

LUNAR MODULE

STRUCTURES, MECHANICAL SYSTEMS  
AND ELECTROEXPLOSIVE DEVICES

COURSE NO. 30915

STUDY GUIDE

FOR TRAINING PURPOSES ONLY



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LM Training

PREFACE

This Document is Designed to  
Support the Structures, Mechanical  
Systems and Electroexplosive  
Devices Subsystem

(Course: 30915)

LIST OF REFERENCES

LMA790-3-IM2	Apollo Operations Handbook
LPL-850-1	Manufacturing Plan for Project Apollo Lunar Module
LED540-43	Lunar Mission Modular Data
LMA790-1	LM Familiarization Manual
LDW320-5400	Level 3 Schematic, Mechanical Design Subsystem
LDW320-54400	Explosive Devices Installation - LM Vehicle Installation - Mechanical Design Subsystem
LED-550-80	System Failure Mode and Effects Analysis of the Explosive Devices Subsystem
	"Insulation" National Research Corp.
	"Handling and Processing of Explosives" North American Aviation, Inc. Space & Information System Division

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## INTRODUCTION

The Lunar Module (LM) consists of two individual stages, the Ascent Stage and the Descent Stage; being joined together at four interstage fittings by explosive nuts and bolts. The composite of the stages provides the necessary work area for the Astronauts as well as a continuity of systems and subsystems. The continuity of the systems between stages is accomplished by interstage umbilicals and hard line connections.

Both stages will function as a single unit during lunar orbit, descent and landing phases of the mission. At the end of the lunar stay; the Ascent Stage alone will be launched from the lunar surface and rendezvous with the Command Module, the Descent Stage remaining on the lunar surface acting as launch platform. Separation of the stages, at this time, is accomplished by explosively severing the four interstage nuts and bolts as well as the interstage umbilicals. The hard lines will automatically disconnect at stage separation. The Ascent Stage having the capability of functioning as a single unit on its return and rendezvous with the C.M. (Refer to Figure 1)

Four individual landing gear assemblies are attached to outrigger extending from the Descent Stage structure. The gear has the capability of providing the Lunar Module with a stable support and a shock absorbing cogency of a lunar landing.

The approximate dimensions and weight of the Lunar Module is as follows:

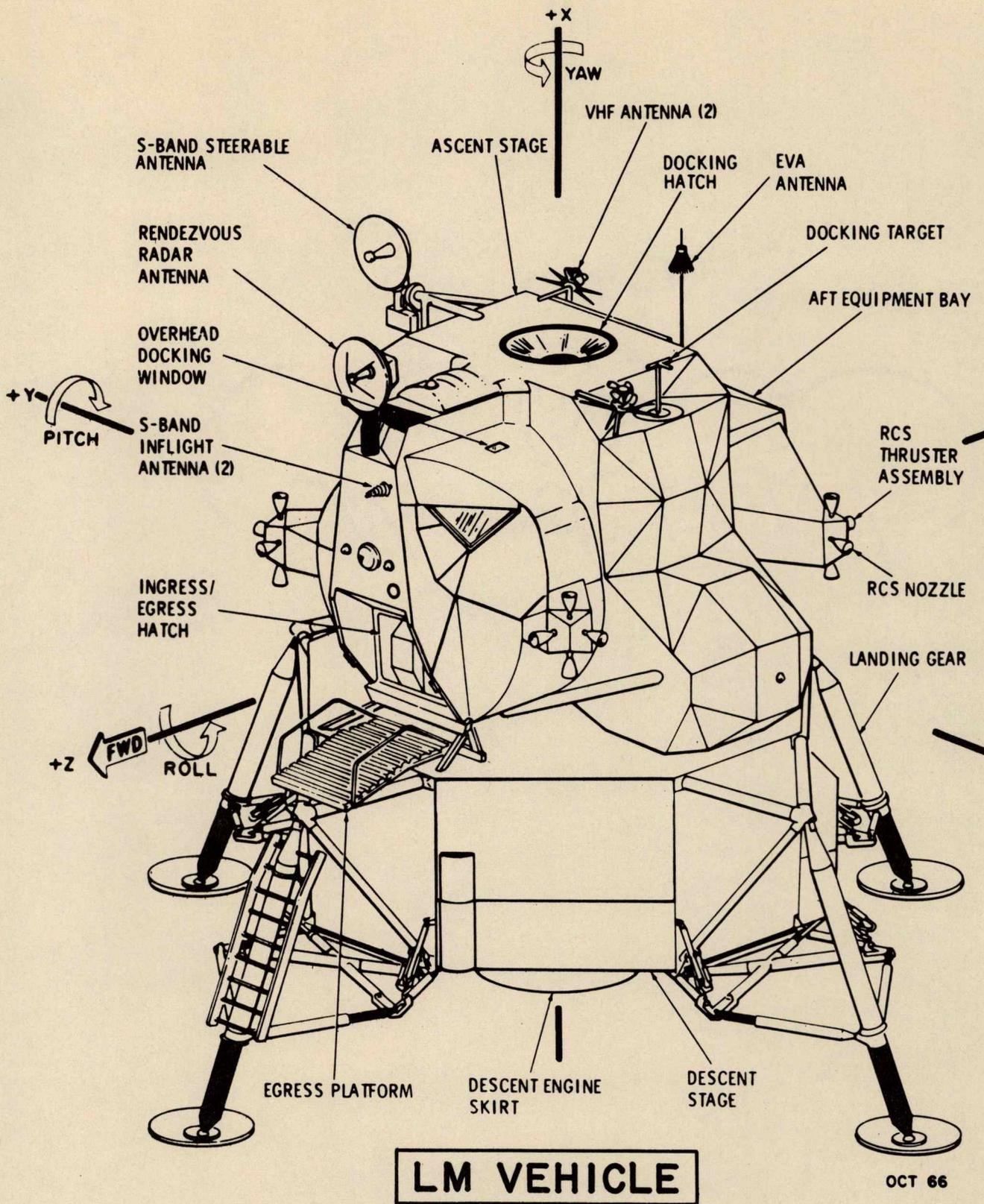
The approximate dimensions of the front, side and top views of the LM are shown on Figure 2.

