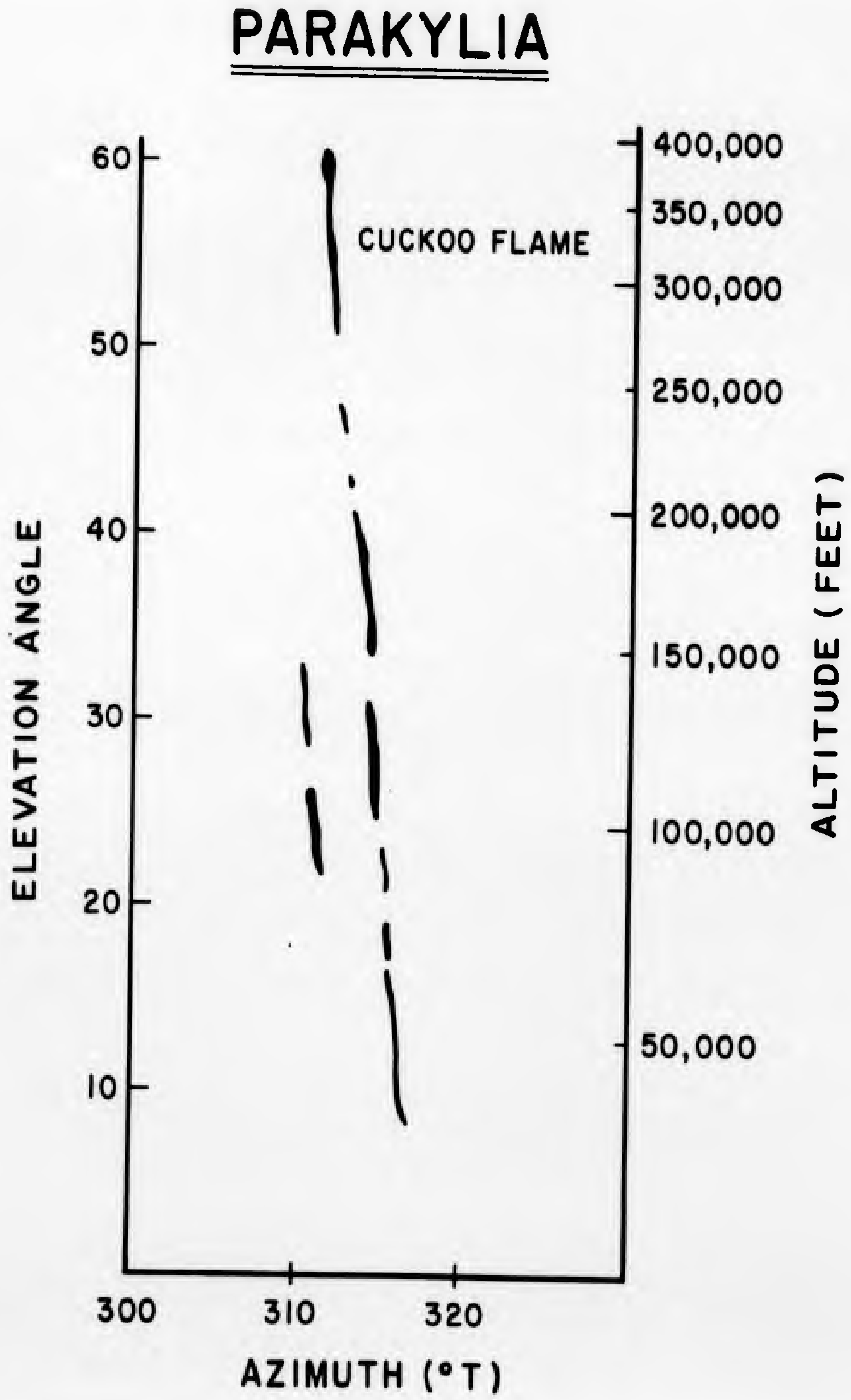


FIGURE 38 TRACINGS OF RE-ENTRY PHENOMENA AS OBSERVED FROM PARAKYLIA

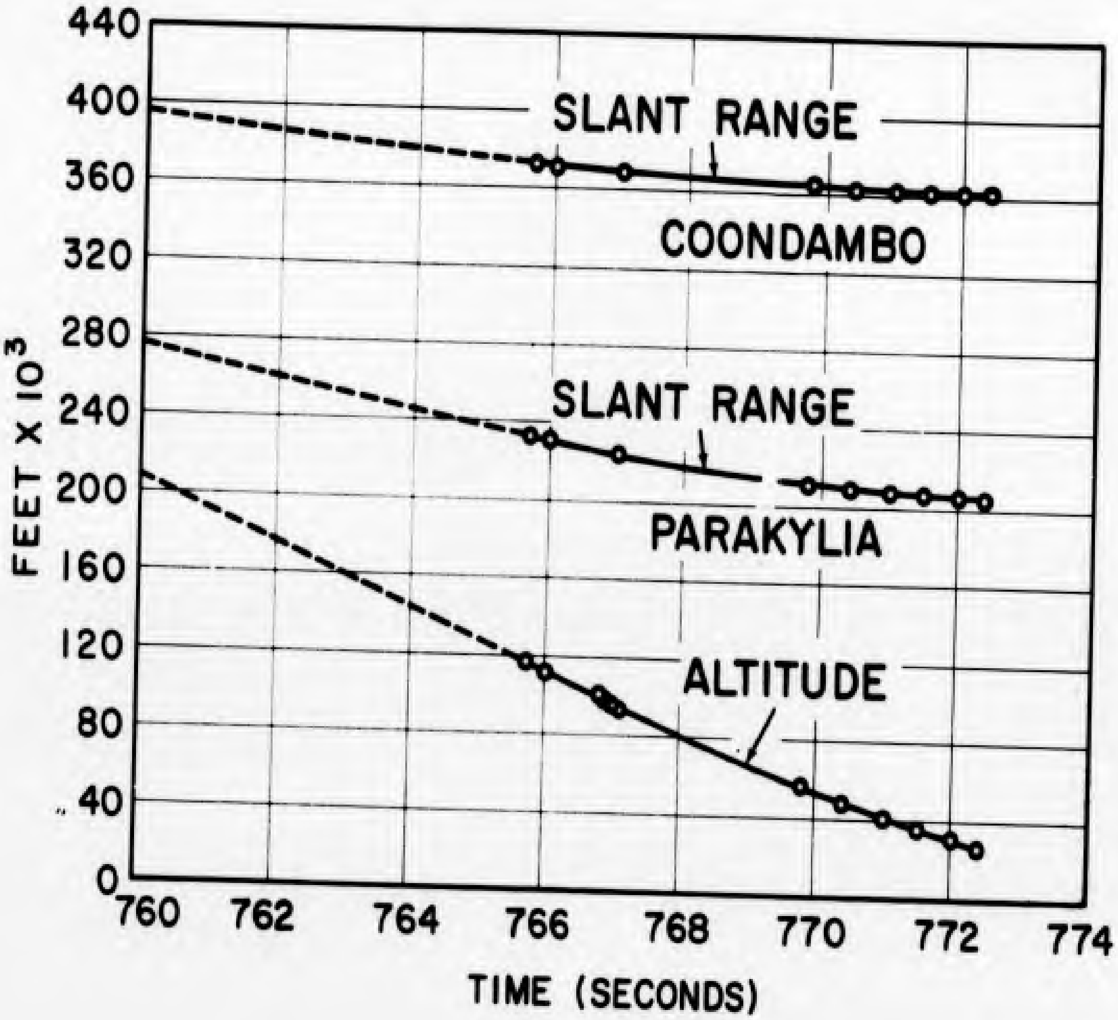


FIGURE 39 ALTITUDE AND SLANT RANGE OF BK09 DURING RE-ENTRY

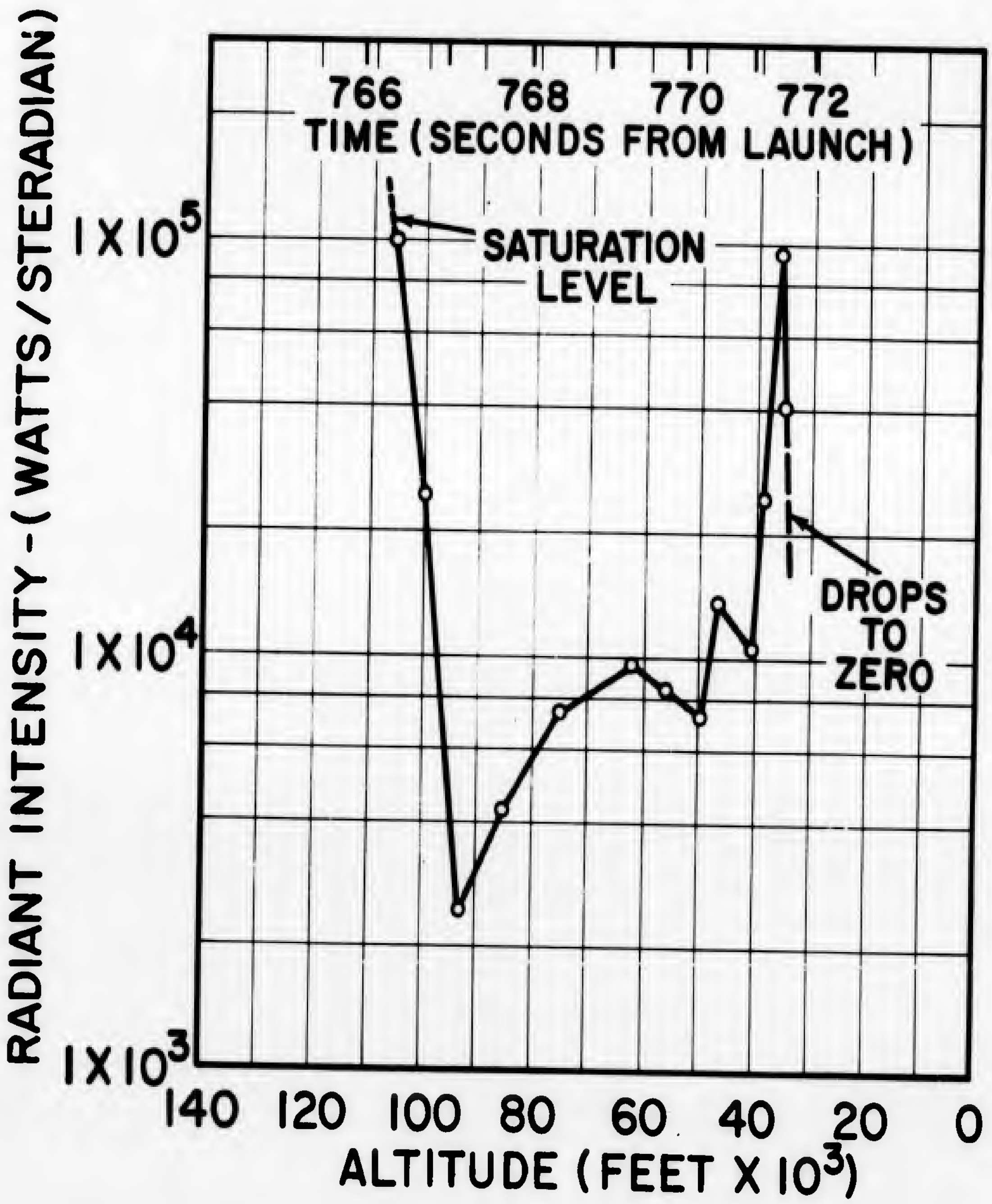


FIGURE 40 BK09 Pb.S. RADIANT INTENSITY OF RE-ENTRY NOSE CONE

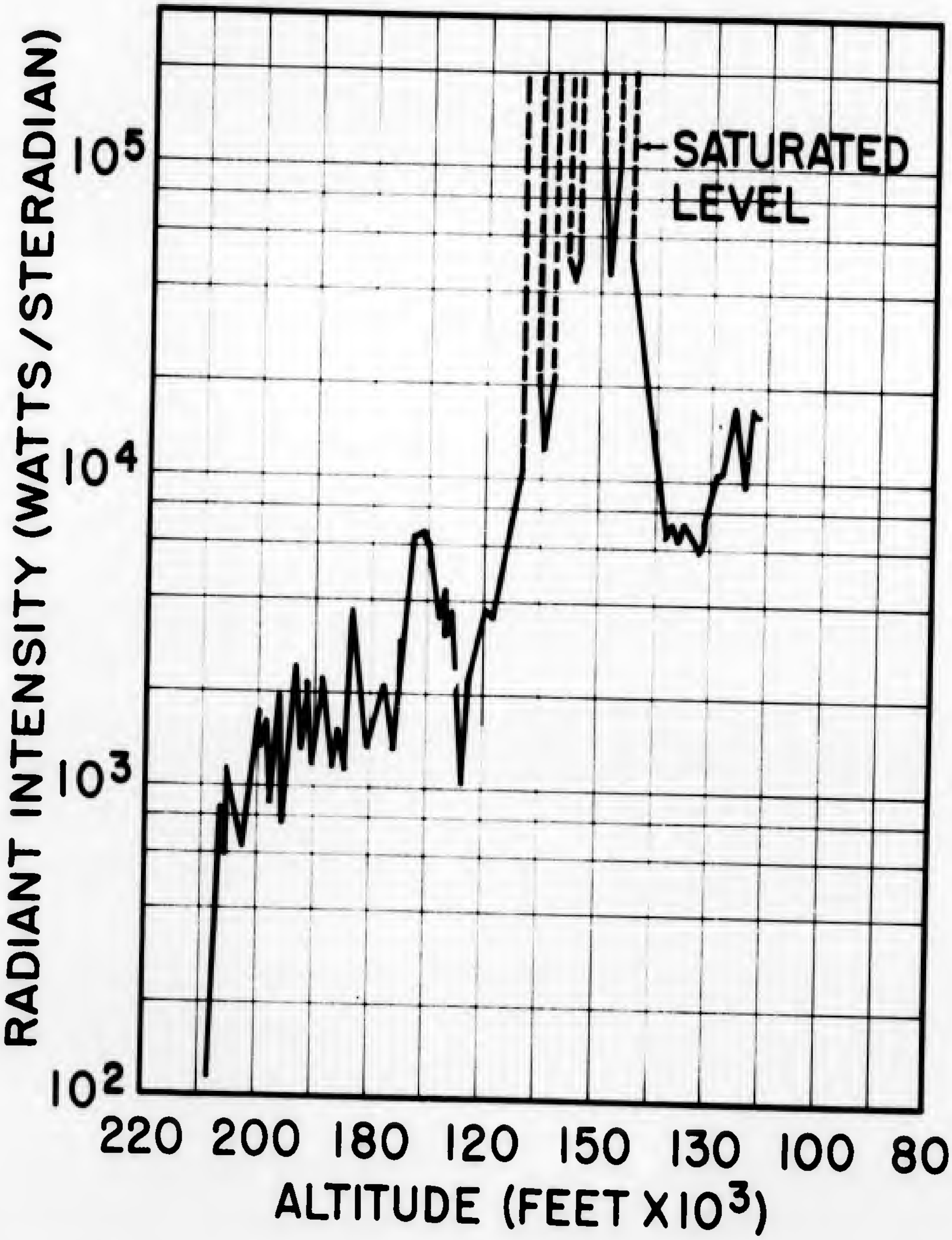


FIGURE 41 BK09 Pb.S. RADIANT INTENSITY OF CUCKOO MOTOR & NOSE CONE

11. (S) The radiant intensity shown on Figure 41 was that of the Cuckoo motor and the nose cone combined. This corresponds to radiation received by the radiometer from point E in Figure 34 down to a point just opposite the brightest glow of the main body but only of the Cuckoo motor and nose cone. The part of the radiation that saturated the instrumentation came at an altitude when the Cuckoo motor and nose cone were just above the point A in Figure 34.

12. (S) The re-entry of the main section of the missile was not acquired by the radiometer at Coondambo until it was down to about 132,000 feet. In Figure 34 this is considerably below point D which is where the Baker Nunn camera first acquired the re-entry of the main body of BK09 (149,000 feet). This altitude of 132,000 