COR-0295
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DEFENSE PRODUCTS DIVISION
Fairchild Camera and Instrument Corporation
Robbins Lane, Syosset, New York

PROJECT VERTICON

PROPOSAL NO. SME-CA-80
1 February 1959

PHOTOGRAPHIC RECONNAISSANCE from VERTICAL FIRING ROCKETS

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DEFENSE PRODUCTS DIVISION
Fairchild Camera and Instrument Corporation

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PROPOSED

An adaptation of a simple and reliable scanning camera for use in small or intermediate size vertical firing rockets.

APPLICATIONS

Rapid and large area surveillance.
Rapid meteorological surveys.
Reconnaissance for geodetic control surveys.

ADVANTAGES

High information yield.
Flexibility of usage.
Low equipment cost and short delivery schedule.

CAMERA DESCRIPTION

The basic camera is a scanning rotary panoramic for use with spinning rockets and a compact array of miniature cameras for non-spinning rockets. Wide lateral angular coverage with 360° azimuthal coverage.

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VERTICAL FIRING ROCKET RECONNAISSANCE SYSTEM

This proposal presents PROJECT VERTICON, a system for photographic reconnaissance from vertical firing rockets.

Vertical firing rockets will be an ideal vehicle for relatively low cost, rapid reconnaissance for meteorological data, large area surveillance, and extremely accurate geodetic control surveys. Depending upon the nature of the mission and rocket selected as the vehicle, the camera installation can run from an extremely simple low cost unit using 16mm, 35mm, or 70mm film to more elaborate and sophisticated installations using special optics for extremely high information content in the case of long range surveillance or precisely calibrated mapping lenses and cameras for geodetic control.

GENERAL DISCUSSION

In the gathering of intelligence information utilizing photographic sensors for reconnaissance purposes in a high altitude vertical firing rocket two primary factors come under consideration - Scale of Photography and Ground Coverage. During the determination of a suitable reconnaissance sensor from the vertical firing rocket two types of cameras have been considered which in general are suitable to the two types of rockets, i.e., spinning rockets and non-spinning rockets.

The scale of the photography is determined by the focal length of the camera selected (regardless of its type) and the altitude of the rocket at the time of exposure. Ideally, the scale would be solved by providing the longest focal length possible in the limitations set by the vehicle.

The ground coverage of the reconnaissance system is determined by the focal length of the camera, the size of the film platen (format) and the altitude of the rocket at the time of exposure. Ideally, the coverage would be horizon to horizon and 360° in azimuth providing complete ground coverage. The same "ideal" coverage applies to the consideration of photographic sensors for meteorological or geodetic control surveys with a reduced emphasis on scale of the photography for meteorological purposes and an increased emphasis on system distortion for geodetic control surveys.

Figure 1 illustrates the general application of the photographic reconnaissance sensor to a mission utilizing a vertically fired rocket and whose usage may include general reconnaissance or "looking over the fence", weather reconnaissance, or geodetic mapping.

In the past, the combination of long focal length and wide or large coverage has been impractical since it means a large and bulky installation of a multiplicity of long focal length cameras. Today, however, the combination can be obtained by the use of a single camera installation which by its technique of operation can provide wide angular coverage. As applied to a spinning rocket, this single camera installation is a SIMPLE ROTARY PANORAMIC CAMERA.

The restriction placed on the installation to obtain this large information level is that the rocket itself or some part of it must spin about its longitudinal axis while rising in its trajectory before and/or after burn-out of the final stage. In the case of rockets which are designed to "spin" this presents no problem.

In the case of the frame by frame camera (or square format camera) applied to a spinning vertical firing rocket installation the large angular coverage which is required makes it mandatory to have either a multiplicity of cameras or fast cycling rate for a single camera with an extremely fast shutter speed required in either case to prevent photographic blur due to rocket rotation. Such an installation can be made using the shorter focal length lenses with the smaller format sizes.

Considering the non-spinning rockets such as "ARCAS", "ARCON" and "IRIS" the photographic reconnaissance mission can be accomplished by a cluster of miniature cameras utilizing existing wide angle lenses such as the 1-1/2" Biogon and a 2-1/4 x 2-1/4" format. The decision as to the camera design to be used actually rests with the rocket design selected to carry out the mission and the type of reconnaissance mission. For a rocket with a 15" diameter such as the Aerobee-Hi a single camera housing utilizing four lenses can be mounted at the extreme lower portion of the rocket. Such an installation is discussed in the next section of this report. It should be noted here that this type of installation will provide reconnaissance from altitudes between the time of sustainer drop off and the peak of the trajectory. During this portion of the flight it can provide photography of the entire area visible, horizon to horizon through a full 360°. Based on the estimated performance data of the Aerobee-Hi this would be from altitudes of 26 miles to 168 miles.

For a rocket of smaller diameter the "cluster" of cameras may be spread out along the longitudinal axis - making five individual miniature cameras and a single miniature to photograph from the bottom portion of the rocket. Where the particular mission requirements permit, a delay in the operation of the vertical camera will permit oblique photography before sustainer drop off and, therefore, provide larger scale oblique photography with a minimum blind spot.

The film footage required in any installation is dependent upon the length of time of the coasting phase and the duplication of photography desired. It is considered appropriate in the case of a "cluster" of cameras that several frames be exposed of the same (full coverage at each exposure station) area since the scale will be different at each exposure station and multiple observations will aid in the interpretation of data.

It must be pointed out that although the specific application presented here is for the vertical firing rocket, the basic approaches may be used in other ballistic trajectory rockets as illustrated in Figure 2.

In the accompanying discussions it is realized that the vehicle payload includes other equipments such as parachute and recovery beacon in addition to the photographic sensor.

Characteristics of typical vertical firing rockets are appended hereto to provide the necessary technical data to aid in system selection and specification.

TECHNICAL DISCUSSION

This section is devoted to a technical discussion of the types of cameras and their application to a vertical firing rocket reconnaissance system.

a. Panoramic

b. Frame by frame cluster of cameras

c. Frame by frame single lens camera

d. Frame by frame four lens camera

A. Panoramic Cameras

The use of a panoramic camera permits the use of lens design techniques which result in a higher performance in terms of image quality than a lens design for a square format (frame by frame) camera within a given weight and cost. This advantage is attributable primarily to the reduction in the 1/2 angle field of view of the lens since the panoramic camera format is a slit (a few thousandths of an inch the width of the film being used) as opposed to the diagonal of a square format camera (usually 1.414 times the width of the film).

Using this advantage of design it is possible to increase the speed of the lens (within the same weight and cost) which permits faster shutter speeds. With modern large aperture lenses (together with improved transmission factors) and the high speed emulsions, very fast shutter speeds can be used to obtain acceptable exposures. In the panoramic camera where the exposure time is obtained as a junction of film transport velocity and slit width speeds upwards of 1/4000 to 1/5000 second are practical. Such exposure times go a long way towards reducing the amount of "smear" normally resulting from image motion.

The determination of the correct film transport velocity across the exposure slit as a function of the rocket spin rate can be accomplished in at least three different ways as follows:

1. A small rate gyro can be installed within the rocket, the spin axis of the gyro being perpendicular to the spin axis of the rocket. An electrical signal can be derived which is proportional to the spin rate and thus becomes the input to a servo drive for film transport.

2. Depending upon the operational concept of the rocket reconnaissance the spin rate may be obtained by photo-electric means such as an input to a photo-electric sensitive surface from the sun.

3. The spin rate of the rocket may be preset before launch.

Combinations of these may also be used, for instance, the determination of preselected spin rate just prior to the last stage burn out by photo-electric means after which the spin rate would have a minimum of change in the absence of atmosphere to retard it.

Figure 3 represents embodiment of a SINGLE ROTARY PANORAMIC CAMERA in a 100 inch focal length showing an extremely long focal length lens in a minimum package and serves to emphasize the major advantage of this type of camera: LARGE SCALE WIDE ANGULAR COVERAGE IN A SINGLE CAMERA. In this camera type the lateral angle is a matter of designer's choice. It is shown in its usual orientation; that is, with its optical axis parallel to the ground plane, with a single reflecting surface in front of the lens to direct the optical axis vertically downward. The instantaneous field of view of the lens is limited to a rectangular area determined by the film width in one direction and the width of an exposing slit in the other.

The feature of flexibility of lateral angular coverage is accomplished as illustrated in Figure 4. Exposure is made by drawing film past the slit as the entire camera including the magazine, rotates about its optical axis. This rotation is continuous in one direction, the angular velocity normally being a function of V/H and overlap requirements. Thus, it is possible to scan continuously, 360° around the longitudinal axis with all parts of the camera moving uniformly without intermittencies of any kind. Film velocity from supply, through the exposing slit to take-up spool in this case would be constant. However, since scan angles greater than 180° (horizon to horizon) are seldom required in a vehicle with its axis horizontal it is necessary to move film across the slit during only part of the rotation. The spools, themselves, however, continue to turn, feeding and taking up film at an average rate which furnishes the amount required for the portion of the rotation during which photography occurs. Chambers for the slack film are provided on each side of the slit. Referring to Figure 4, the transport cycle proceeds as follows:

Film is drawn from the supply spool by a pair of pinch rollers turning at a speed which is integrally tied to the rotational speed of the camera, which in turn is proportional to V/H. The film then passes under a roller attached to the scan stop switch, thence through the pressure plate assembly around the metering drive roller, and idler roller, and onto the take-up spool. The metering roller is mounted on a rocking member in such a way that it does not contact the film except during the scan period. This roller is continuously driven at a speed proportional to the camera rotation. It is brought into contact with the film by the solenoid (shown schematically) when the camera reaches the point selected for starting the scan. The film previously accumulated in the supply chamber is then drawn past the exposing slit at a speed which is synchronous with the image being swept across the slit by the rotating mirror. As the film runs out of the supply chamber it actuates the scan stop switch, which de-energizes the solenoid, causing the rocker arm to tilt counter-clockwise, disengaging the driving roller and engaging a fixed roller on the opposite side of the gate, which serves as a brake to hold the film from coasting or being fed across to the take-up spool when the latter takes out the slack loop which has been transferred into the take-up chamber.

The take-up spool is simply overdriven sufficiently to take out all the slack film before the next scan occurs. In a more refined version or where the mass of film is great, a second pair of pinch rollers would be used at the take-up side to meter the film to the spool at a rate which would keep the spool turning continuously.

Control of the supply loop by the above method prevents accumulative build-up, or loss by virtue of the fact that all the film (whether too much or too little) is withdrawn each cycle. The effect of a slight over or under supply is merely to add or subtract proportionately from the angle scanned.

Figure 4 indicates one way in which the entire camera can be rotated by a single drive motor. In this case a fixed sleeve which would be mounted to the aircraft structure or a mount as the case might be, supplies bearing support for the camera. A belt is used to couple the motor to the camera through a cut-out in the fixed sleeve. Driving of the various rotating members in the magazine is effected by a pinion which rolls on an internal ring gear fastened to the fixed sleeve.

In order to maintain the shutter speed through variations in V/H the adjustable slit mechanism will contain an overriding control, which will be actuated as a function of the rotational speed.

Other functions such as remote exposure control involving iris and/or the slit width are readily adaptable by usual servo methods. The only difference here is that all these items will be rotating continuously about the optical axis.

As used in a vertical firing spinning rocket the basic camera described above would be oriented with its optical axis perpendicular to the ground plane with a single reflecting surface mounted so as to have a field view downward and outward. Although the camera housing is shown separate from the rocket shell it is pointed out that the camera and shell rotate together at the rocket spin rate. If final installation considerations show it to be advantageous the camera housing and rocket shell can be combined as one unit.

Depending upon the vertical velocity and spinning rate of the rocket the field of view of a continuously operating camera may result in a spiral coverage with a discontinuity of coverage in the radial direction. To prevent such an occurrence the reflecting surface may be programmed to pivot about its midpoint as a function of the vertical velocity and spin rate.

In order to determine the optimum exposure altitude for each panoramic sweep it is necessary to determine the coverage which can be made from a specific altitude.

Figure 5 is a plot of the ground coverage (arc distance on the earth's surface) as a function of altitude for two angles off the vertical. In this case 64° and 74° were selected since a panoramic camera of 12" focal length using 5" wide film is under consideration. The optical axis is positioned at 74°, therefore, providing a field of view from 63-1/2° to 84-1/2°. (Only a nominal angular value (64°) has been used in the plot). Also shown is the radius (arc distance) to the horizon as a function of altitude.

This plot provides a way of selecting the altitudes for exposures to be made Thus, if the first exposure is made at 25 miles, coverage is provided from a radius of 50 miles out to the horizon at 425 miles. Since the high oblique contains information which is not extremely useful for certain intelligence purposes, it may be necessary to provide overlap in the radial direction.

For purposes of illustration, consider 50% radial overlap or the next exposure at such time as the blind spot becomes approximately 100 miles (see 25 mile altitude at 74° curve on plot). Such an exposure will extend from approximately 100 miles to the horizon at 625 miles.

By following this sequence, the exposure stations can be determined. Figure 7 with the overlays illustrates the coverage of this type of operational technique with the following conditions:

Exposure No.	Altitude	Extent of 360° Coverage
1 (red)	25 miles	104 to 886 miles
2 (green)	40 "	170 to 1120 "
3 (black)	75 "	344 to 1530 "
4 (blue)	140 "	624 to 2076 "
5 (yellow)	275 "	1380 to 2870 "
6 (orange)	345 "	1894 to 3194 "

The coverage as shown is predicated on the use of a 12" focal length lens and 5" film configured into a Fairchild Rotary Panoramic Camera as shown in Figure 6.

To make full consideration of the rocket performance, Figure 8 illustrates the application of a 12" panoramic camera with a rotatable mirror used to overcome wobble which is experienced in the rocket during sustainer firing and after sustainer fall off.

The foregoing descriptions of specific panoramic cameras and coverage also applies to panoramic cameras using 35mm or 70mm film. These smaller sizes are quite ideal for weather reconnaissance using the smaller diameter rockets.

B. Frame by Frame Cameras

For application to non-spinning rockets the same coverage as indicated above can be obtained utilizing 5 cameras set in an oblique position as indicated in Figure 9. As can be seen the five oblique cameras have been "stacked" along the longitudinal axis of the rocket to fit into a 6 inch rocket such as the ARCON. Similar installations using other cameras and film sizes can be made for the 12 inch diameter IRIS, the 4-1/2" diameter ARCAS, the 8" diameter instrumentation chamber of the AEROBEE-300 (SPAEROBEE) or in the case of weather reconnaissance even smaller rockets. Specifically consideration has been made for a 16mm rotary panoramic camera using a 25mm lens to provide 360° coverage from up to 38 different altitudes in a two inch diameter rocket.