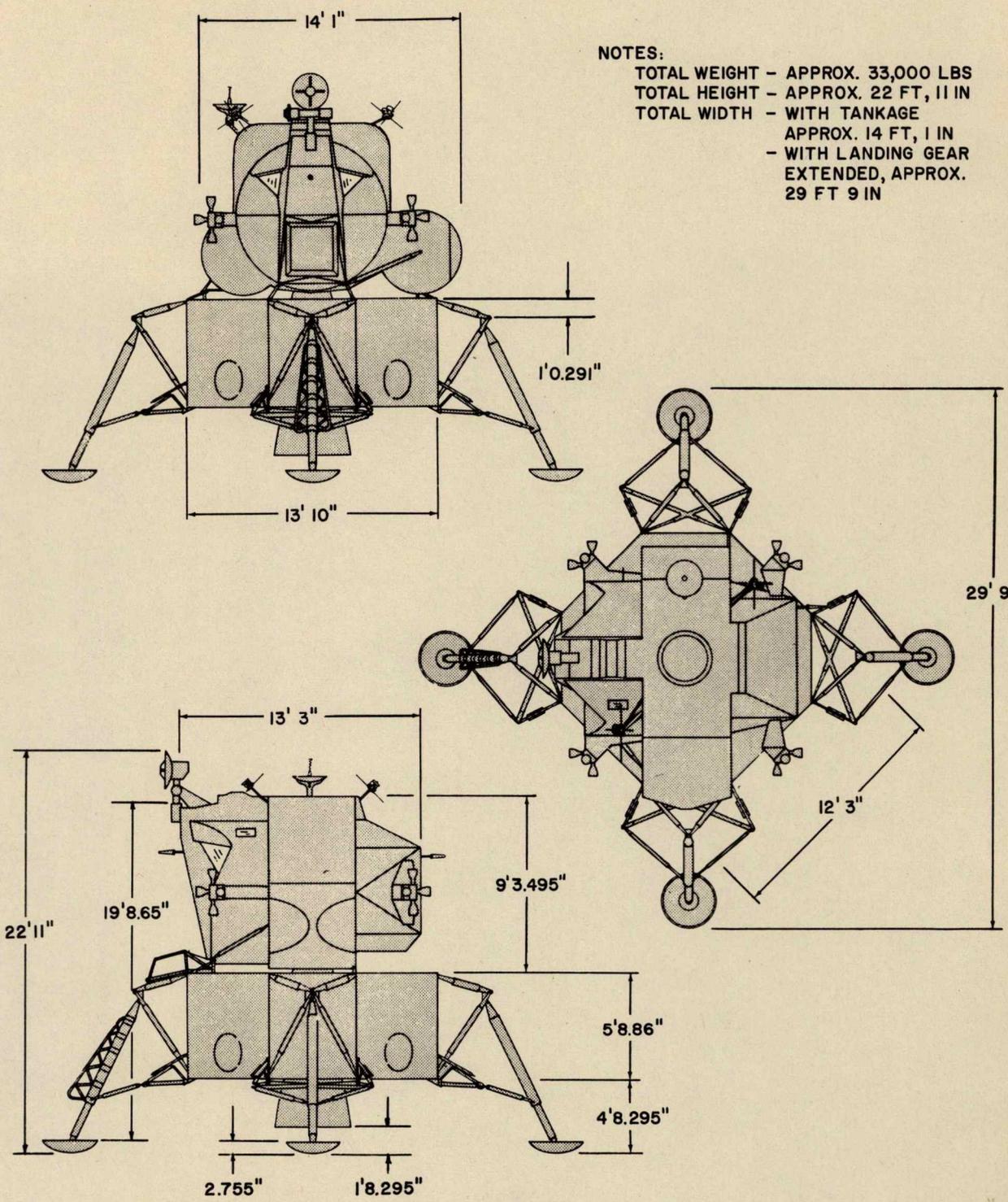
The approximate weights of the LM are at:

Earth Launch	30,000 Pounds
Lunar Landing	15,000 Pounds
Lunar Lift Off	10,000 Pounds
Rendezvous	5,000 Pounds

The weights shown being earth weight. The dry weight of each stage is approximately 5,000 pounds the balance of the weight being taken up by usable on board materials.

Inch station reference measurements are established as follows: The Z and Y axis reference starts at a point where both axis intersect the centerline X axis. (Z axis fore and aft - Y axis left and right) A zero inch reading being established at the intersection. (Refer to Figure 3)