feet corresponds approximately to a point on the trace of the main stage just opposite point A in Figure 34. The graph of radiant intensity versus altitude for the main stage of BK09 is shown in Figure 42.

13. (S) The 4-barrel photometer located at Parakylia obtained some excellent data from the re-entry of BK09. The data acquired from the photometric recording has been reduced to radiant intensity and is shown in Figures 43 through 46. Figure 43 shows the radiant intensity versus range time as indicated by the 4205 Å photometer. The first reading was recorded at a range time of 761.8 seconds which corresponds to about 180,000 feet. The photometer centered at 5850Å acquired the missile earlier than the photometer at 4205 Å as is shown in Figure 44. The first acquisition of this photometer corresponds to an altitude of about 210,000 feet which closely corresponds to the first acquisition of the lead sulfide radiometer stationed at Coondambo. The nose cone was first acquired by the photometers by itself when it was at an altitude of approximately 110,000 feet. This acquisition occurred only on the photometer centered at 5850 and 6825 Å. The photometer at 4205 Å only recorded energy in this spectral region at 769.6 seconds which corresponds to an altitude of 59,000 feet. Peaks in energy are seen on the 5850 and 6825 Å photometer at this same time. The radiation at Coondambo recorded the energy received in the 1.8 to 2.7 micron region just a slightly higher altitude of 62,000 feet. It is worth noting that the blue photo tube recorded a radiant intensity of only 1.5 x 10^{-1} power watts/steradian/angstrom while the photometer centered at 5850 Å recorded a radiant intensity of 2.5 x 10^{-1} and the photometer centered at 6825 Å recorded a radiant intensity of 6.0 x 10^{-1} watts/steradian/angstrom. The only record from the photometer centered at 7915 Å appeared when the main body of the missile saturated the other 3 channels. This time corresponds to the point of maximum intensity of the body shown in Figure 46 and amounted to 3.3 x 10^{2} watts/steradian/angstrom.

14. (U) Surface meteorological conditions were observed just prior to the firing of BK09. A profile of the virtual temperature to the height of an altitude of 120,000 feet was also obtained at this time. The temperature at the ground was 49.7 degrees F, with a relative humidity of 76 percent and a surface pressure of 1007.8 mbs.