Figures 10 and 11 indicates the coverage obtainable from such an array of cameras from altitudes of 100 miles and 600 miles respectively.

Fairchild Camera and Instrument Corporation has recently completed a preliminary design of a four lens camera for use as a reconnaissance camera from high altitude. The application of this camera to a vertically fired rocket is shown in Figure 12. This camera provides an angular coverage of 156° "lateral" or 78° from vertical in all directions (360° coverage in azimuth). As illustrated in Figure 12, it is obvious that such an installation is applicable to rockets of 15" diameter and larger, whose sustainer is ejected. It is not impossible in the larger rockets to make provisions for retracting the camera (or take-up spools) to allow for recovery techniques required such as sealing the end of the nose cone. This installation will photograph the entire earth's surface (horizon to horizon - 360° in azimuth) from altitudes of 110 miles and above.

Figures 13, 14 and 15 are photographs of the mockup made of this camera. Figure 16 is an artist cutaway view of the four lens camera showing the relationships of formats, film supplies, drive package and the automatic exposure control sensing element.

GROUND SUPPORT EQUIPMENT

The intelligence obtained from the photographic record will depend to some extent upon the ground support equipment furnished. This equipment falls into two major categories, each identified with the type of camera; panoramic and frame by frame.

For general reconnaissance each category must provide a rectification of the photographic record to a useable datum. In the case of the panoramic camera, this rectification may be done in several ways. The most direct approach would be an autofocusing enlarger which would rotate to cause an exposure of a narrow field of view and simultaneously increase its height above the datum to compensate for the rocket increase in altitude during a single panoramic exposure. The relationship between the rate of rotation and translation will depend on the vehicle selection (rate of spin and velocity at the time of exposure).

Other types of rectification may be possible for certain types of intelligence to be obtained such as point location, continuous charting of a single feature such as river, coast line or transportation network. In this type of intelligence, point by point rectification may be considered adequate.

In the case of a frame by frame camera where each frame of a cluster of cameras may be considered as a single rectification the problem is simple. The overall picture, however, that of transferring from detail in one frame to detail in another frame taken from the same exposure station becomes somewhat more involved. Here it is presently considered appropriate that the ground support equipment would be based on an analytical solution relating each frame to the vertical as a "zenith angle" and "azimuth angle". From such analytical data, adjustments may be made as multiple observations are made of the same points in subsequent exposures.

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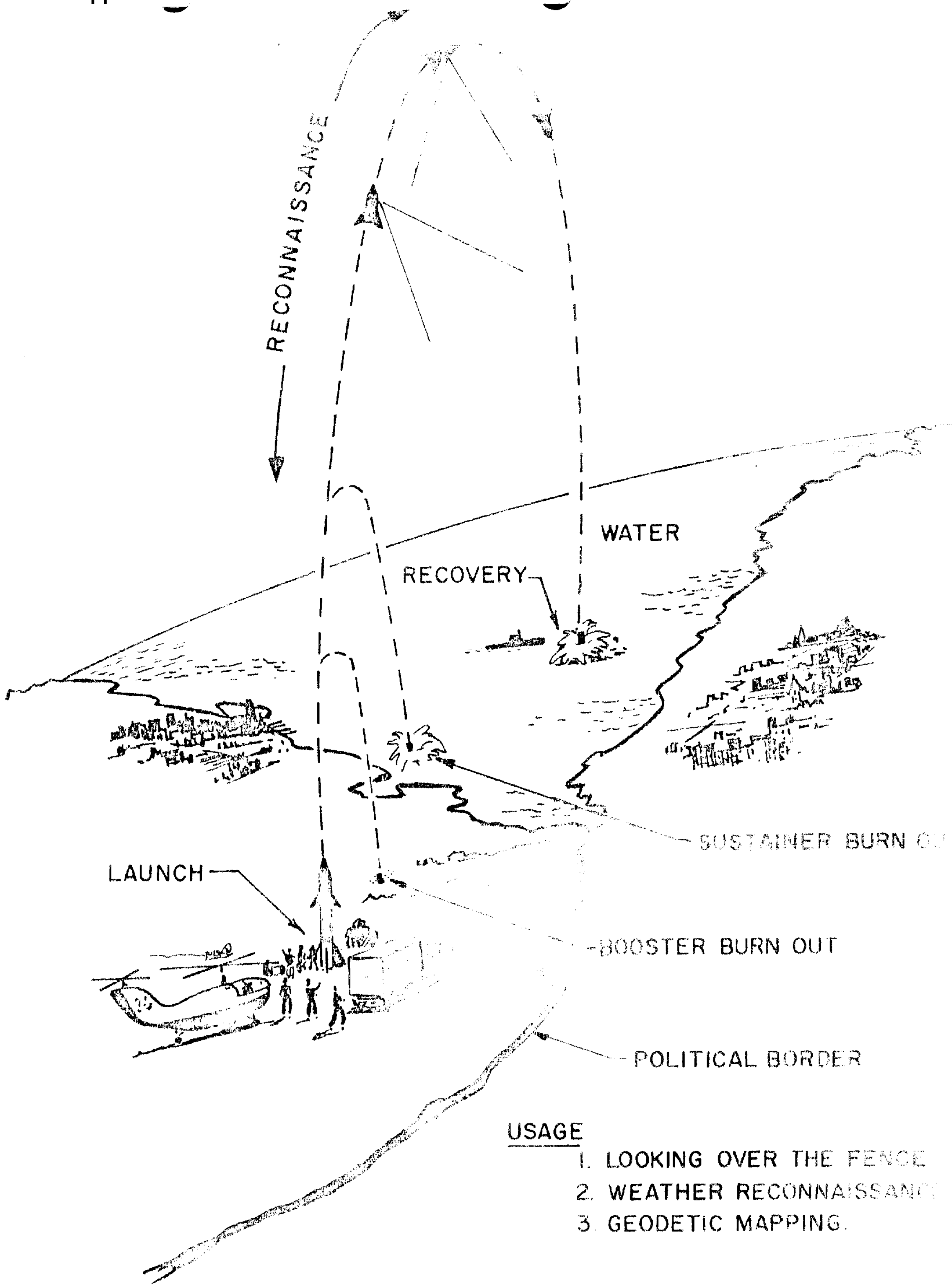


FIGURE I.

VERTICAL ROCKET RECONNAISSANCE

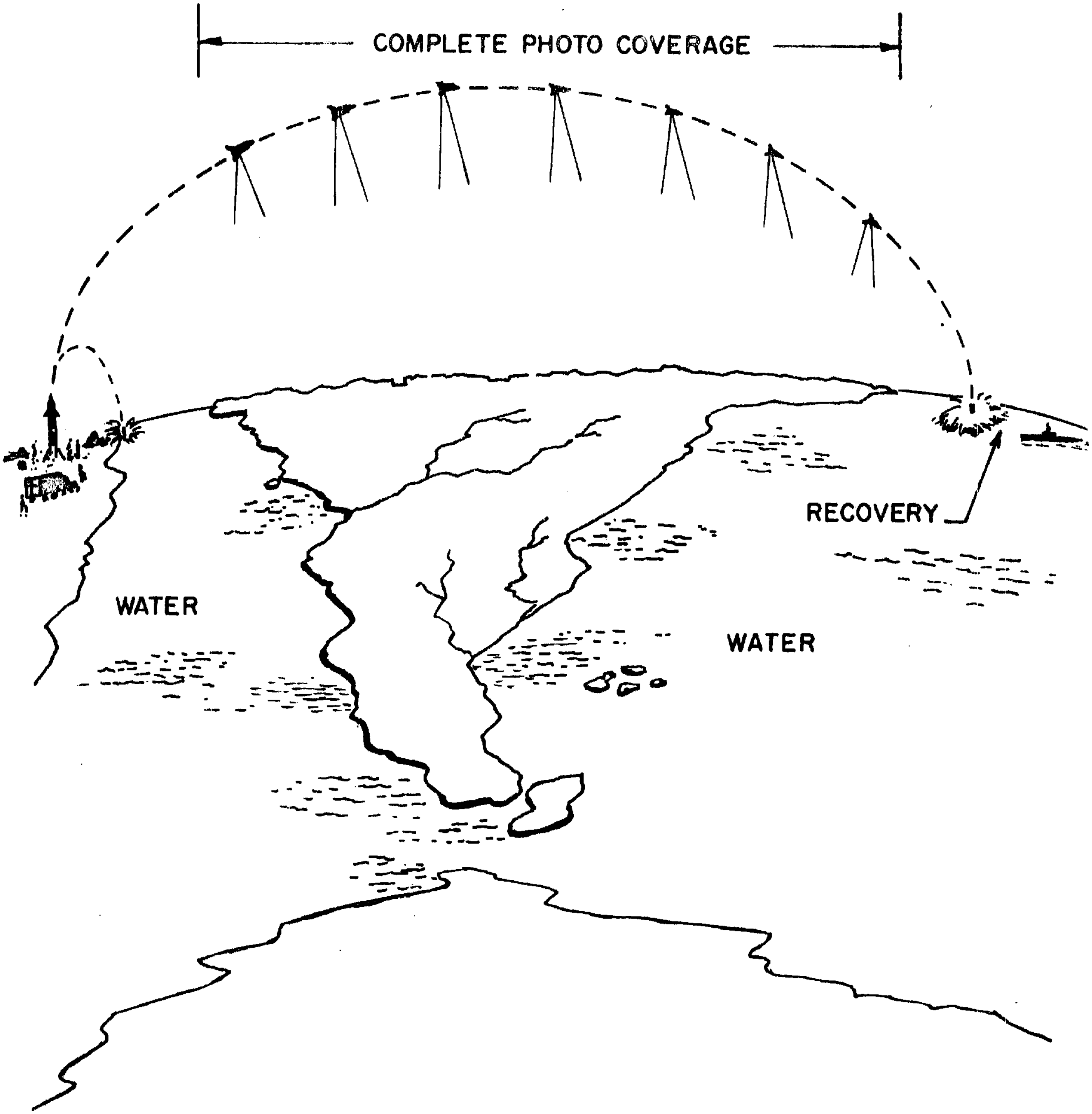


FIGURE 2
RECONNAISSANCE SYSTEM FOR BALLISTIC TRAJECTORY ROCKET

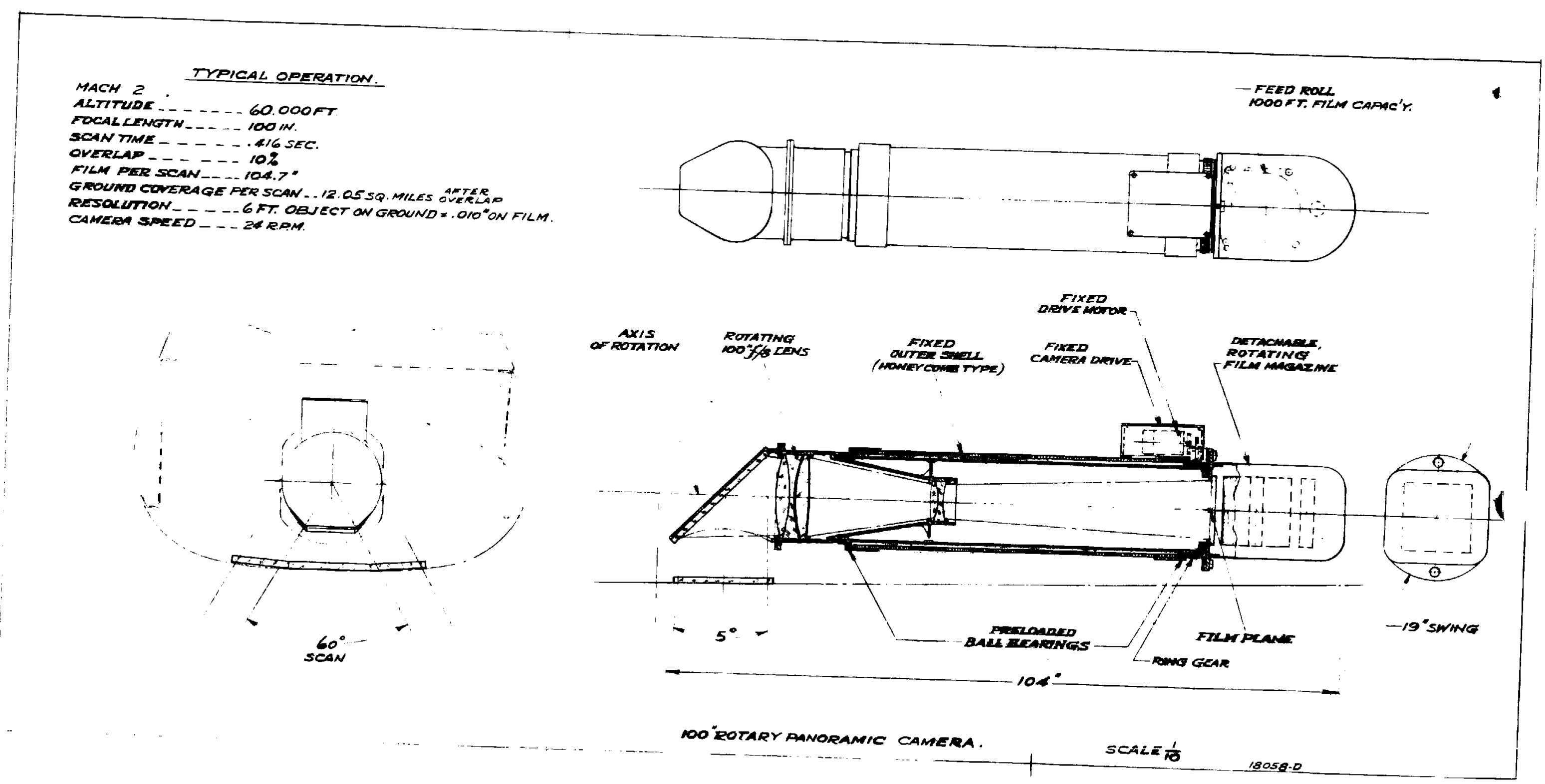
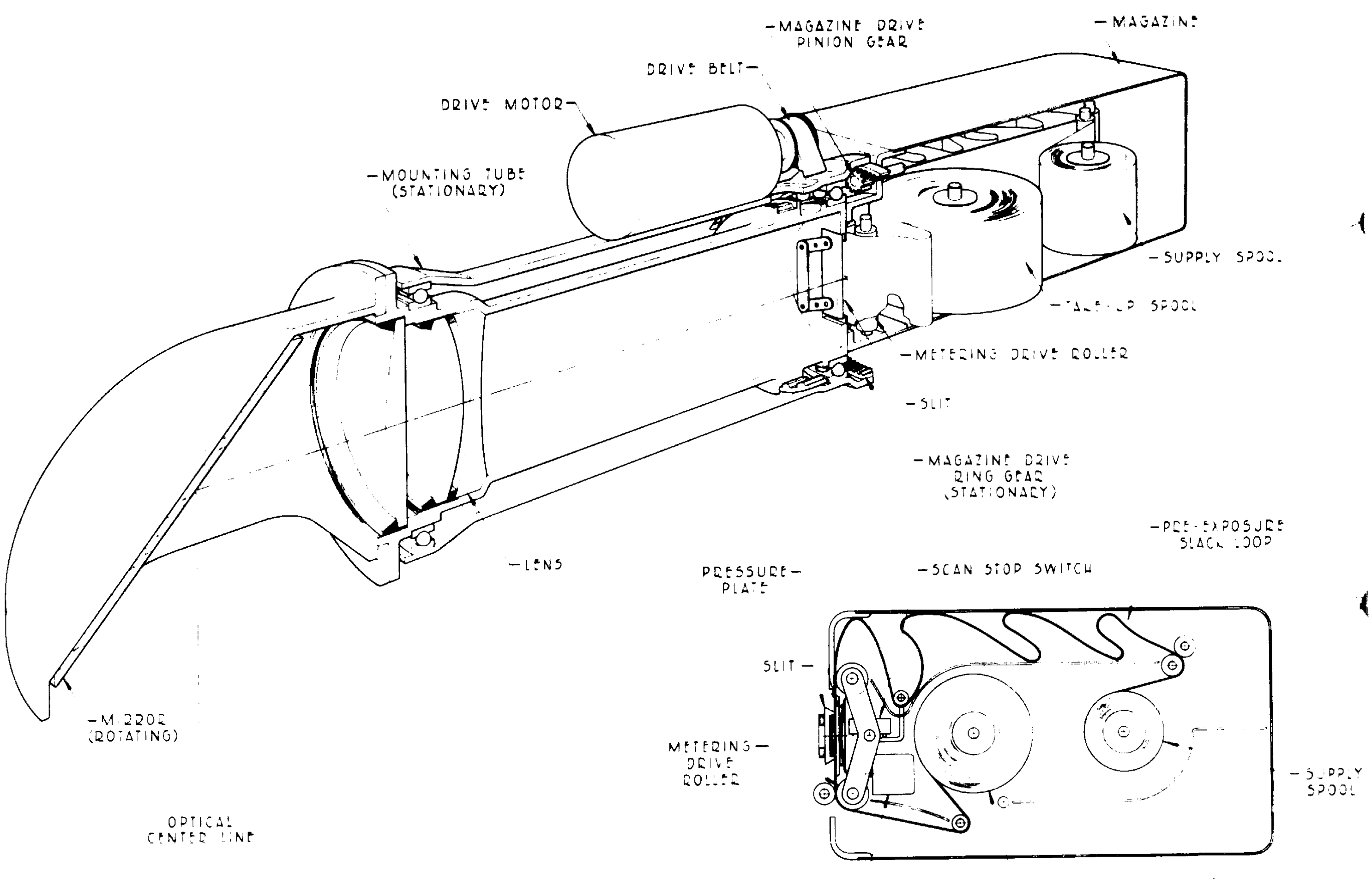