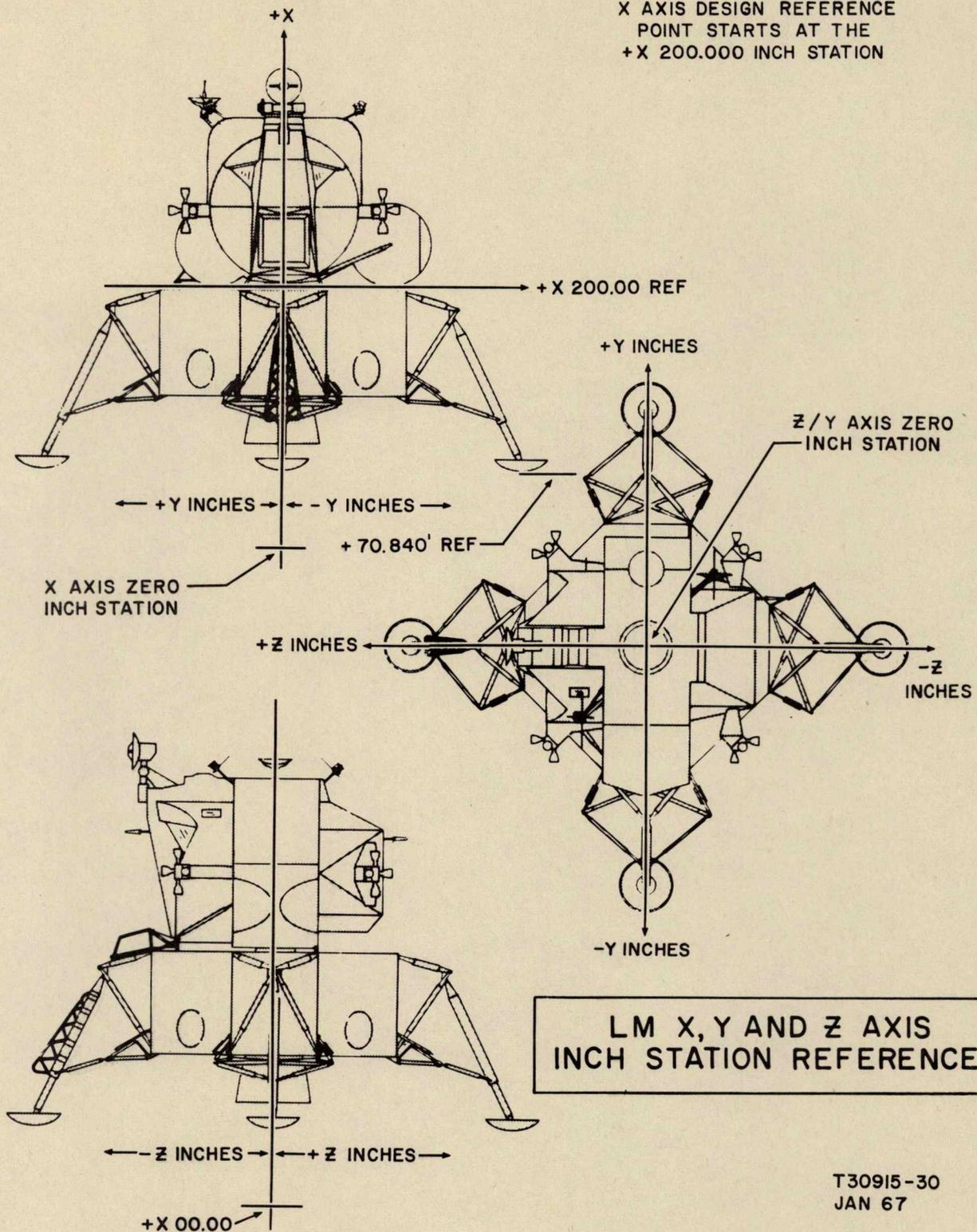


NOTES:  
 TOTAL WEIGHT - APPROX. 33,000 LBS  
 TOTAL HEIGHT - APPROX. 22 FT, 11 IN  
 TOTAL WIDTH - WITH TANKAGE  
 APPROX. 14 FT, 1 IN  
 - WITH LANDING GEAR  
 EXTENDED, APPROX.  
 29 FT 9 IN

LM DIMENSIONS

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X AXIS DESIGN REFERENCE  
POINT STARTS AT THE  
+X 200.00 INCH STATION



LM X, Y AND Z AXIS  
INCH STATION REFERENCE

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Figure 3

The +Y inch measurements start at the zero intersection and extend to the right increasing in inch measurement from zero, the -Y is identical but extending to the left. The + and -Z measurements are derived in the same manner, +Z being forward and -Z being aft.

The X axis inch references start at a design reference point given as the X 200.00 inch station. The X 00.00 inch reference being approximately 70 inches below the bottom surface of the foot pads, therefore all X inch readings are referred to as +X inches.

## ASCENT STAGE

### GENERAL DESCRIPTION

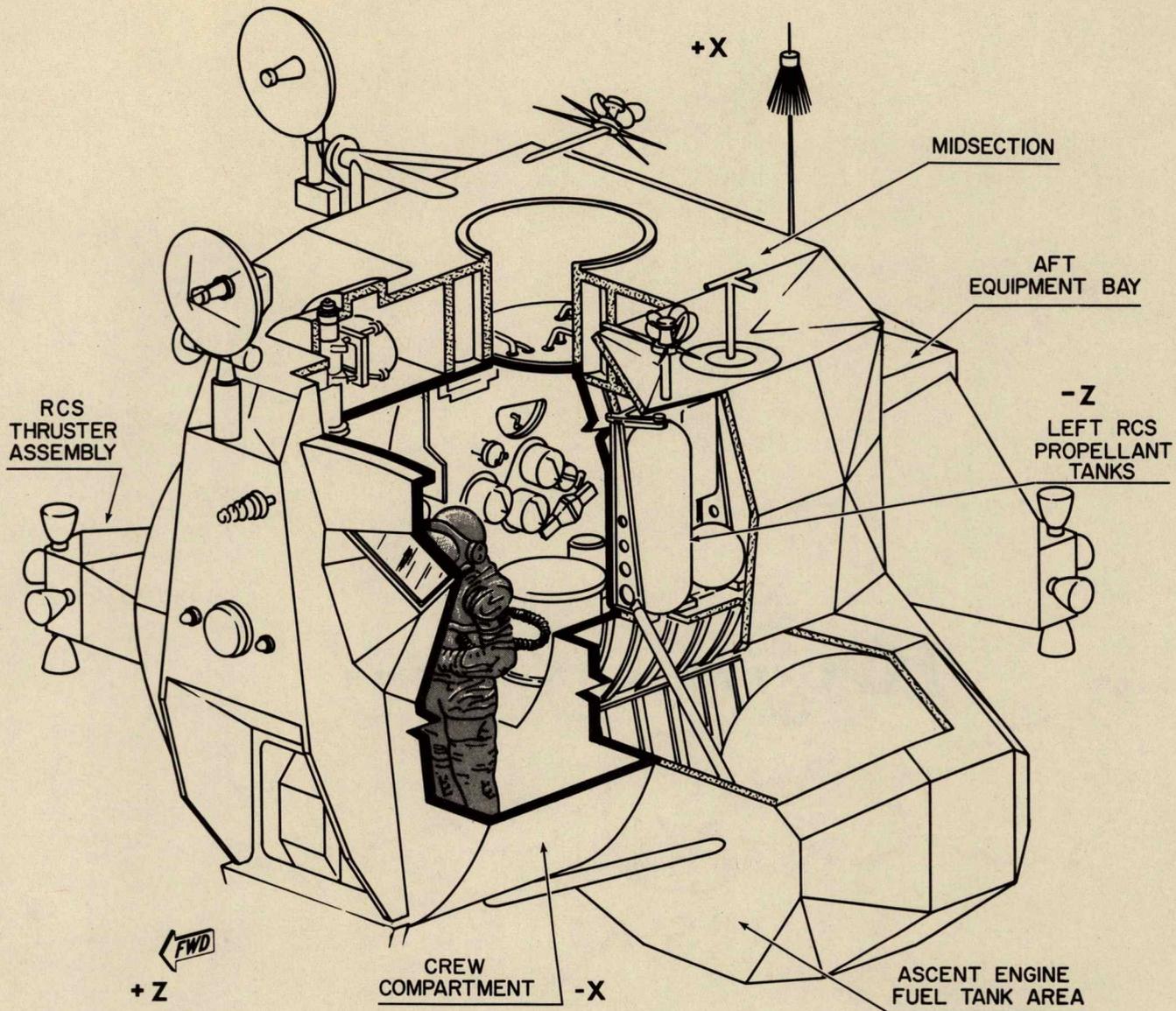
The Ascent Stage is the manned portion and control center of the Lunar Module. It has the capability of carrying the two astronauts from the Command/Service Module to the lunar surface and return. These phases of the mission will be performed at the control center within the crew compartment.