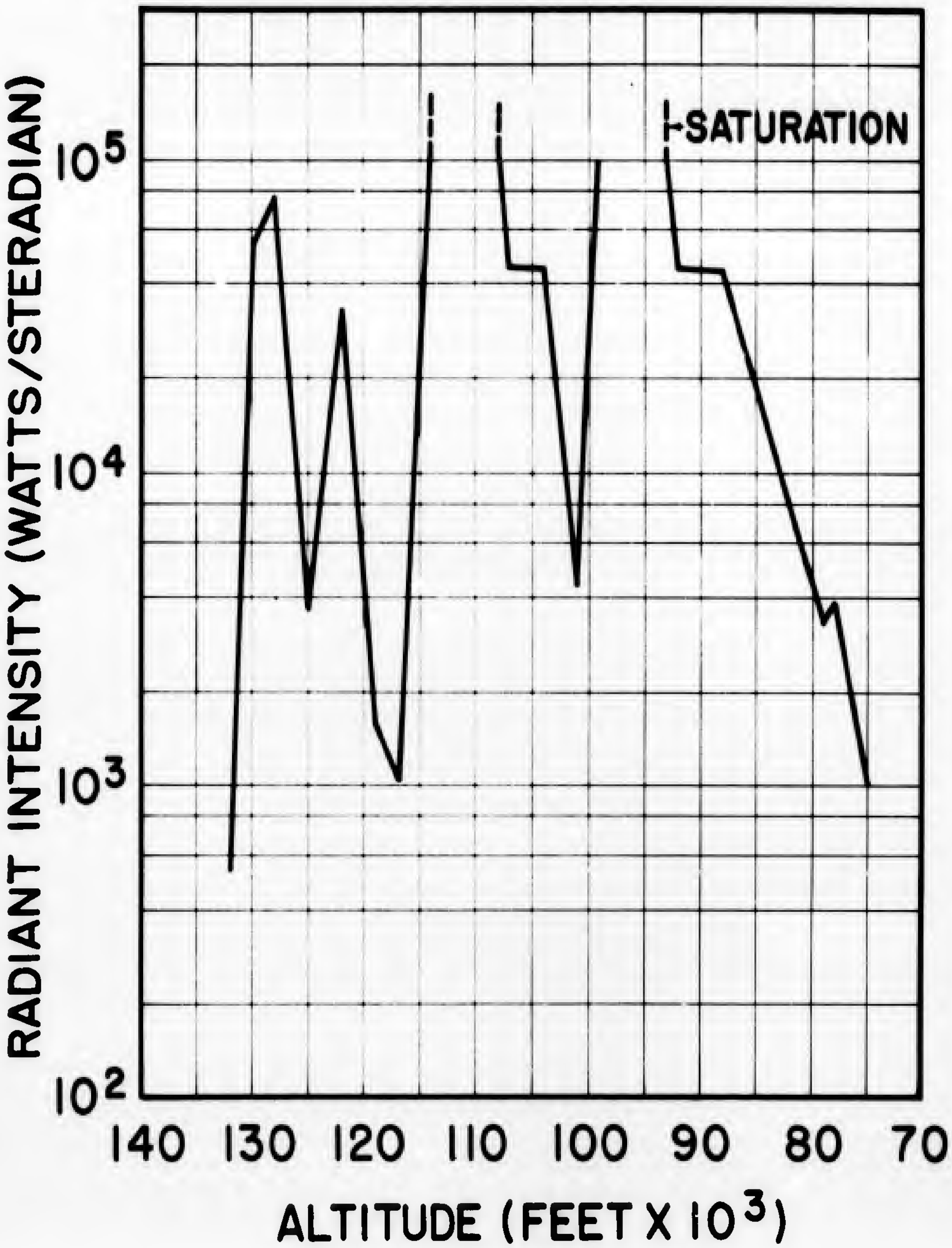


FIGURE 42 BK09 Pb.S. RADIANT INTENSITY OF RE-ENTRY MAIN STAGE

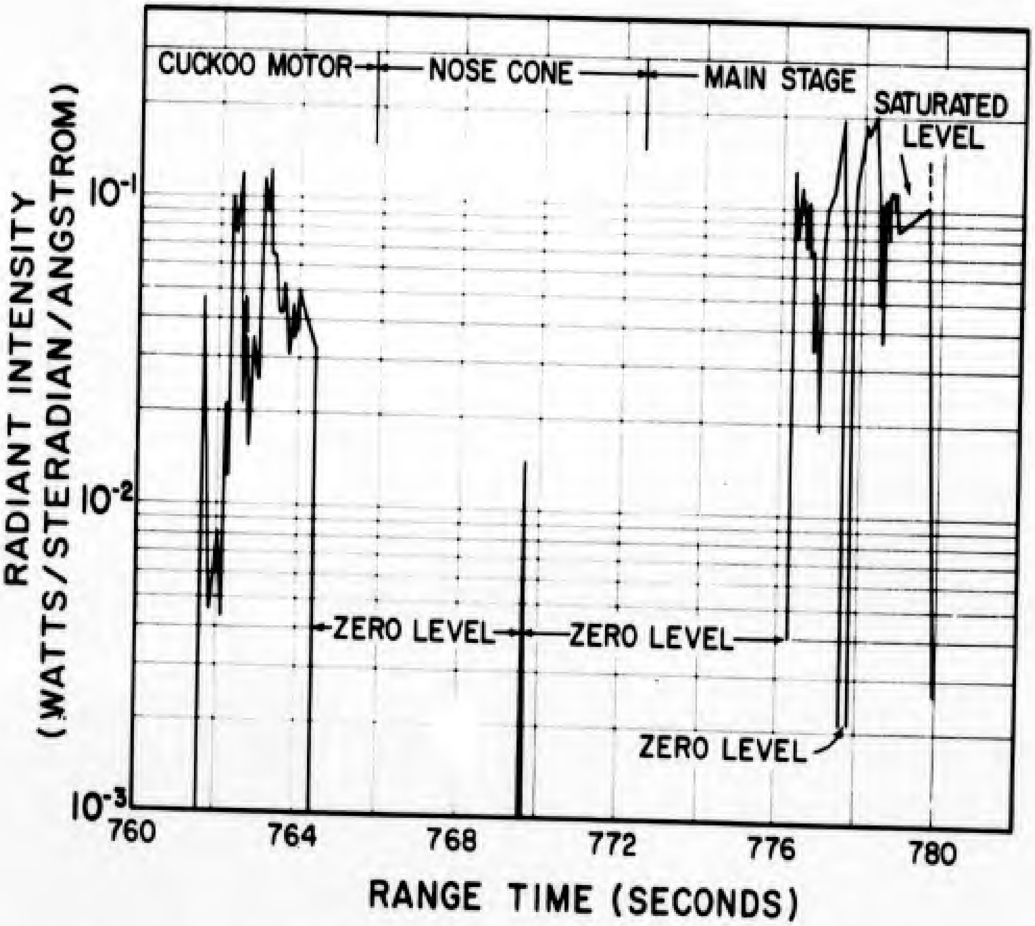


FIGURE 43 BK09 RADIANT INTENSITY DURING RE-ENTRY (4205 A)