FIGURE 3

FAIRCHILD
CAMERA AND INSTRUMENT



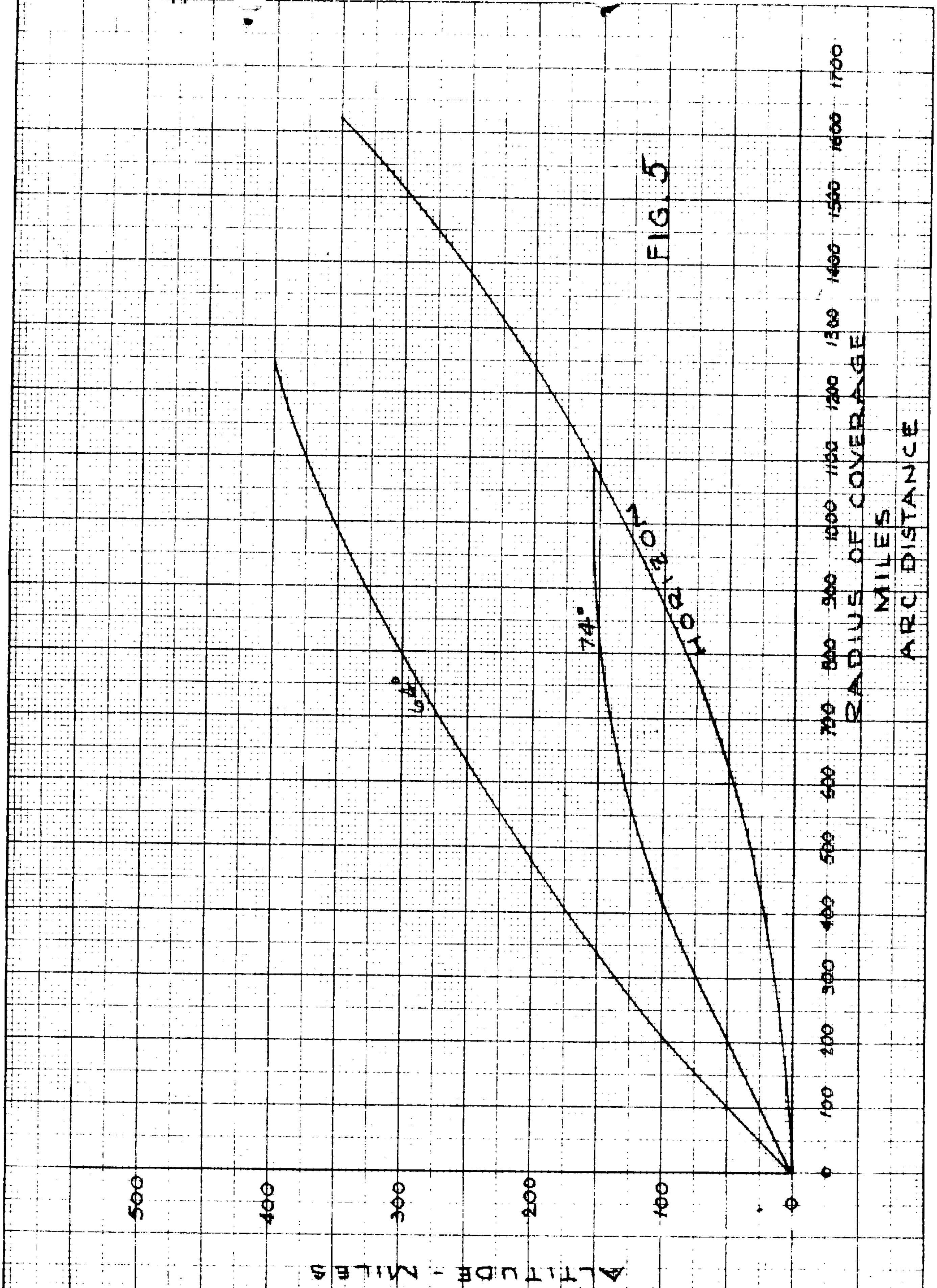
BASIC ROTARY PANORAMIC CAMERA

MAGAZINE SCHEMATIC

FAIRCHILD CAMERA AND INSTRUMENT

FIGURE 4

FAIRCHILD CAMERA AND INSTRUMENT CORPORATION



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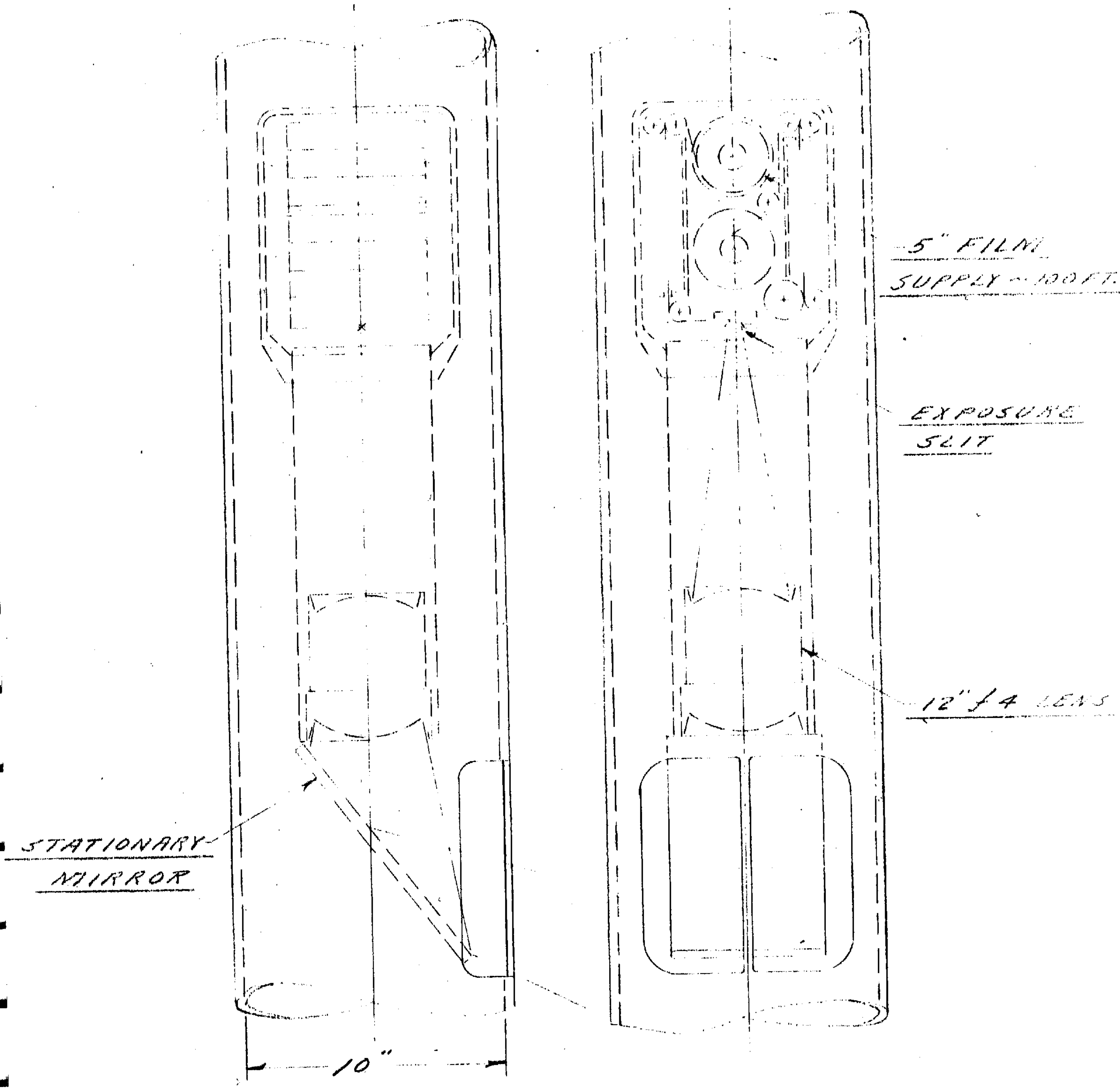