The Ascent Stage consists of the cabin (crew compartment and mid-section), aft equipment bay, tank areas, ascent engine, reaction control engine cluster and insulation and outer skin. The cabin or work area comprising of both the crew compartment and midsection giving an overall approximate area of 235 cu.ft. This area being climatic controlled and pressurized to 4.8 psi., providing a stable working environment for the astronauts. All aspects of the spacecrafts performance will be monitored and controlled from the crew station within the cabin. (Refer to Figures 4 and 5)

The areas other than the cabin are unpressurized and will house the various systems and subsystems to support the mission.

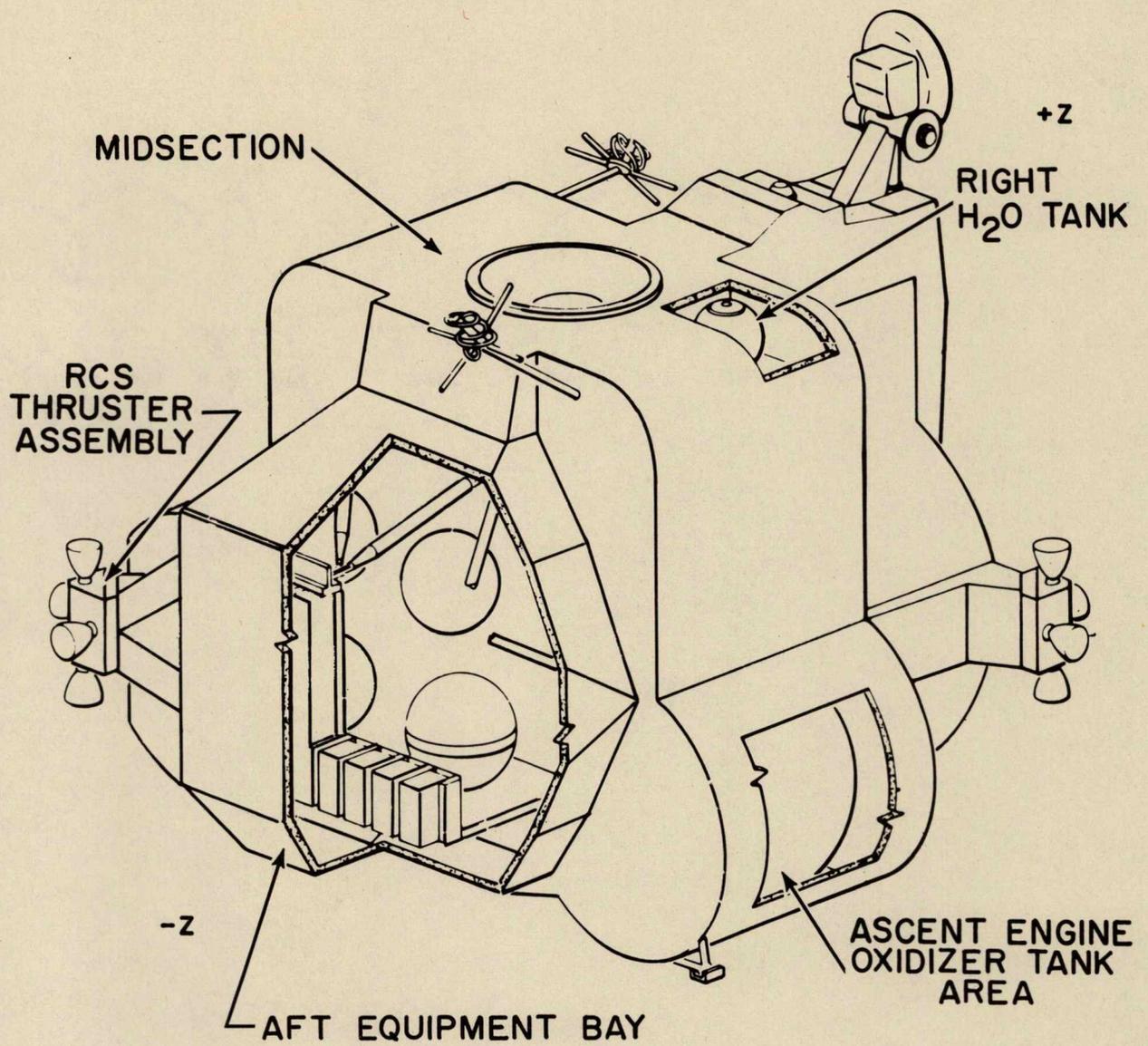
The aft equipment bay will house the following: The cold rail assembly containing the various electronic equipment requiring temperature control, two GOX tanks and two helium tanks are also mounted within the area.

On both sides of the upper area of the midsection are mounted the reaction control system related tankage (two fuel, two oxidizer and two helium), feed and control systems; two water tanks and a portion of the environmental control system. On the lower area of the midsection are mounts for the fuel (left) and oxidizer (right) tanks of the ascent engine system; between the two tanks in a separate compartment is housed the ascent engine.



**ASCENT STAGE  
 (FWD-LEFT CUTAWAY)**

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ASCENT STAGE  
AFT-RIGHT CUTAWAY

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The four reaction control engine clusters are mounted on truss members extending from both sides of the crew compartment (two forward clusters) and both sides of the midsection (two aft clusters).

The various radar and communications antennas are mounted to the outer structure of the crew compartment and midsection. (Figure 1)

Adequate windows, hatches and stowage compartments are provided within the cabin area.

The Ascent Stage structure is designed to withstand environmental conditions and design limit loads without permanent deformation. Its structural configuration is designed to perform the following tasks:

Provide environmental protection for a two-man crew during the lunar landing, lunar stay, ascent, rendezvous, and docking phases of the LM mission.

Support all Ascent Stage equipment.

Provide required visibility for the astronauts for lunar landing, ascent, rendezvous and docking maneuvers.

Provide for astronaut and equipment transfer between the LM and CSM and between the LM and lunar surface.