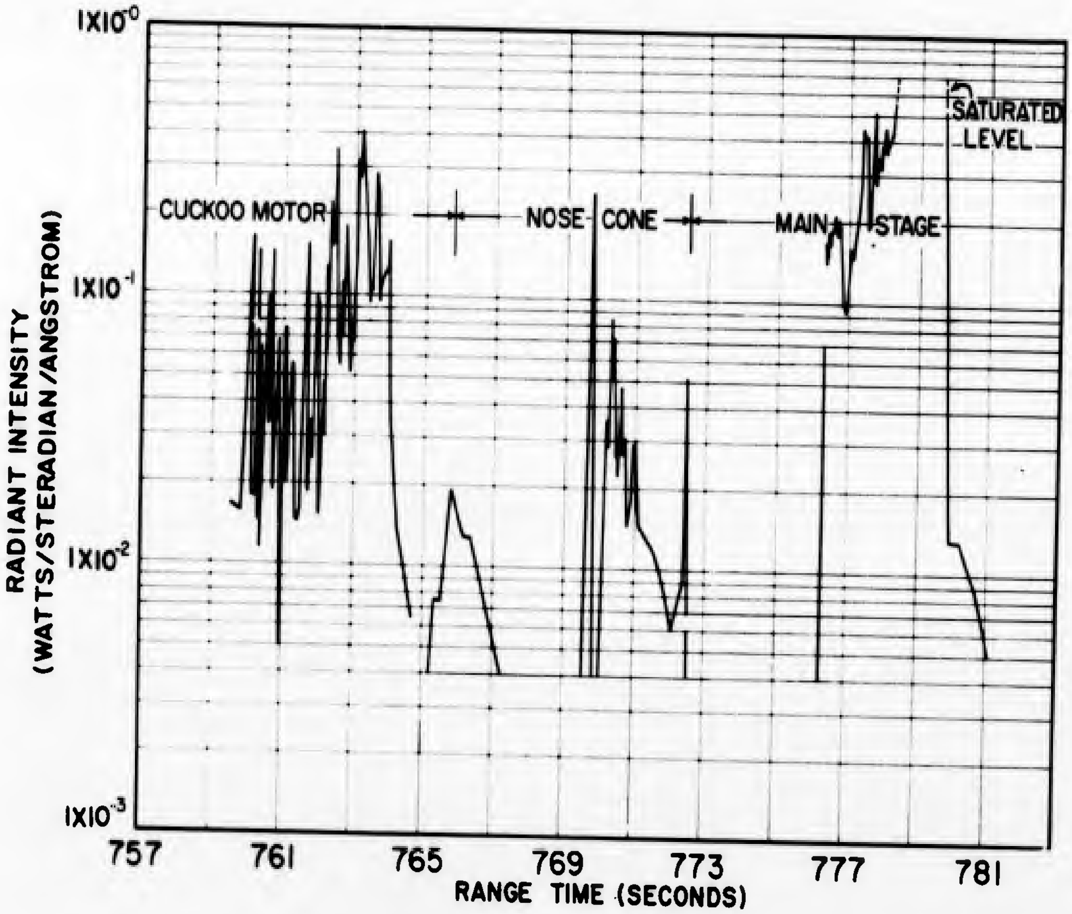


FIGURE 44 BK09 RADIANT INTENSITY DURING RE-ENTRY (5850 Å)

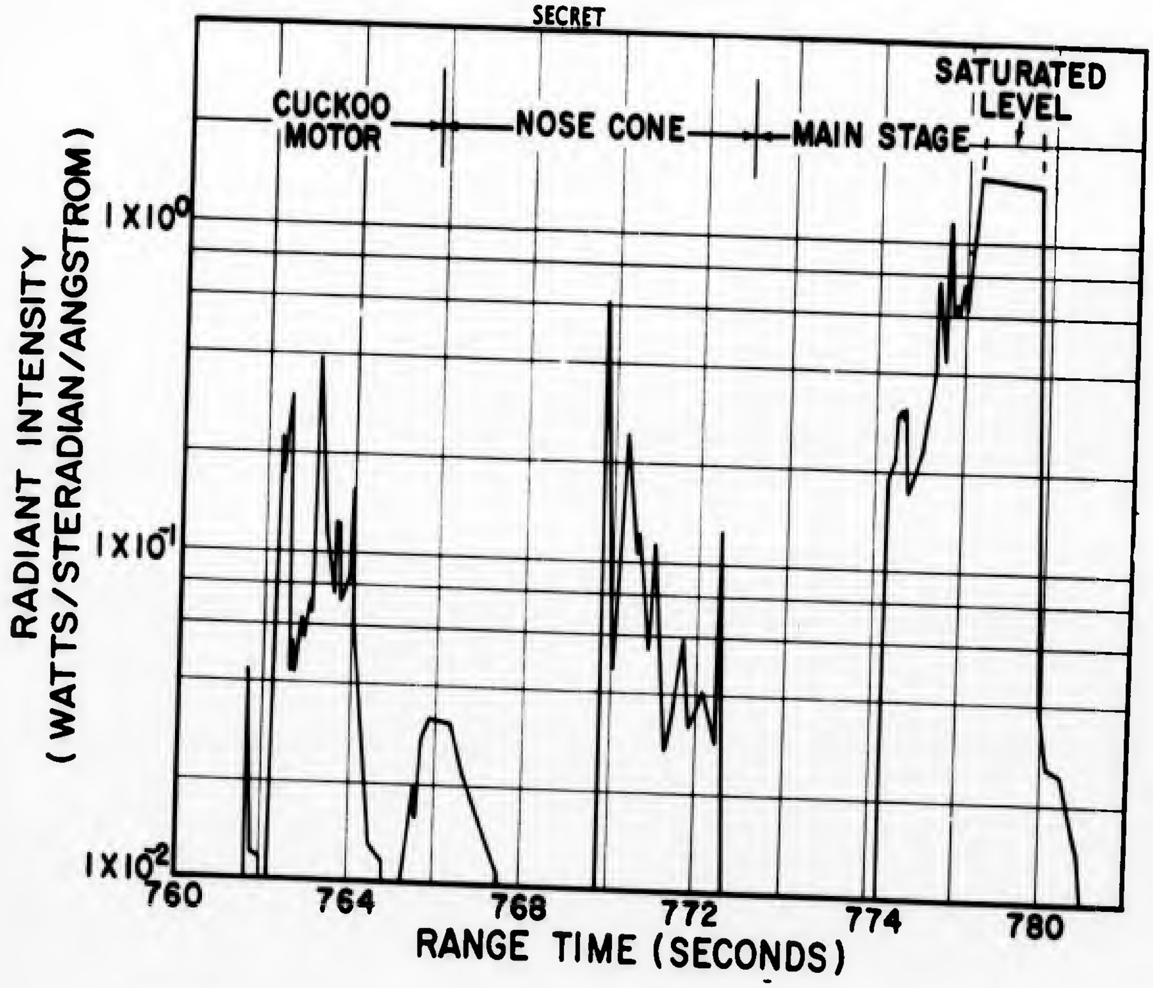


FIGURE 45 BK09 RADIANT INTENSITY DURING RE-ENTRY (6825 Å)