12" ROTARY PANORAMIC CAMERA
FOR HIGH ALTITUDE ROCKET

FIG. 6

18681

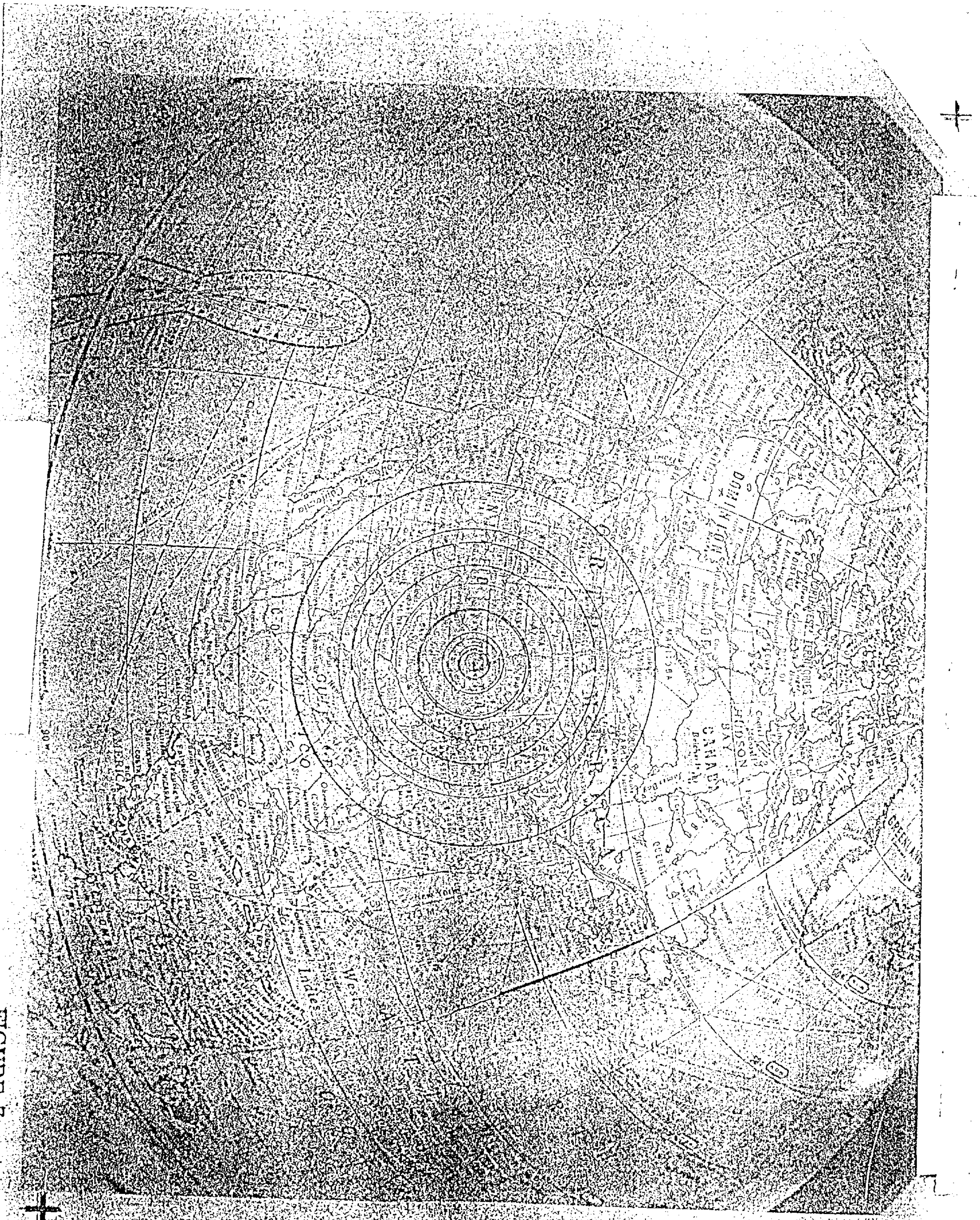

FIGURE 7

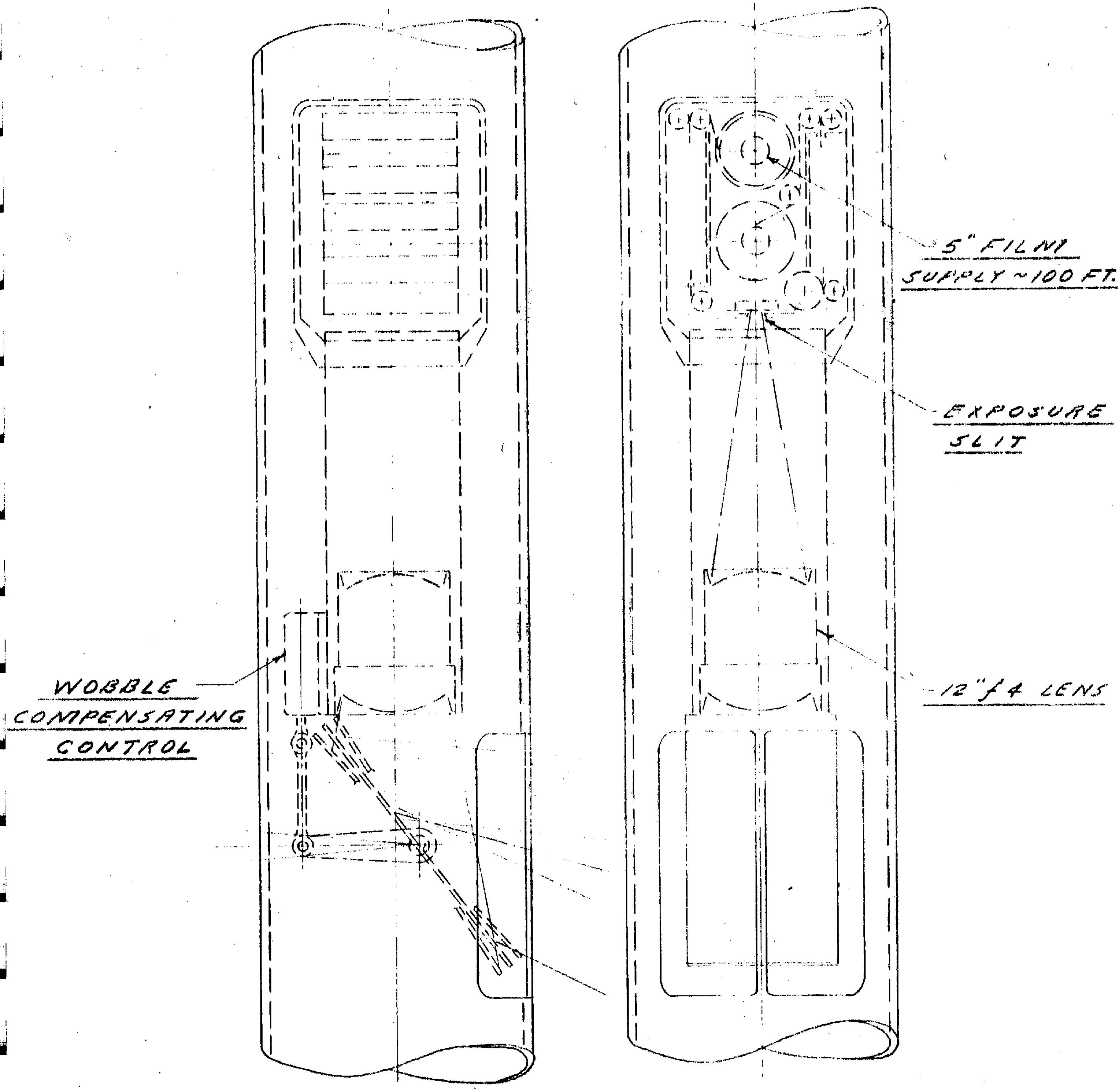

FIG. 8

12" ROTARY PANORAMIC CAMERA WITH WOBBLE CONTROL

18678

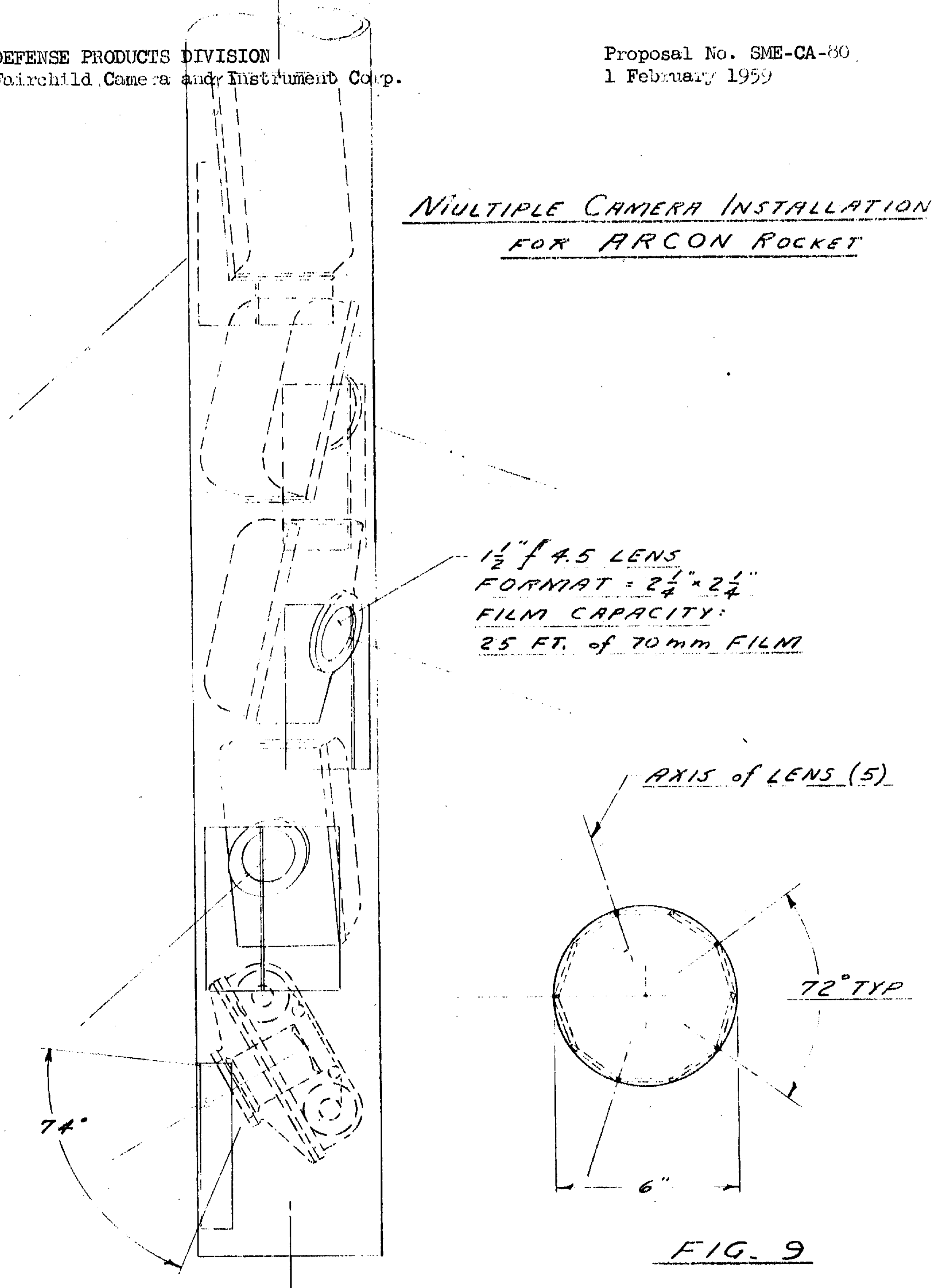

FIG. 9

 18677

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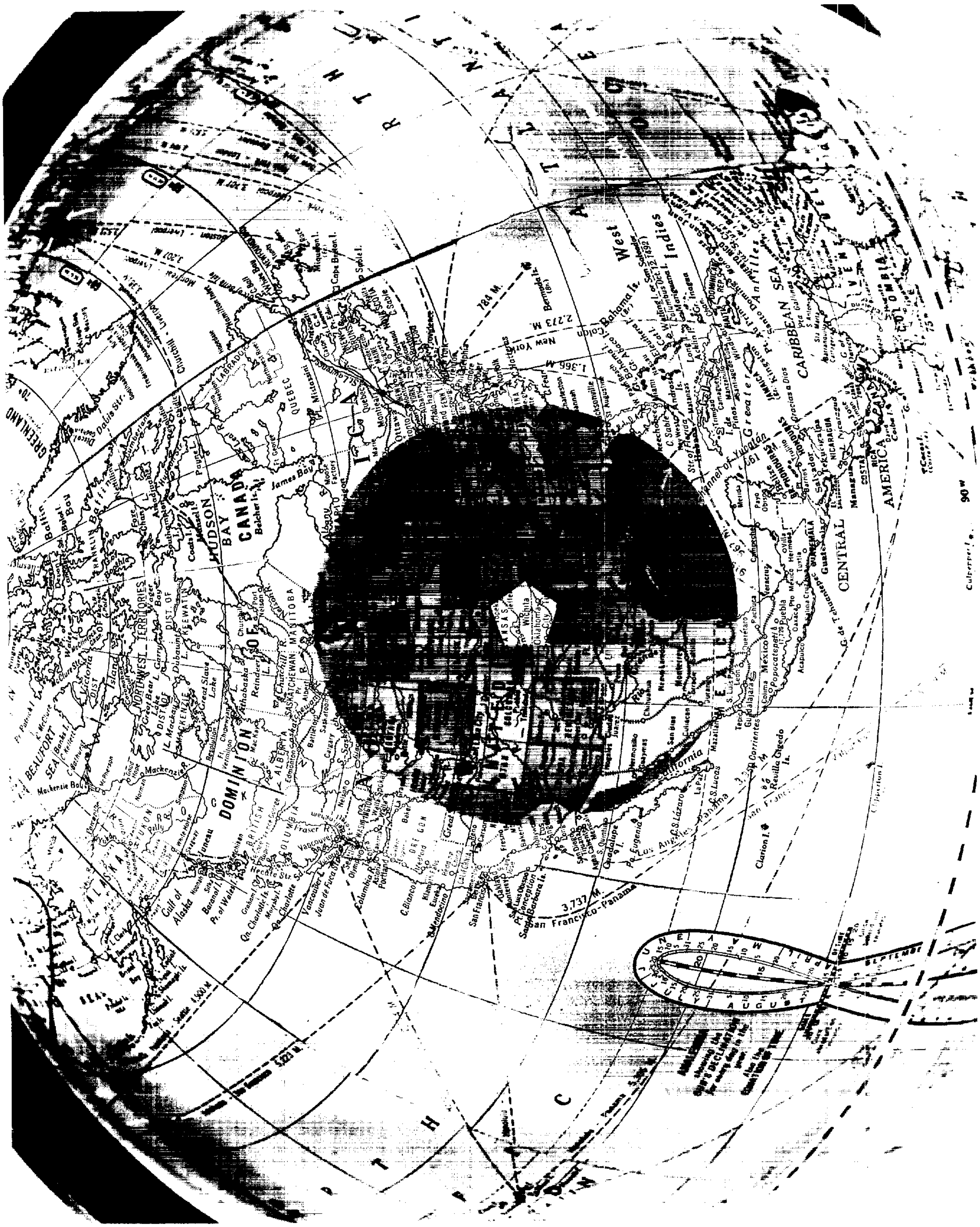
GREENLAND
BEAUFORT SEA
ALASKA
HUDSON BAY
CANADA
DOMINION OF CANADA
QUEBEC
MANITOBA
ALBERTA
BRITISH COLUMBIA
West Indies
CARIBBEAN SEA
CENTRAL AMERICA
COLOMBIA
California

FIGURE 10


HUDSON BAY
CANADA
James Bay
QUEBEC
MANITOBA
DOMINION OF CANADA
BRITISH COLUMBIA
Gulf of Alaska
UNITED
MEXICO
GULF OF MEXICO
Gulf of California
West Indies
CARIBBEAN SEA
CENTRAL AMERICA
COLOMBIA
NICARAGUA