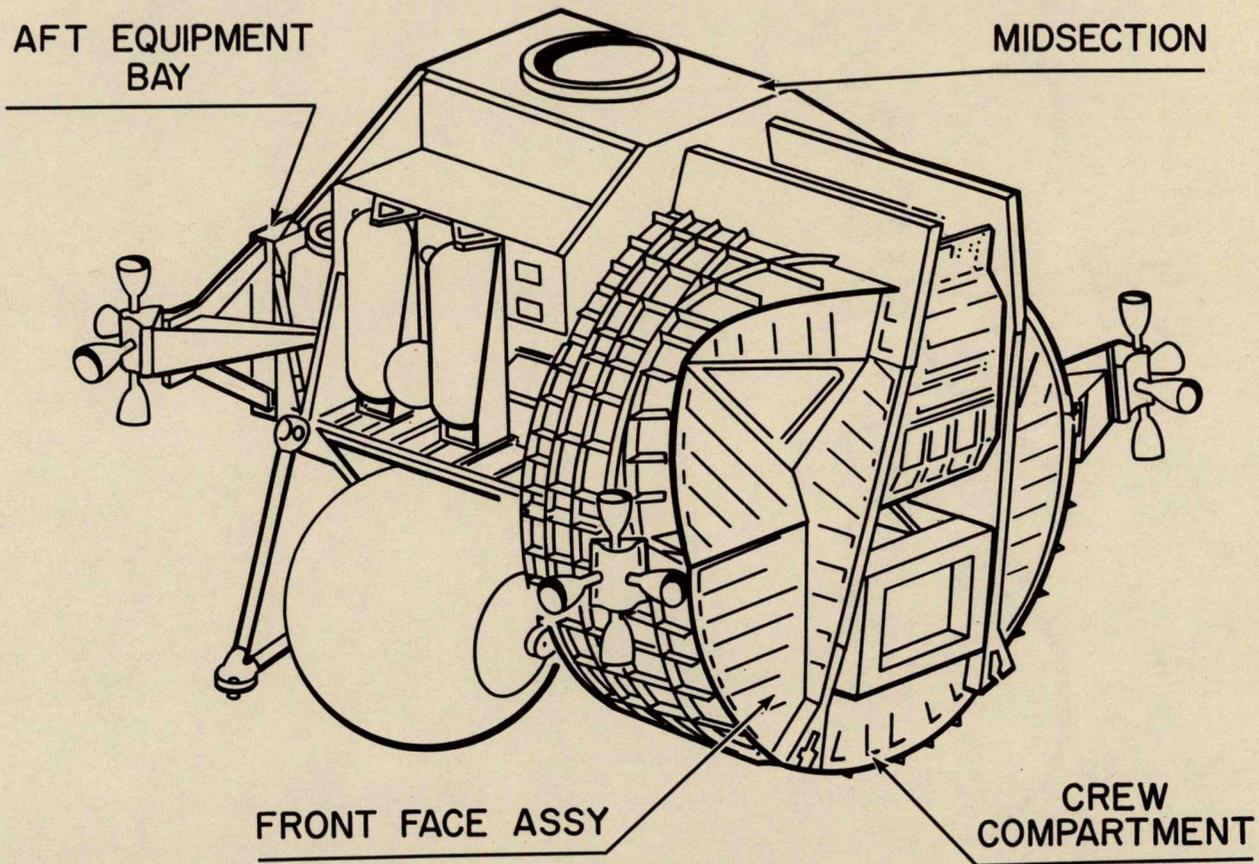
Provide passive thermal control (some subsystems are actively controlled) of the Ascent Stage Subsystem environment.

Protect the Ascent Stage subsystems from meteoroid environment.

#### STRUCTURAL CONTEXTURE

The Ascent Stage's structural make-up is divided into five structural areas; crew compartment, midsection, aft equipment bay, tank and equipment mountings, and insulation and outer skin. Aluminum alloys (the major alloy being 7075T6) is used exclusively in the construction of the Ascent Stage. A small amount of titanium is also used for brackets and fasteners. (Figure 6)

Aircraft type construction methods are utilized in the fabrication of the structure. Skin and web areas are chem-milled to reduce weight. Mechanical fasteners are used to secure the major structural assemblies



**LM STRUCTURE**

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together. Epon 934 is used as a sealant prior to securing the mating assemblies. Within the pressurized area of the Ascent Stage Subassembly parts are fusion welded together, wherever possible, to minimize pressurization leaks.

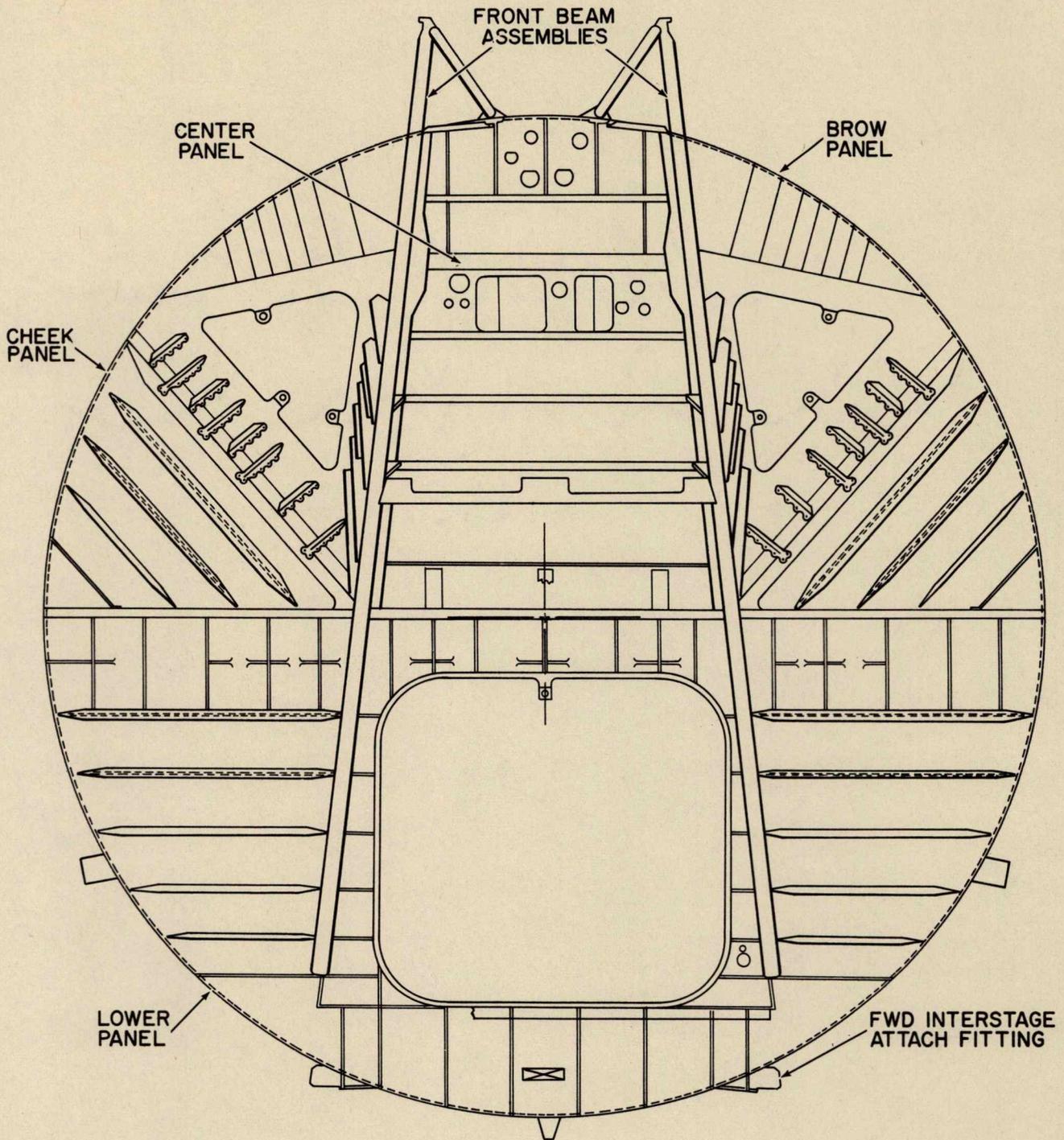
The crew compartment structural shell (Figure 8) is cylindrical and of semimonocoque construction. The shell is both a fusion welded and mechanically fastened assembly of aluminum alloy sheet and machined longerons. The shell is supported by formed "Z" sheet metal rings that are riveted cross-section to the structural skin, forming a structure 92 inches in diameter. A front face assembly is mechanically secured to the cylindrical shell. Its construction methods are the same as the shell.