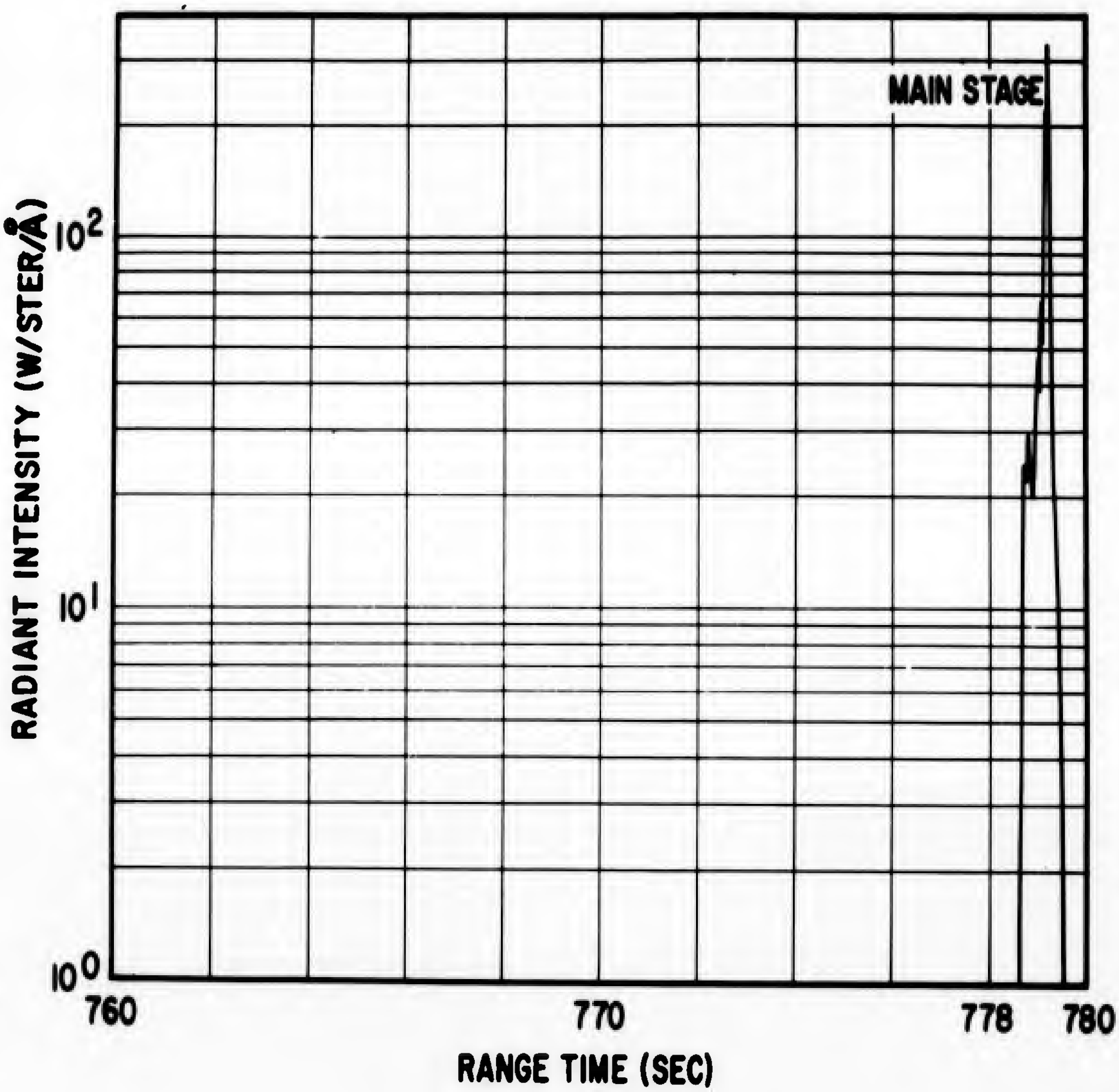


FIGURE 46 BK09 RADIANT INTENSITY DURING RE-ENTRY (7915 Å)