FIGURE 11

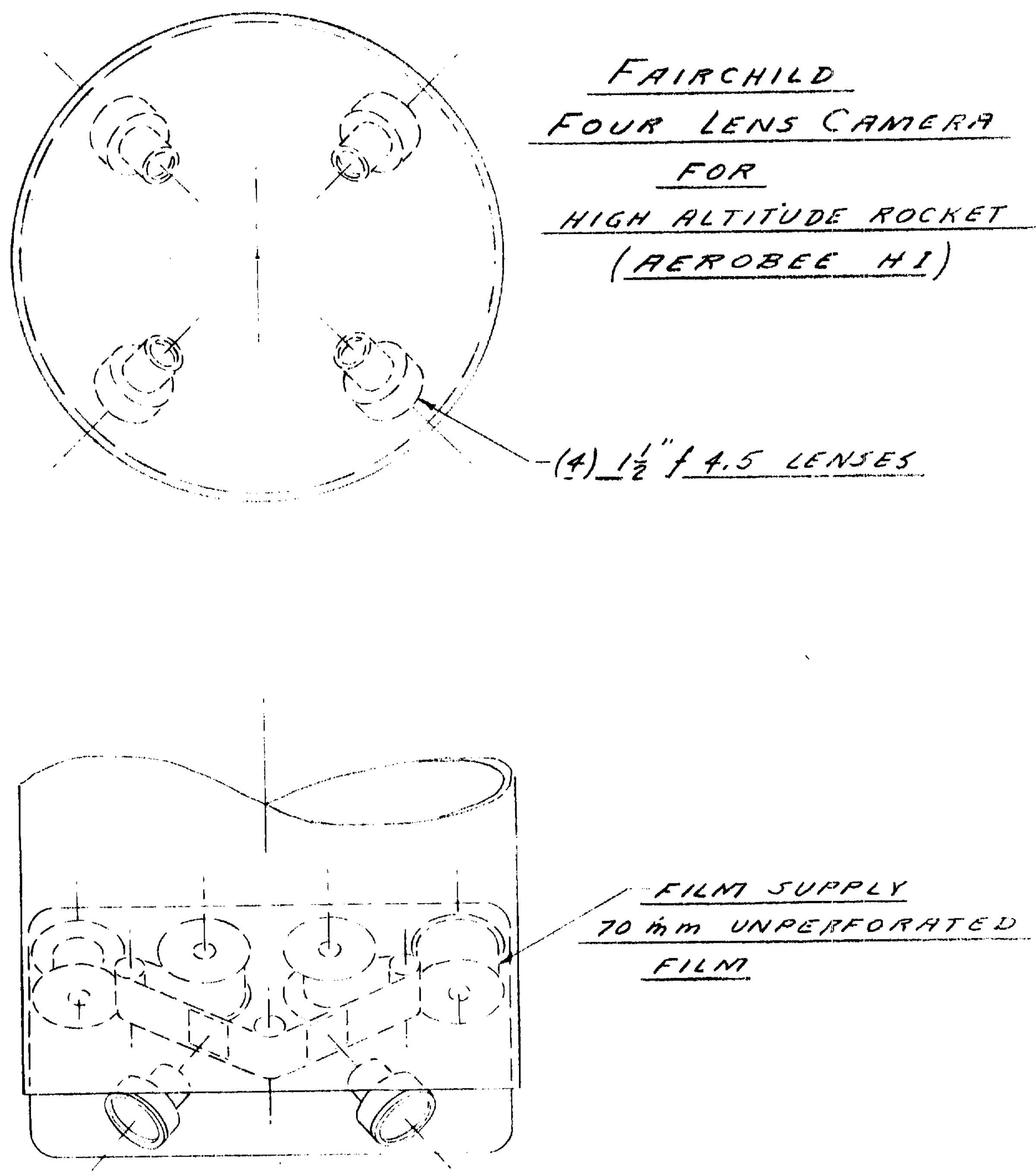
FAIRCHILD
FOUR LENS CAMERA
FOR
HIGH ALTITUDE ROCKET
(AEROBEE HI)
(4) 1½" f 4.5 LENSES
FILM SUPPLY
70 mm UNPERFORATED
FILM