The front face assembly (Figure 7) incorporates openings in the structure for two triangular windows and the egress/ingress hatch. Two large structural beams extend up the forward side of the front face assembly, utilized to carry and support the structural loads applied to the cabin structure. The lower ends of the beams support the two forward interstage mounts; while the upper ends are secured to additional beam structure extending across the top of the cylindrical crew compartment aft to the midsection structure. Structural loads are transmitted from the interstage fitting through the combined beam assemblies to the super structure of the midsection, relieving unnecessary stress loads to the crew compartment structure.

The forward RCS engine clusters are mounted on aluminum alloy (2219-0) tubular truss members bolted to both sides of the front face assembly. A truss member extends aft and is secured to a longeron located at the compartment's maximum breadth. Additional external mountings are secured to the structure for radar and communications antennas.

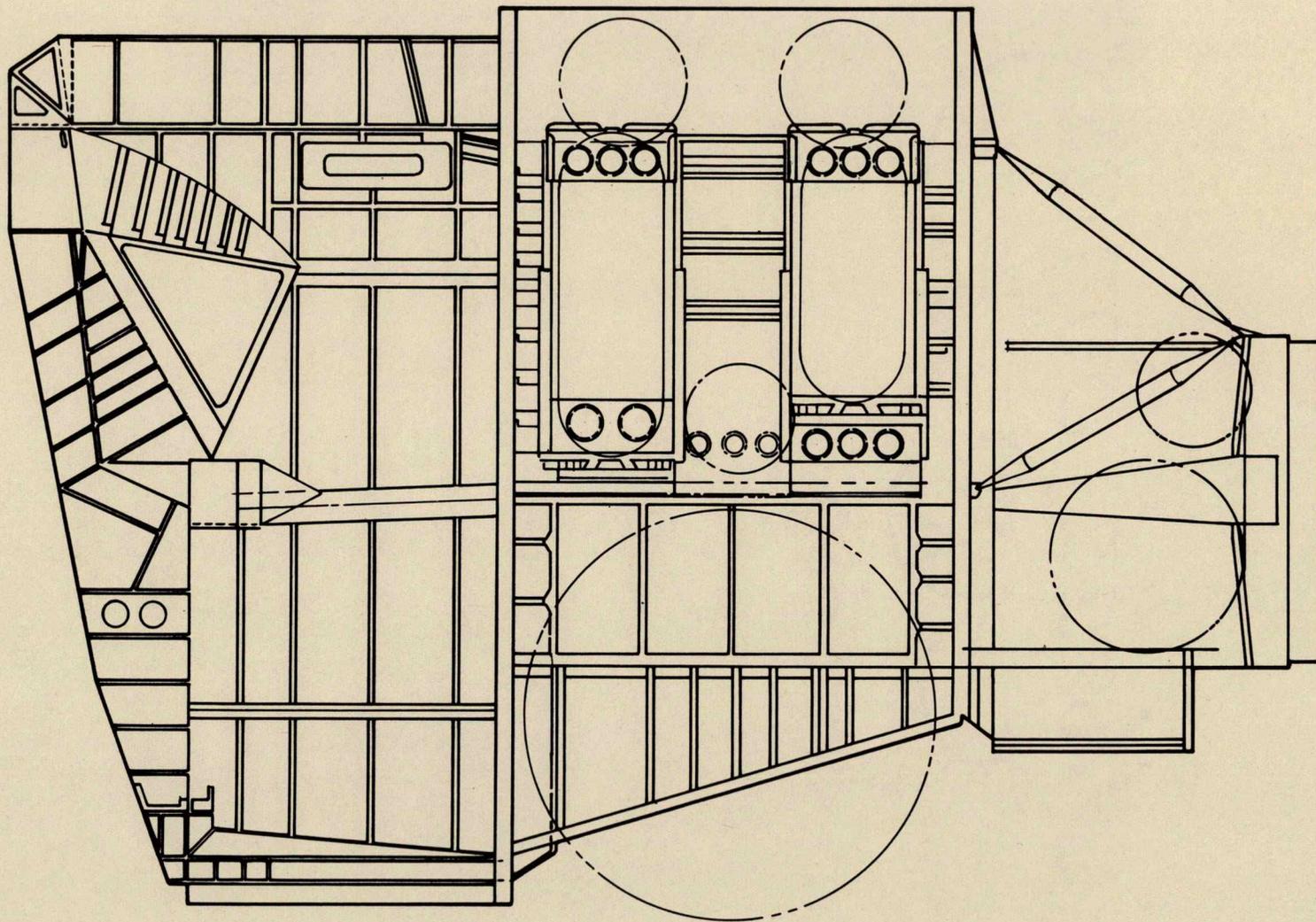
The aft bulkhead/frame of the crew compartment, which mates with the midsection, is designated as station +Z27.000. The front face assembly is mounted to the main circular structure at an angle; the lower end at station +Z64.557 angling to a measurement of 86.180 at the top. The compartment is symmetrical about the Y axis.