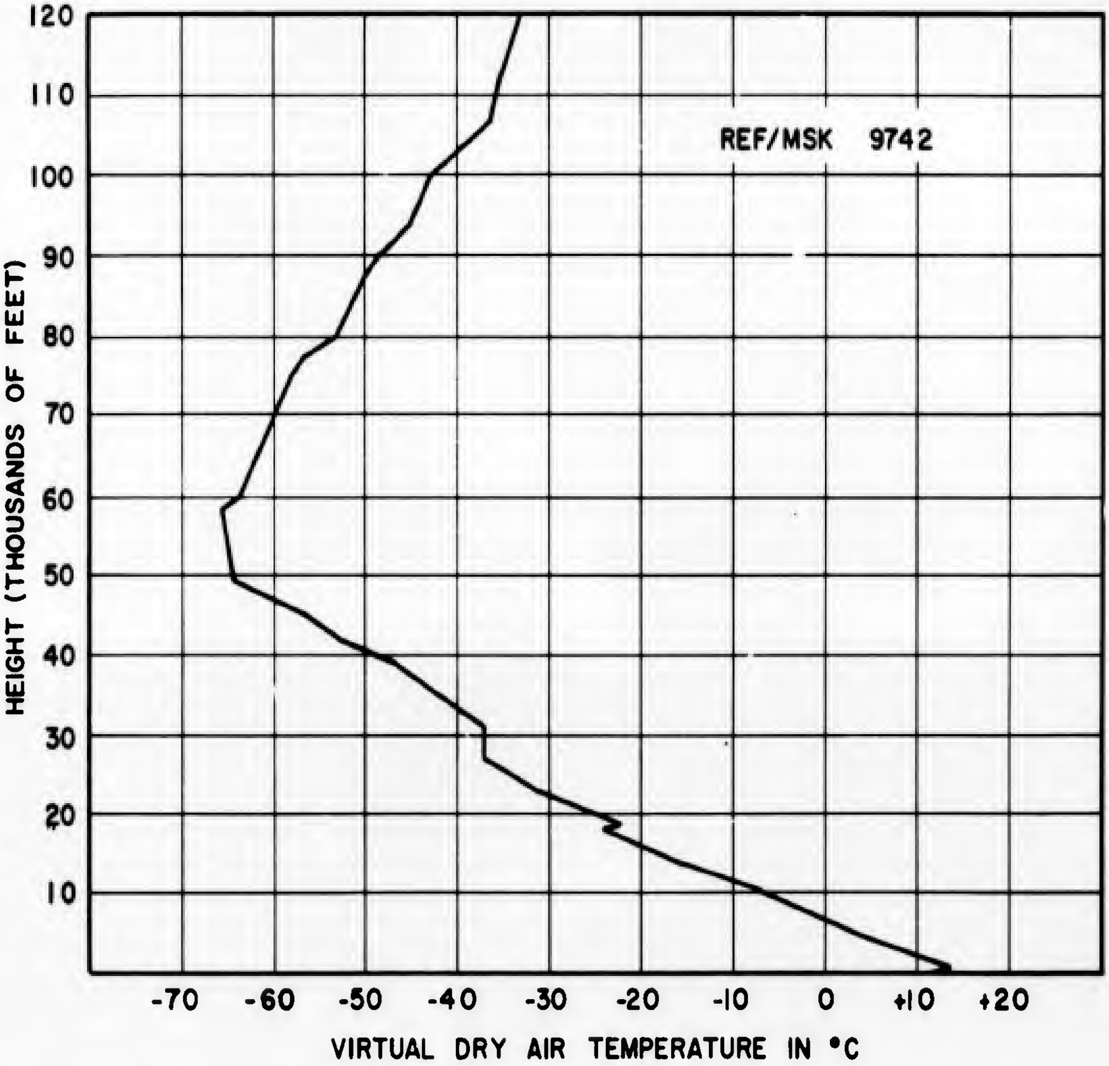


FIGURE 47 VIRTUAL AIR TEMPERATURE PROFILE PRIOR TO FIRING BK09

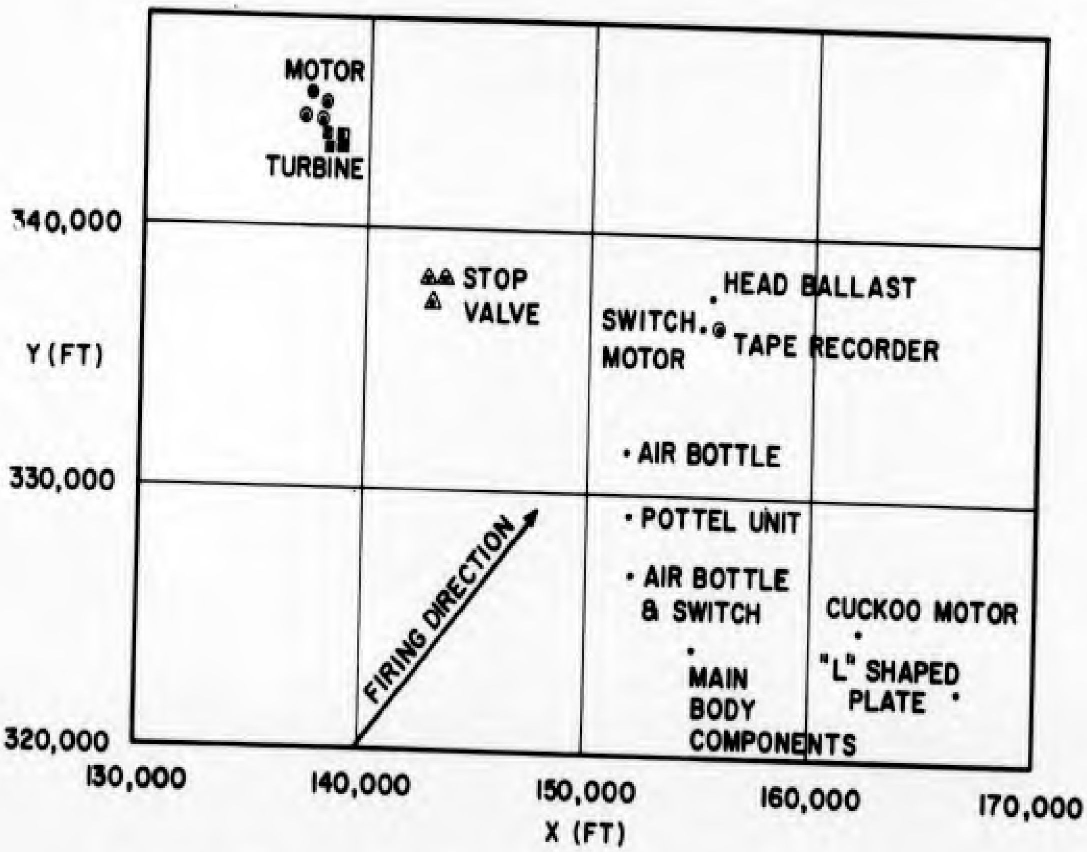


FIGURE 48 DISTRIBUTION OF RECOVERED PARTS OF BK09

Fine isolated growths were present as about 5,000 feet. The visibility was approximately 35 miles on the horizontal and very good vertical. Surface winds below 100 feet were South by South-Southeast at 5 feet per second with very small gusts. Figure 47 shows a profile of the virtual temperature up to 120,000 feet. The tropopause was located at approximately 50,000 feet with a minimum temperature of -65 degrees.

15. (C) One of the big advantages of the Woomera Range is the ability to retrieve any particles that survive the re-entry from the desert floor. Figure 48 presents a plot of the location of numerous constituencies of Black Knight Missile, BK09 that were collected. The X and Y directions and dimensions are measured from the X, Y, Zero coordinate point as indicated in Figure 3. One of the important facts evident from Figure 48 is the number of relatively large pieces and components of the missile that survive the re-entry process. The wide dispersion of the objects perpendicular to the firing direction may indicate very high velocity upper atmosphere in periodic winds. This dispersion of objects indicates that there is considerable need to know more about these high altitude winds in the case of any re-entry measuring experiment.

VIII BK07.

1. (C) Black Knight Missile, BK07 was fired at Woomera, Australia on the 25th of July 1960. The missile was of a single stage construction, as was shown in Figure 4. The re-entry nose cone was a low temperature steel heat-sink type.

2. (S) The launch phase of BK07 did not perform according to the pre-described plans. The total thrust of the missile was less than had been expected, which resulted in a lower re-entry velocity than had been anticipated. The lower re-entry velocity, combined with the heat sink type nose cone produced a rather unspectacular re-entry phenomena. The main stage of the missile was first observed at an altitude of about 115,000 feet and continued to glow to an altitude of approximately 80,000 feet. No data was obtained on the nose cone alone.

3. (C) One of the reasons for the lack of data was that one of the shutter solenoids on the spectroballistic cameras at Parakylia, burned out and blew the main fuze at 70 seconds before re-entry. As a result, there were no records from any of the equipment at Parakylia. The Coondambo radiometer obtained some results. A Hulcher camera and a K24 camera with gratings at Mt. Eba did obtain data. Figure 49 shows a qualitative reduction of the spectra information obtained by the Hulcher camera at Mt. Eba. This data is being further reduced at the present time.