FIG. 12

18680

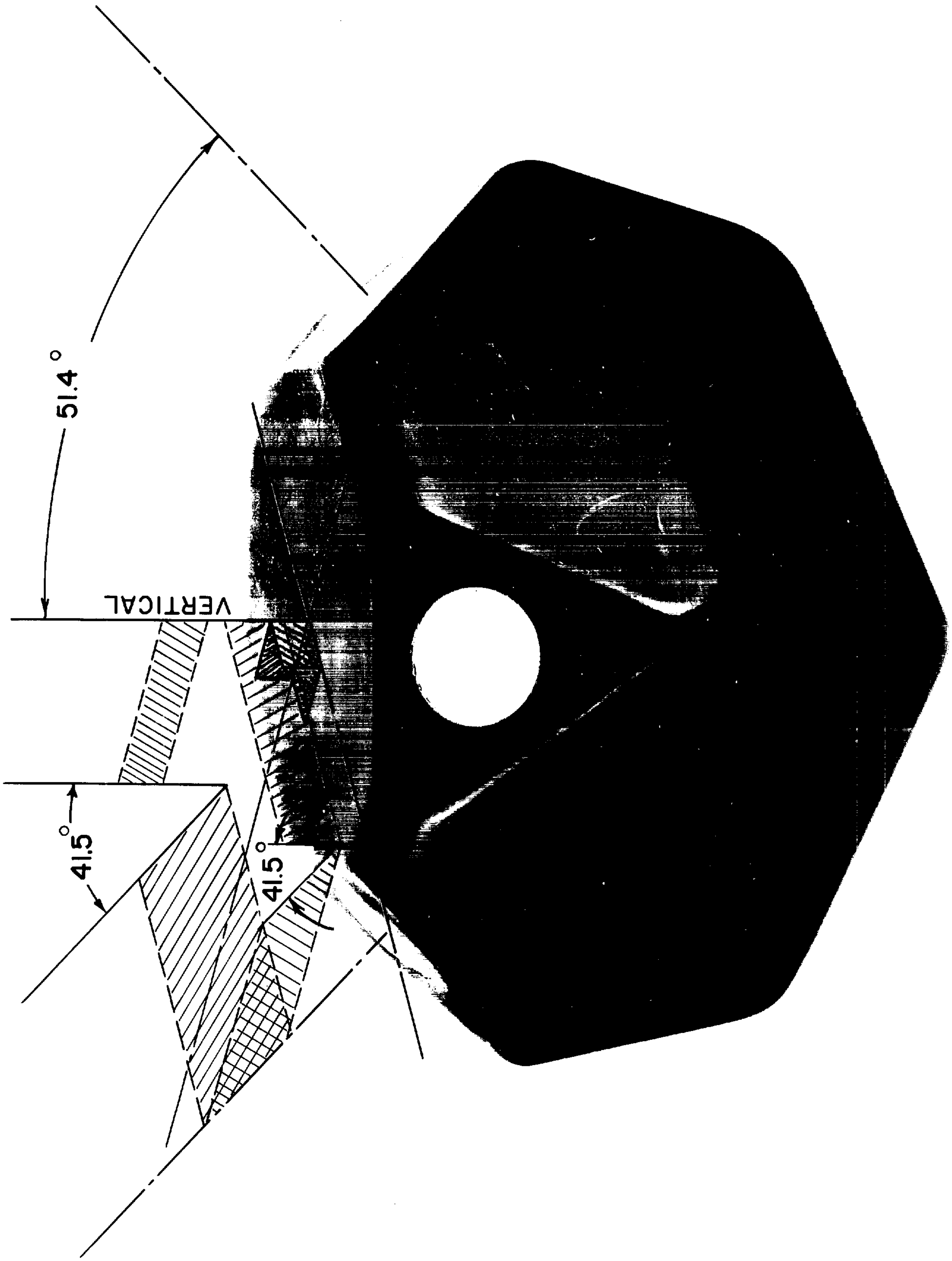

FIGURE 13

FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

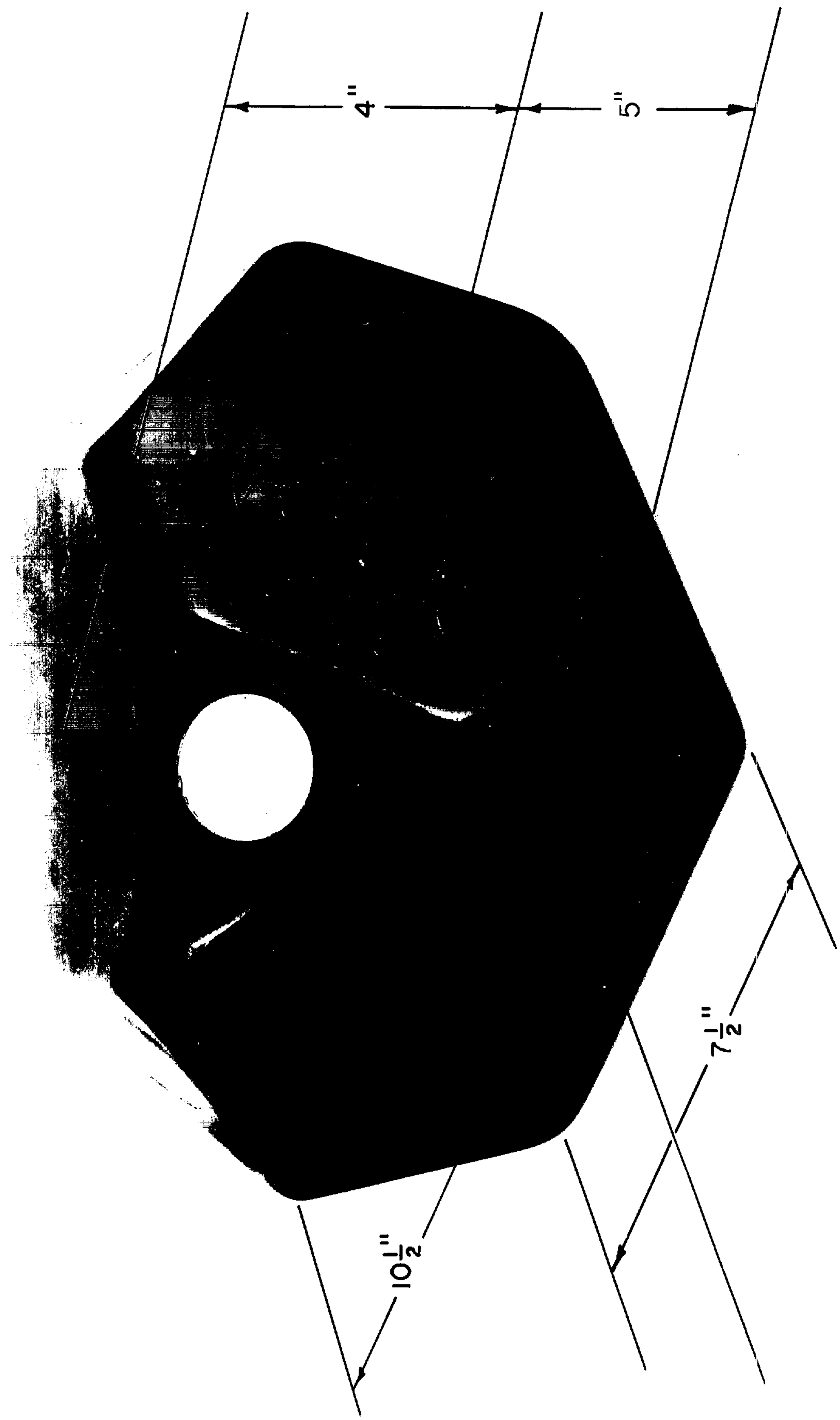

FIGURE 14

FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

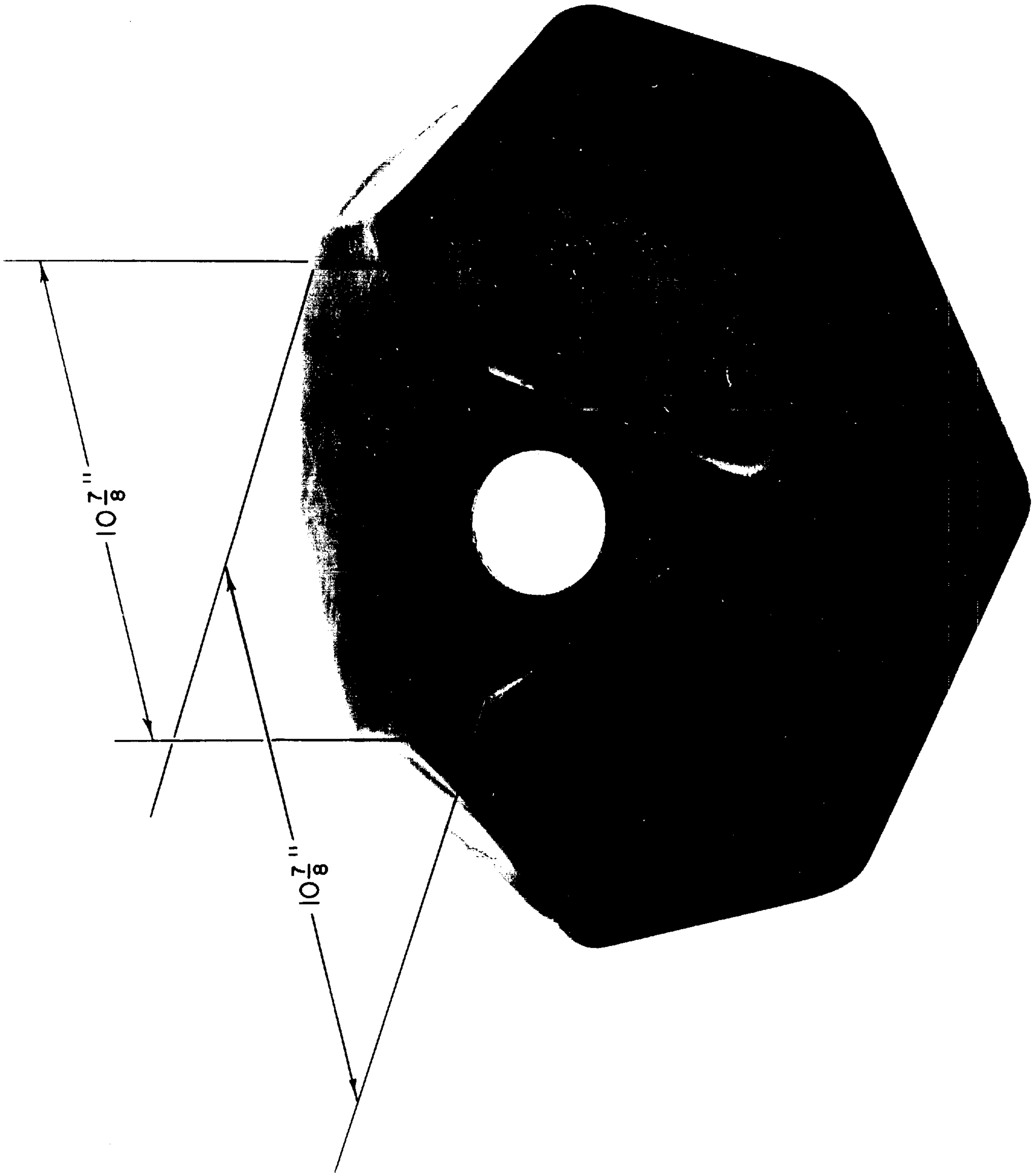

FIGURE 15

FAIRCHILD CAMERA AND INSTRUMENT

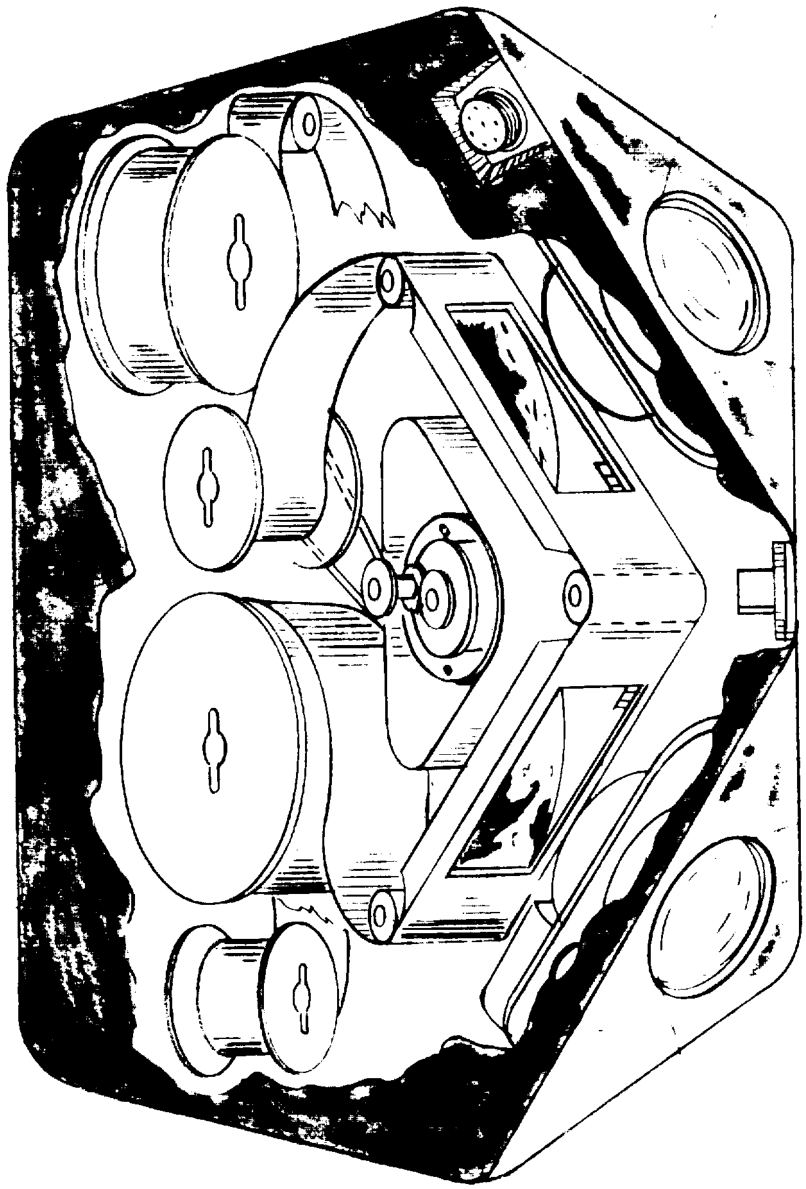

FIGURE 16

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SINGLE CAMERA INSTALLATION FOR ARCON ROCKET

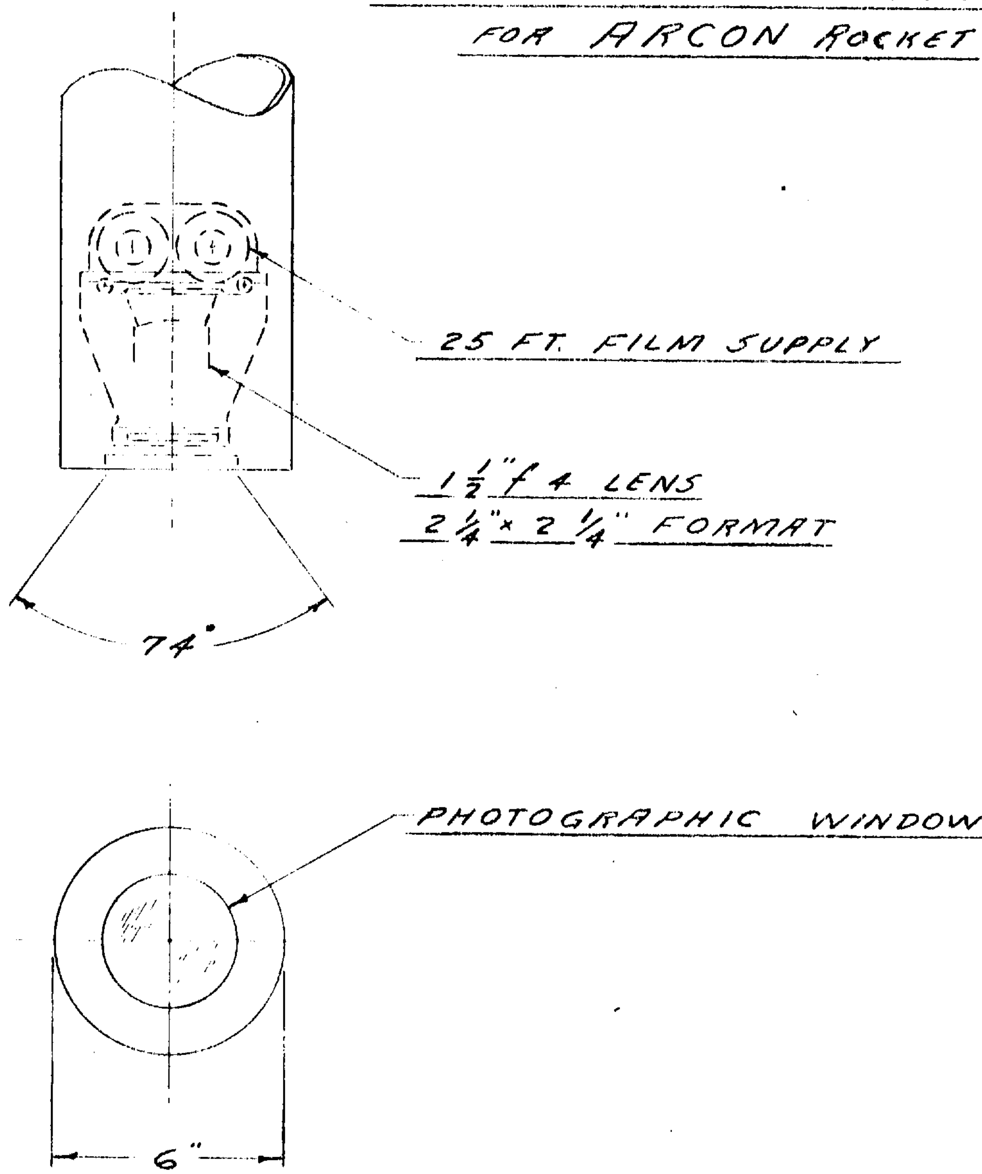
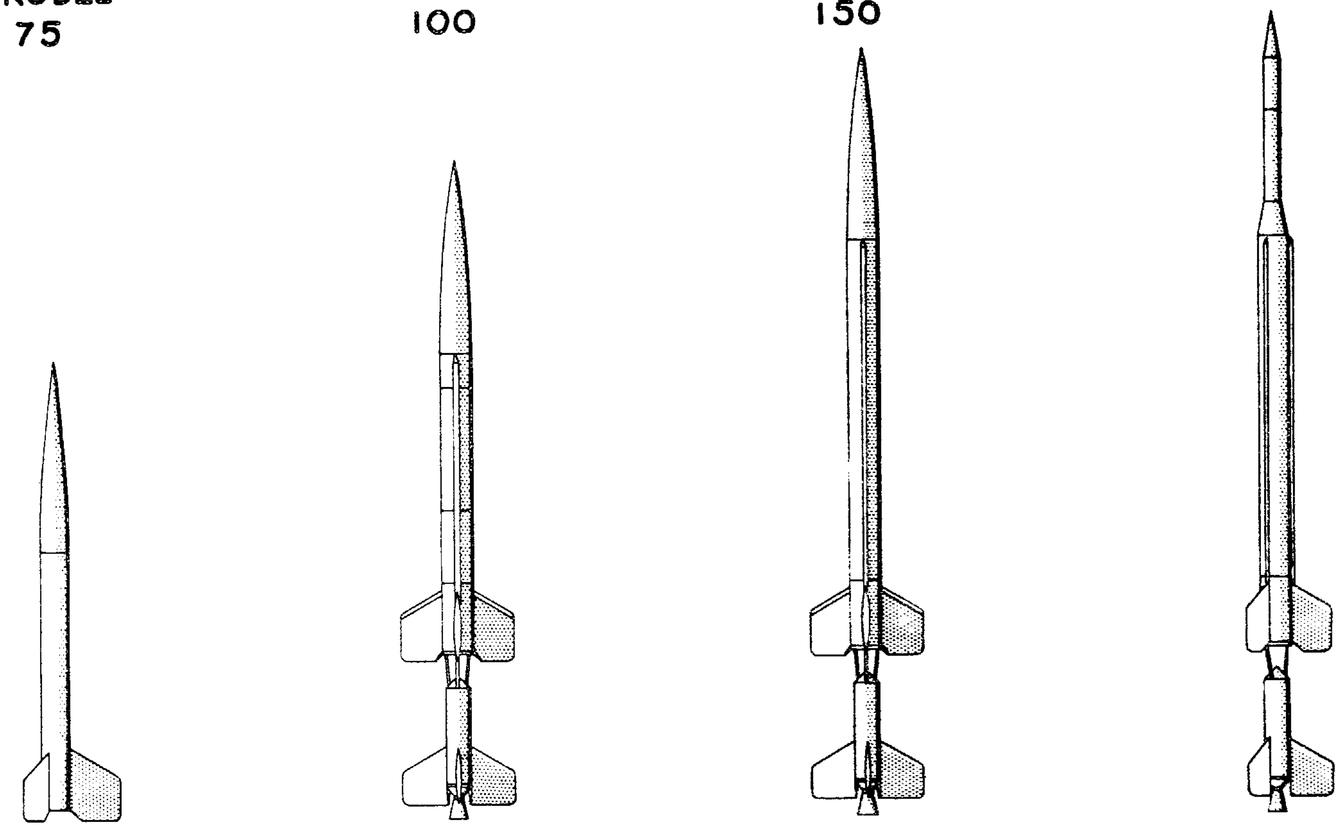


FIG. 17

AEROJET UPPER ATMOSPHERE SOUNDING ROCKETS

AEROBEE 75	AEROBEE 100	AEROBEE 150	AEROBEE 300



NO BOOSTER	SOLID BOOSTER	SOLID BOOSTER	SOLID BOOSTER
DUAL-THRUST SOLID	RFNA - JP-4	RFNA - ANFA	RFNA - ANFA (1ST STAGE) SOLID (2ND STAGE)
100 LB	40 LB	120 LB	65 LB
75 MILES	100 MILES	190 MILES	300 MILES

FIN-STABILIZED — NO GUIDANCE

SPECIFICATIONS AND PERFORMANCE PARAMETERS

Weights, lb

Inert	315
Propellants	628
Launching weight (excluding payload)	943

Dimensions

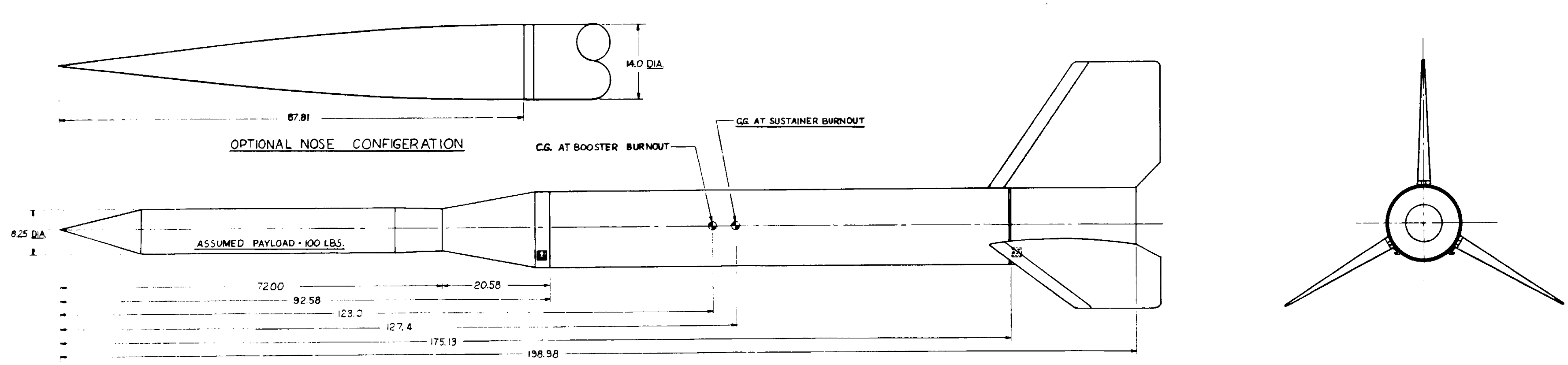
Length, overall, in.	205
Body diameter, in.	14.0
Available payload volume, ft^3	up to 4.0

Sounding-Rocket Performance, 100-lb Payload

	Launching Elevation: Sea Level	Launching Elevation: 4,000 ft
Zenith altitude, ft	358,500	423,000
Zenith altitude, mi	68	80
Sustainer burnout altitude, ft	77,130	86,400
Sustainer burnout velocity, ft/sec	4,327	4,670

Stability Calibers, 100-lb Payload

Launching	3.7
Booster burnout	3.5
Sustainer burnout	1.5



AEROBEE - 75

Approved For Release 2002/08/23 : CIA-RDP63-00313A000600150042-4

SPECIFICATIONS AND PERFORMANCE PARAMETERS

Weights, lb

Sustainer	
Inert	260
Pressurizing air	24
Propellants	
Oxidizer (IRFNA)	424
Fuel (JP-4)	96
Starting slug (UDMH)	0.7
Sustainer, loaded weight (less payload)	804.7
Booster	
Inert	340
Propellant	260
Booster, loaded weight	600
Launching weight (less payload)	1404.7