The midsection structure consists of a ring-stiffened semimonocoque shell of construction similar to that of the crew compartment. The side bulkheads are aluminum alloy (7075T6) chem-milled skin with machined stiffeners and longerons fusion welded to it. The upper and lower integrally stiffened machined decks of aluminum alloy close off the midsection at stations +X294.643 and +X233.500. The decks being fusion welded to the curved bulkheads. The midsection assembly shell is



**FRONT FACE ASSEMBLY**

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LM STRUCTURE (LEFT SIDE VIEW)

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Figure 8

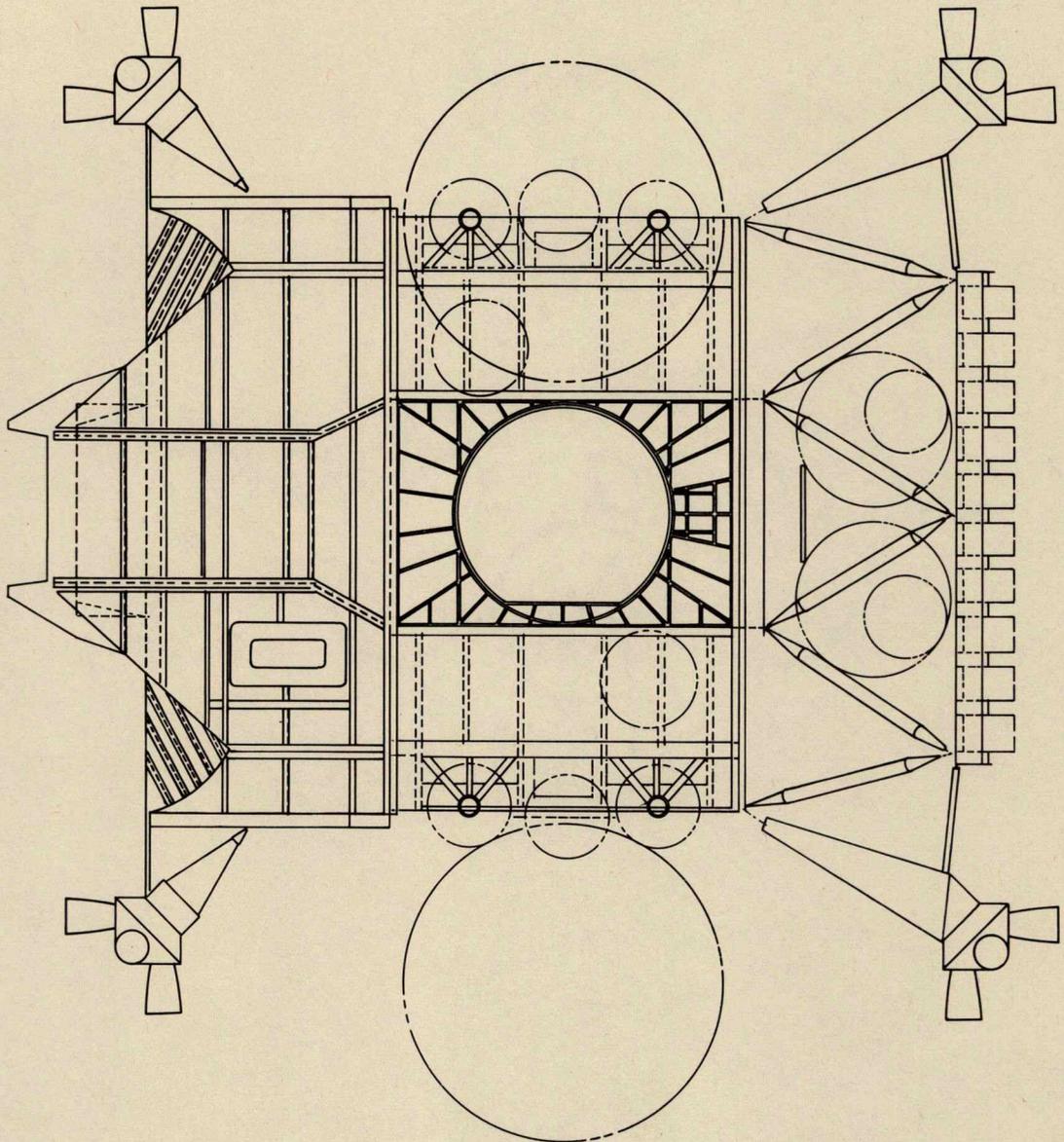
mechanically fastened to flanges on the major structural bulkheads at stations +Z27 and -Z27. The bulkheads are integrally stiffened machine assemblies of aluminum alloy plate. The crew compartment shell is mechanically secured to an outboard flange of the +Z27 bulkhead, completing the pressurized portion of the Ascent Stage. All mechanically fastened assemblies are coated with Epon 934 prior to mating. (Figures 8 and 9)

The lower deck, of the midsection at station +X233.500, provides the structural support for the Ascent engine. The upper deck, at station +X294.643 provides the structural support for the docking tunnel and docking hatch. The lower end of the 32 inch diameter tunnel is welded to the deck structure while the upper end of the 16 inch long tunnel is secured to an outer deck. Two main beams running fore and aft, integral with those above the crew compartment, are secured to the upper deck and support the outboard end of the outer deck. The aft ends of the beams are fastened to the aft bulkhead, -Z27.000.

The aft, -Z27.000, bulkhead has provisions for bolting the tubular truss members for both aft interstage fittings. (Therefore, stress loads applied to the front beam are transmitted through the two beams atop the upper deck to the aft bulkhead through the aft interstage support members to the fittings. Thus the combination of the beams, bulkhead and truss members form a cradle effect for the cabin assembly taking up all the stress load applied to the Ascent Stage.) The Ascent engine propellant storage tanks are mounted on tubular truss members secured to the +Z27 and -Z27 bulkheads. The RCS propellant tanks support assemblies are secured externally to both sides of the curved bulkheads.