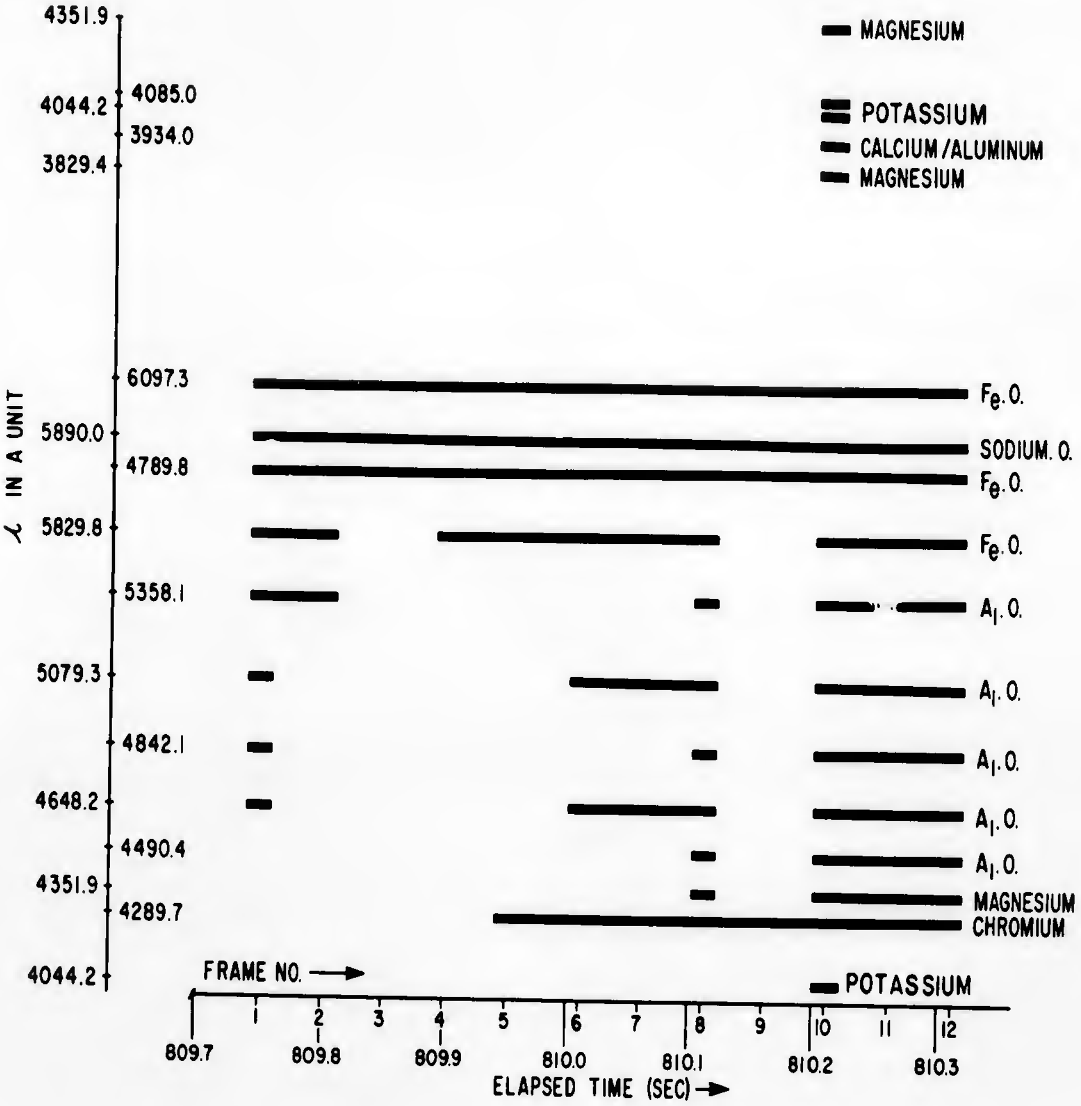


FIGURE 49 AVAILABLE SPECTRA DATA ON BK07

IX. RECOMMENDATION FOR FUTURE OPERATIONS

1. (C) Measurements of BK08, BK09 and BK07 have shown that there is a requirement for additional and more sophisticated equipment on the Woomera Range. The Australians feel that it would be highly advisable to equip both Coondambo and Parakylia with complete sets of identical instruments and to increase the coverage of the spectroballistic cameras. The main advantage to be gained by such a duplication of instrumentation is the protection against the loss of results due to:

a. Missile re-entry at some point in the launch re-entry area not covered by both sites.

b. Operator's difficulty in acquisition and tracking during the short period of re-entry glow.

c. Overlapping trajectories and spectra of various re-entering components.

d. Cloud cover at either site.

e. Power, timing and intercommunication failures.

2. (C) Certain essential equipment modifications are needed for Operation Gaslight equipment in order to continue the program at the present level. These are as follows:

a. The lead sulfide radiometer package at Parakylia is not performing correctly and appears to give erroneous measurements. This will require a new detector package.

b. Considerable data has been lost on the radiometers and on the photometers because of the scaling factors on the recorders. This will require multiple channel recorders with extended dynamic range.

c. Four (4) replica transmission gratings have been taken from the spectroballistic cameras to be used on other Weapons Research Establishment equipment. This equipment is also obtaining data for the Operation Gaslight, thus, there is a need to replace the four replica transmission gratings.

d. A black body calibration source is badly needed so that the radiometers can be calibrated on the range.

e. An azimuth and elevation recording mechanism is required on the Mark 51 Director. This would permit the computation of reasonably accurate quick-look trajectories of tracked objects.

3. (C) An enlarged Operation Gaslight on the Woomera Range would require an expansion and addition to the present equipment. These are listed as follows:

a. The need for a master slave servc tracking system for greater accuracy and instrumentation load.

b. The replacing of existing ballistic spectral cameras with more sensitive cameras.

c. The need to provide coverage in the ultra-violet range of the electromagnetic spectrum.

d. The need to replace the 35mm cinespectrometers with more sensitive 70mm instruments.

e. The need for additional radiometric measurements in the longer wavelengths of the spectrum.

(1) A search-track gold-doped Germanium instrument.

(2) A 32-element gold-doped Germanium scanner that could give 3 x 6 mils spacial resolution.

f. The need for a wide-field highly sensitive image-orthicon system so that tracking can be accomplished much earlier in the missile flight history.

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