Dimensions

Lengths, in.	
Sustainer	230.9
Booster	78
Overall length	308.9
Body diameter, in.	15
Available payload volume, ft^3	4.75

Engine Type and Performance

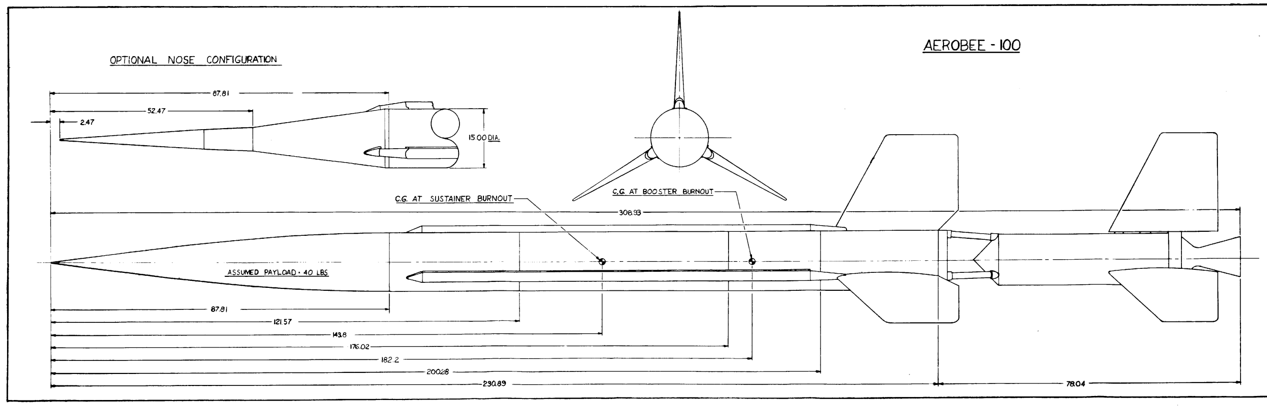
	Booster	Sustainer
Type of engine	Uncooled solid-propellant	Ceramic-lined liquid-propellant
Thrust (nominal, sea level), lb	18,600	2,600
Burning time, sec	2.5	40
Specific impulse (sea level, actual), lb-sec/lb	178	200
Total impulse (sea level), lb-sec	46,400	104,000
Overall impulse-to-weight ratio, lb-sec/lb	77.3	129
Chamber pressure, psia	1,340	330
Exit area, ft^2	0.494	0.205

Sounding-Rocket Performance (4000-ft Launching)

	40-lb Payload	100-lb Payload
Zenith altitude, ft	480,480	380,160
Zenith altitude, mi	91	72
Sustainer burnout altitude, ft	97,200	89,600
Sustainer burnout velocity, ft/sec	5,000	4,390

Stability Calibers (40- and 100-lb Payloads)

Launching	1.50	1.8[illegible]
Sustainer burnout	1.33	2.4[illegible]



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SPECIFICATIONS AND PERFORMANCE PARAMETERS

Weights, lb

Sustainer	
Inert	269
Pressurizing helium	7
Propellants	
Oxidizer (IRFNA)	757
Fuel (65-35 AN-FA)	301
Starting slug (30-70 AN-FA)	9
Sustainer, loaded weight (less payload)	1343
Booster	
Inert	340
Propellant	260
Booster, loaded weight	600
Launching Weight (less payload)	1943

Dimensions

Lengths, in.	
Sustainer	294
Booster	78
Overall length	372
Body diameter, in.	15
Available payload volume, ft^3	4.25

Engine Type and Performance

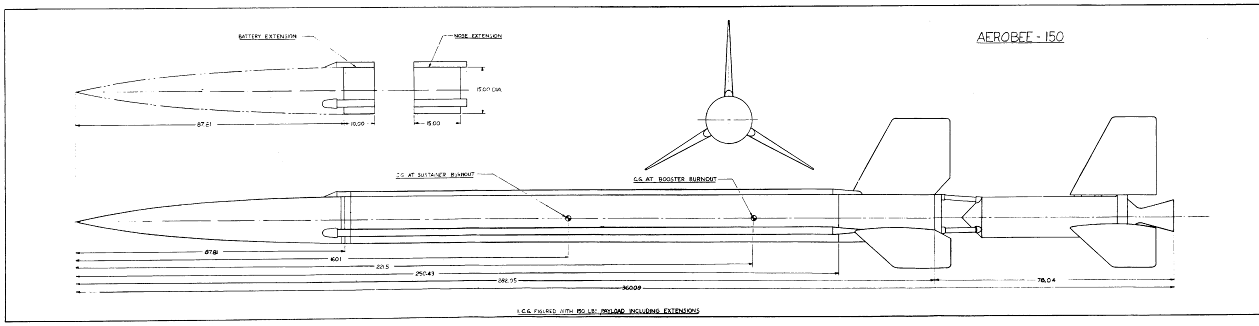
	Booster	Sustainer
Type of engine	Solid-propellant	Regeneratively cooled, liquid-propellant
Thrust (nominal, sea level), lb	18,600	4,100
Burning time, sec	2.5	50.9
Specific impulse (sea level, actual), lb-sec/lb	178	198
Total impulse (sea level), lb-sec	46,400	208,690
Overall impulse-to-weight ratio, lb-sec/lb	77.3	156
Chamber pressure, psia	1,340	324
Exit area, ft^2	0.494	0.297

Sounding-Rocket Performance (4000-ft Launching)

	150-lb Payload
Zenith altitude, ft	886,000
Zenith altitude, mi	168
Booster burnout altitude, ft	4,900
Booster burnout velocity, ft/sec	750
Sustainer burnout altitude, ft	139,300
Sustainer burnout velocity, ft/sec	6,828

Stability Calibers, 150-lb Payload

Launching	3
Booster burnout	4
Sustainer burnout	2



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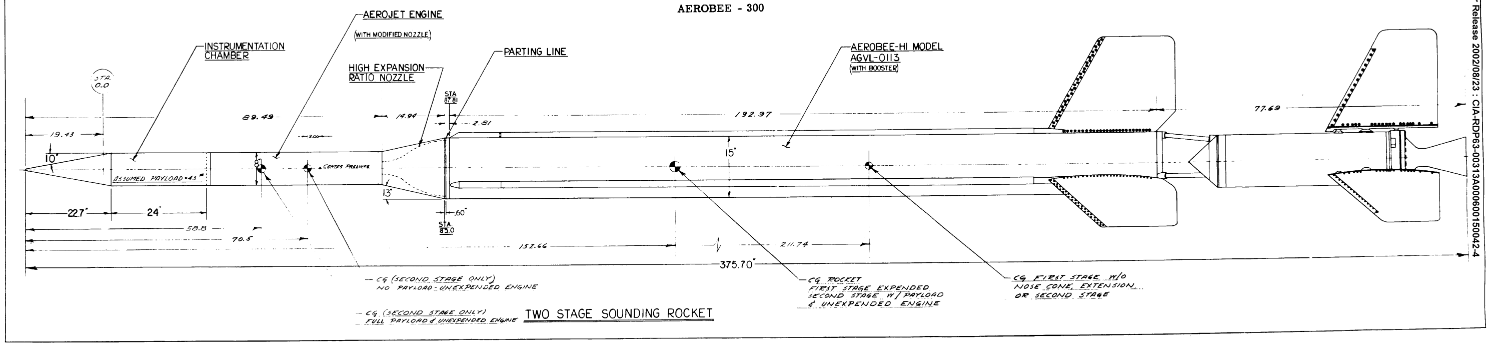
PRELIMINARY AERODYNAMIC PARAMETERS

Stability	M_{α} ft-lb/deg	$C_{m\alpha}$ per degree
At burnout, 1st stage	-65	-0.23
At burnout, 2nd stage	-20	-0.40

Fin Heating	Max Temp, °F
At burnout, 1st-stage fins	500
At burnout, 2nd stage (Temp of aft conical skirt)	600

Trajectory, 57-lb Payload	Velocity fps	Altitude ft	Time sec
At burnout, 1st stage	6,000	128,000	51
At burnout, 2nd stage	9,000	140,000	53
Zenith, 2nd stage	--	1,584,000	350

AEROBEE - 300



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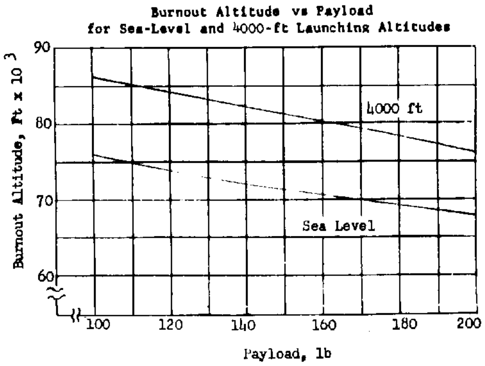

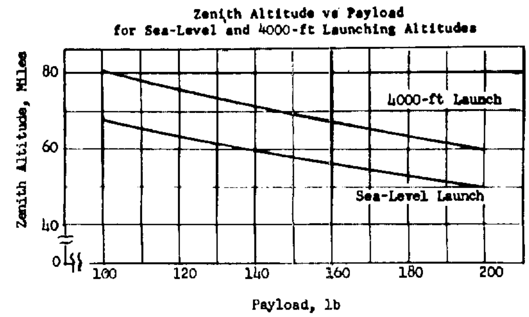

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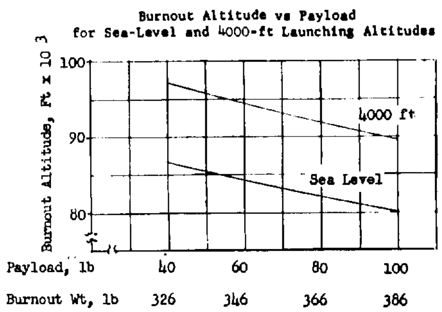

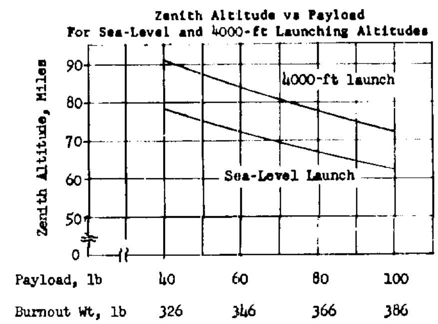

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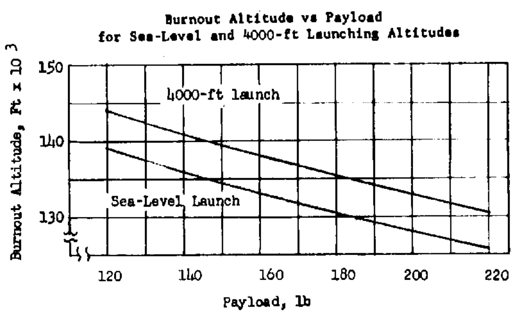

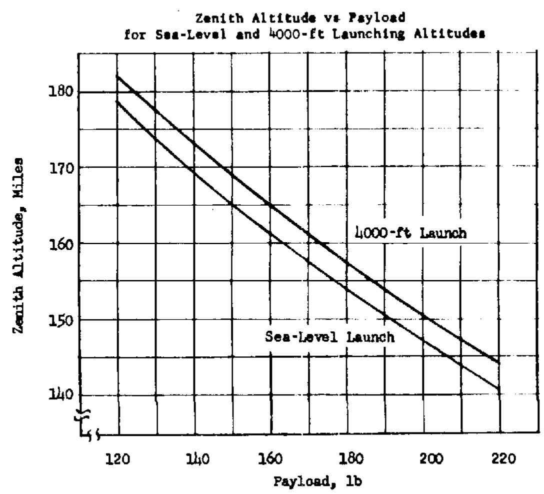

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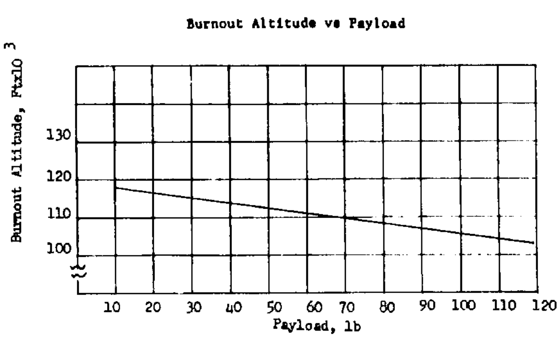

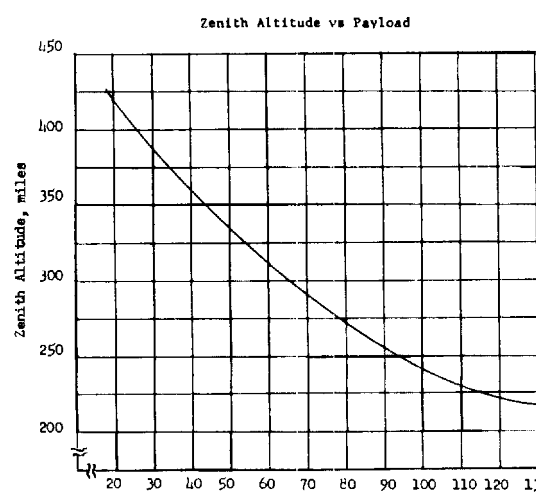

ATLANTIC RESEARCH CORPORATION
ALEXANDRIA, VIRGINIA

CONFIDENTIAL

Preliminary Design Characteristics for Iris Rocket

Calculated

	Mod 2 Cylindrical	Mod 3 Tapered	
I. Dimensions			
A. Lengths (inches)			
1. Over-all	225.8	225.8	
2. Components			
a. Motor	137.5	137.5	
b. Nozzle (extension)	8.3	8.3	
c. Nose Cone	80.0	80.0	
3. Grain Length	136.0	136.0	
		Nozzle	Head
B. Diameters (inches)			
1. Motor OD	12.128	12.128	12.128
2. Motor ID	12.000	12.000	12.000
3. Insulation OD	11.995	11.995	11.995
4. Insulation ID	11.600	11.600	11.900
5. Grain OD, inhibited	11.585	11.585	11.885
6. Grain OD, uninhibited	11.500	11.500	11.800
C. Thicknesses (inches)			
1. Motor	0.064	0.064	0.064
2. Insulation	0.200	0.200	0.050
3. Inhibitor	0.050	0.050	0.050
D. Volume (cubic feet)			
1. Nose Cone	4.14	4.14	
II. Weights (pounds)			
A. Motor			
1. Motor Case and Head	113.78	113.78	
2. Nozzle	29.91	29.91	
3. Insulation	59.69	30.25	
B. Components			
1. Fin Assembly	34.75	34.75	
2. Nose Cone	12.10	12.10	
C. Propellant			
1. Propellant Grain	867.91	897.35	
2. Inhibitor	10.44	10.58	
D. Payload			
1. Payload Weight	100.00	100.00	
Total	1228.58	1228.72	
Mass Ratio (Motor)	0.801	0.829	
Mass Ratio (total)	0.707	0.730	

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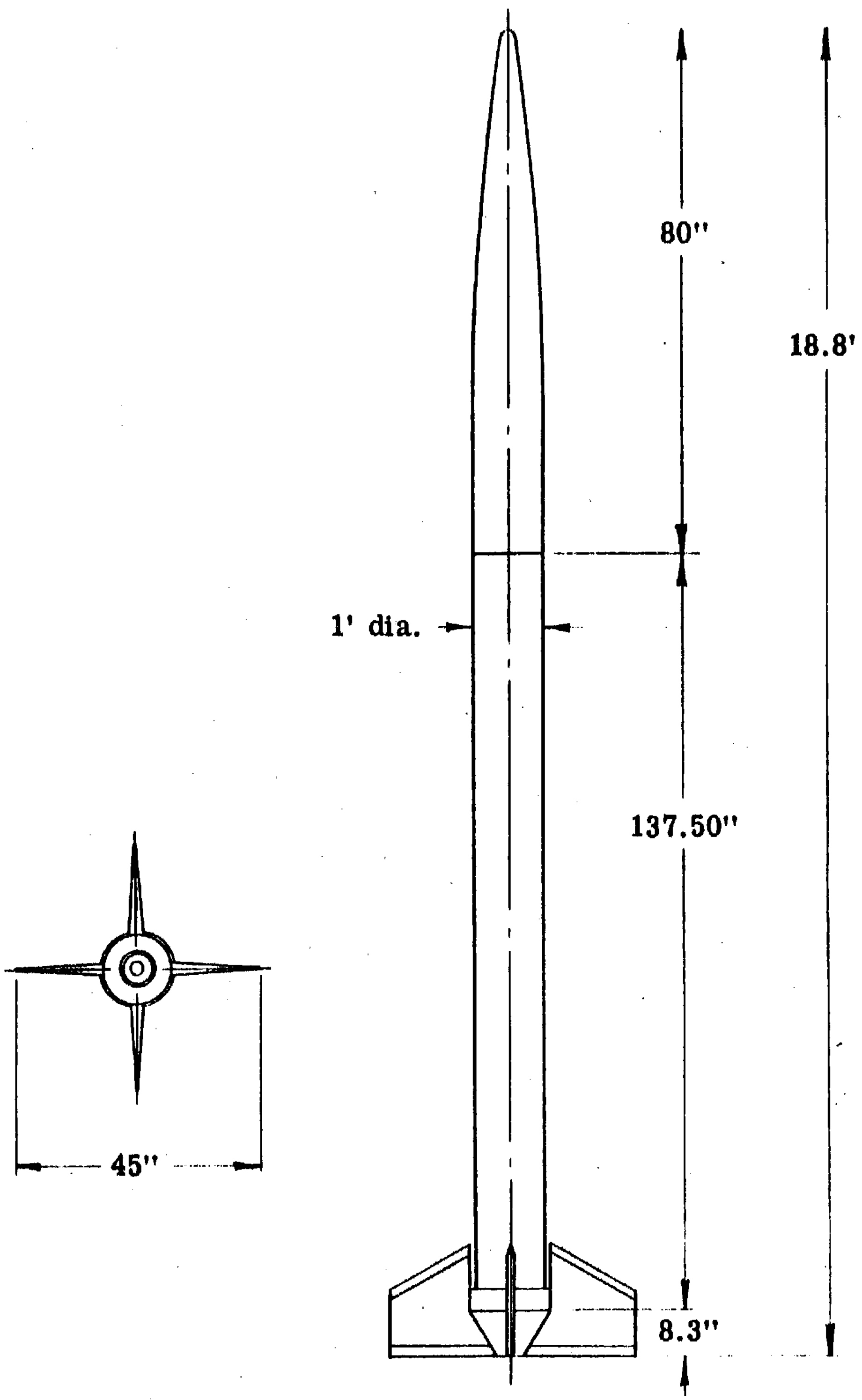
		Mod 2 Cylindrical	Mod 3 Tapered	
III. Operating Parameters				
A. Pressure	psi	1200	1200	1300
B. Burning Time	sec	46.6	45.9	
C. Thrust	lbs	4100	4160	4510
D. Mass Discharge Rates	lbs/sec	18.7	18.7	20.2
E. Propellant				
1. Type		Arcite 368	Arcite 368	
2. Density	lbs/ft^3	0.062	0.062	
3. Specific Impulse	lb-sec/lb	223	223	
4. Burning Rate	in/sec	2.92	2.92	3.00
5. Number of Wires		37	37	
F. Nozzle				
1. Throat Area	in^2	2.19	2.19	
2. Exit Area	in^2	22.06	22.06	
3. Expansion Rati		10	10	
4. Expansion To	psi	14.7	14.7	15.9
IV. Performance				
A. Maximum Altitude				
1. Miles		161.49	188.6	
2. Feet		852,667	995,808	
B. Time to Maximum Altitude	sec	274.53	289.2	
C. Altitude at Burnout	ft	115,491	120,668	
D. Maximum Velocity	ft/sec	6,791	7,286	
E. Initial Acceleration	g	2.38	2.38	
F. Final Acceleration	g	11.45	12.82	

Iris Sounding Rocket Outline Dimensions



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Design Characteristics of Arcon Rocket

	10-lb Payload	40-lb Payload
I. Dimensions		
A. Lengths (inches)		
1. Over-all	134	134
2. Components		
a. Motor	99	99
b. Nozzle (Extension)	5	5
c. Nose Cone	30	30
3. Grain Length	96.5	96.5
B. Diameters (inches)		
1. Motor OD	6.094	6.094
2. Motor ID	6.000	6.000
3. Insulation OD	5.975	5.975
4. Insulation ID	5.685	5.685
5. Grain OD, inhibited	5.665	5.665
6. Grain OD, uninhibited	5.500	5.500
C. Thicknesses (inches)		
1. Motor	0.047	0.047
2. Insulation	0.145	0.145
3. Inhibitor	0.082	0.082
D. Volume (cubic feet)		
1. Nose Cone	450	450
II. Weights (*Measured)		
A. Motor		
1. Motor Case (integral head)	30.34*	30.34*
2. Nozzle	8.40*	8.40*
3. Motor Insulation	13.97*	13.97*
B. Components		
1. Fin Assembly (total)	11.50	11.50
2. Boattail	1.50*	1.50*
3. Nose Cone	1.85*	1.85*
C. Propellant		
1. Propellant Grain	139.25*	139.25*
2. Inhibitor	6.25*	6.25*
D. Payload		
1. Payload Weight	10.00	40.00
Total (lbs)	223.06	253.06
Mass Ratio (Motor)	0.702	0.702
Mass Ratio (total)	0.595	0.552

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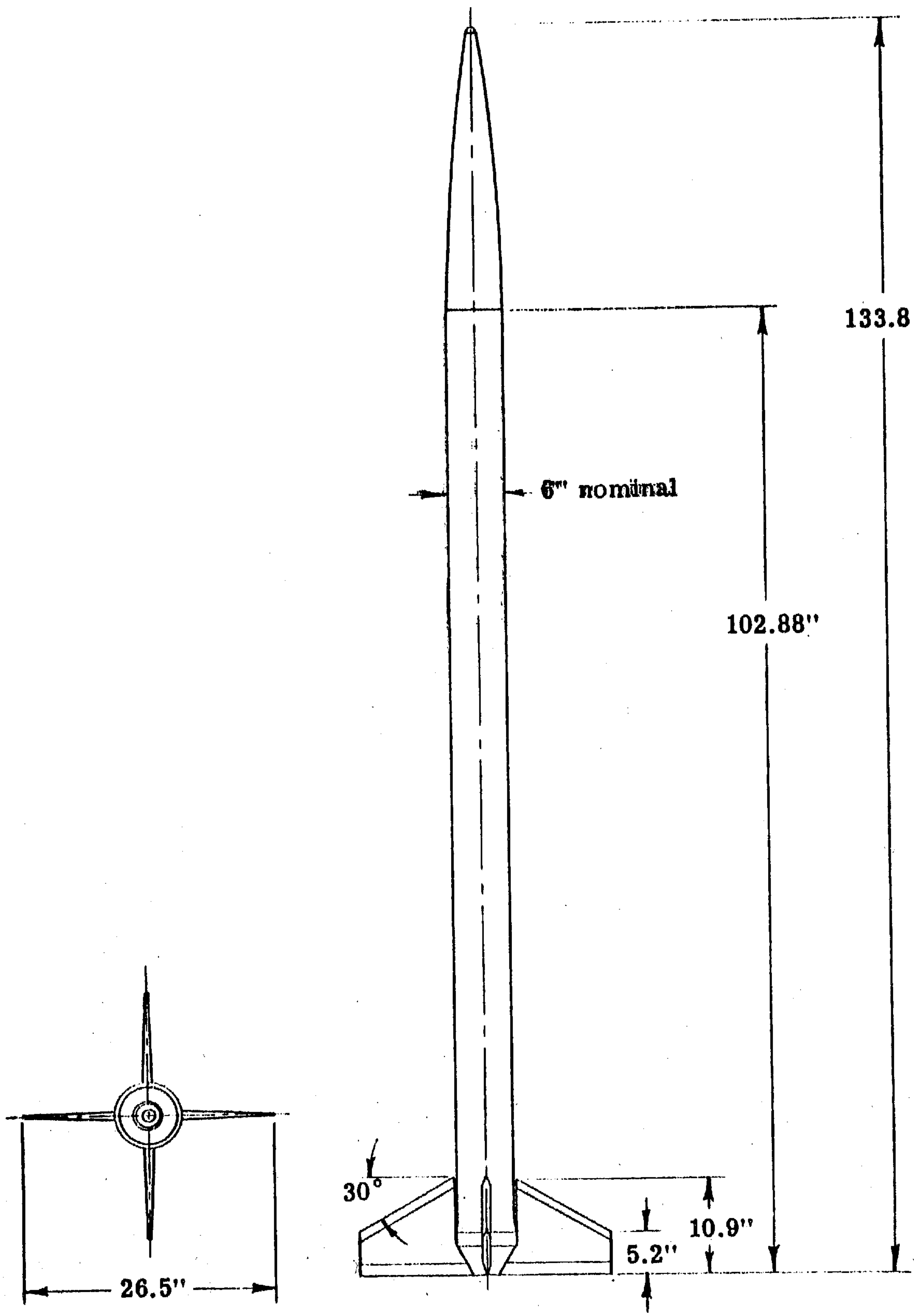
			10-lb Payload	40-lb Payload
III.	Operating Parameters			
	A. Pressure	psi	1200	1200
	B. Burning Time	sec	33.0	33.0
	C. Thrust	lbs	945	945
	D. Mass Discharge Rates	lbs/sec	4.24	4.24
	E. Propellant			
	1. Type		Arcite 368	Arcite 368
	2. Density	lbs/ft^3	0.062	0.062
	3. Specific Impulse	lb-sec/lb	223	223
	4. Burning Rate	in/sec	2.92	2.92
	5. Number of Wires		19	19
	F. Nozzle			
	1. Throat Area	in^2	0.545	0.545
	2. Exit Area	in^2	5.45	5.45
	3. Expansion Ratio		10	10
	4. Expansion To	psi	14.7	14.7
IV.	Performance			
	A. Maximum Altitude			
	1. Miles		100.1	61.1
	2. Feet		528,565	322,384
	B. Time to Maximum Altitude	sec	203.9	162.5
	C. Altitude at Burnout	ft	71,682	57,900
	D. Maximum Velocity	ft/sec	5,426	4,194
	E. Initial Acceleration	g	3.26	2.75
	F. Final Acceleration	g	10.51	7.30

Arcon Sounding Rocket Outline Dimensions



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Preliminary Design Characteristics

For Arcas Rocket

I. Payload	
A. Total (pounds)	12
1. Sonde	6.5
2. Parachute	3.5
3. Nose Cone and Parachute Housing	2.0
II. Dimensions	
A. Lengths (inches)	
1. Overall	73
2. Components	
a. Motor	46
b. Nozzle	4
c. Parachute Housing	14
d. Nose Cone	9
3. Grain	44
B. Diameters (inches)	
1. Motor OD	4.5
2. Motor ID	4.4
3. Insulation OD	4.4
4. Insulation ID	4.1
5. Grain OD, inhibited	4.1
6. Grain OD, uninhibited	4.0
7. Parachute Mylar (ft)	24
C. Thicknesses (inches)	
1. Motor Wall	0.05
2. Insulation	0.15
3. Inhibitor	0.05
D. Volume (cubic inches)	
1. Parachute Container	200
2. Nose Cone	112
III. Weights (pounds)	
A. Metal Parts	10.0
1. Motor Case	3.2
2. Nozzle	
B. Insulation	5.6
C. Propellant	35
D. Inhibitor	1.2
E. Fins	1
F. Nose Cone and Payload (incl Parachute)	12
Total	68

IV. Operating Parameters

A. Pressure (psi)	800
B. Burning Time (secs)	25
C. Thrust (lbs)	375
D. Propellant Type	Arcite 373
E. Nozzle	
1. Throat Area (in^2)	0.255
2. Exit Area (in^2)	2.55
3. Expansion Ratio	10

V. Performance

A. Maximum Altitude	
1. Miles	38
2. Feet	200,000
B. Time to Max Altitude (secs)	100
C. Altitude at Burnout (ft)	$<$40,000
D. Maximum Velocity (ft/sec)	3,500
E. Acceleration at Launch (g)	$>$20
F. Type of Launch	Closed Breech