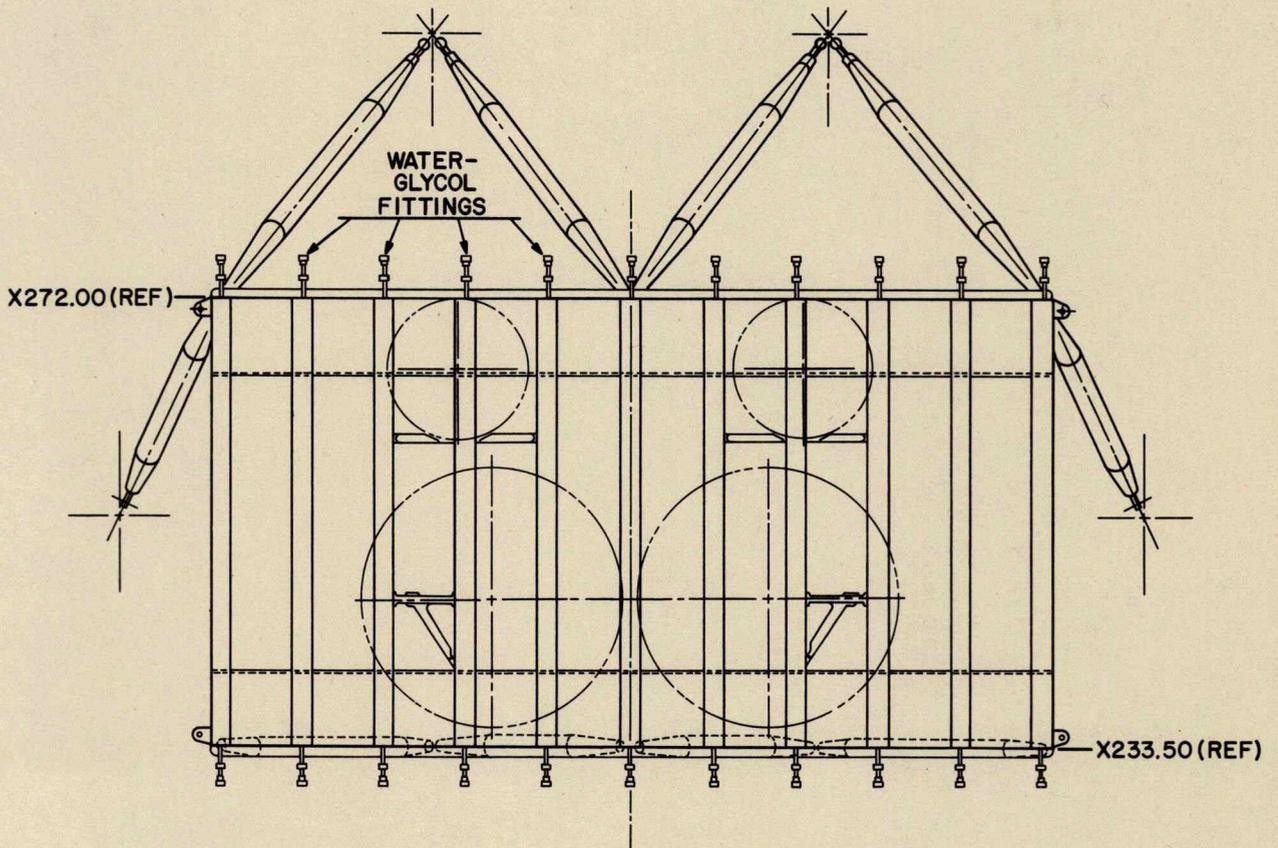
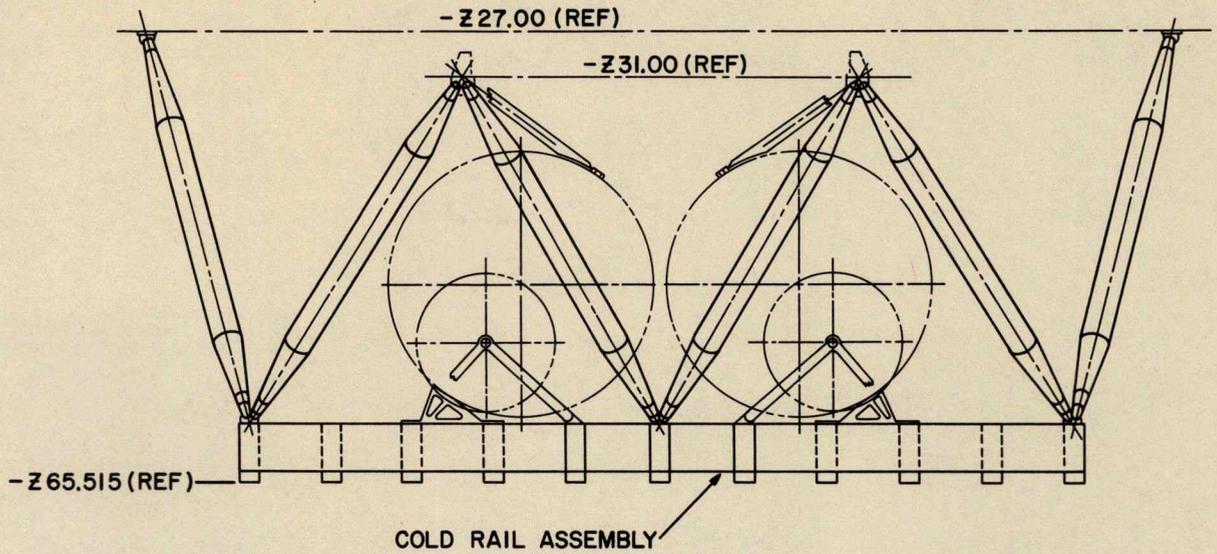
Two cantered beam assemblies are secured to the bottom of the lower deck and both fore and aft bulkheads, forming the Ascent Engine Compartment. The engine support ring truss members are bolted to the lower deck. The center of the ring being the center of gravity of the Ascent Stage.

The aft equipment bay, aft of the midsection pressure-tight bulkhead (-Z27) is an unpressurized area. The main supporting structure of the bay are tubular truss members bolted to the aft side of the -Z27 bulkhead. The truss members extend aft to the equipment rack (the truss members utilized as a cantilever type construction). The equipment rack assembly is constructed of a series of vertical box beams supported by an upper and lower "Z" frame. The beams have integral cold plates, serving as a heat transfer link to the electronic equipment mounted on the beam racks. The cold plates are mounted vertically in the structural frame being supported at its upper and lower edges by the truss members. Water-glycol coolant flows through the cold plates as the heat absorbing medium. (Figure 10)



LM STRUCTURE (TOP VIEW)

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**AFT EQUIPMENT BAY STRUCTURE**

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Two gaseous oxygen and two helium tanks are secured to truss members and brackets, within the area between the -Z27 bulkhead and equipment rack. Various support mounting and brackets are secured to the aft side of the -Z27 bulkhead, these serve as supports and mounts for valves, plumbing lines, wiring, ECS components and propellant subsystem components which do not require a pressurized environment.

The two aft RCS thruster clusters are supported by truss members bolted to the upper and lower corners of the equipment rack assembly and to the -Z27 bulkhead.

The entire LM Ascent Stage structure is enveloped with a thermal and micrometeoroid shield which is a composite of an outer sheet (or skin) of aluminum and multiple layers of aluminized mylar. These are mounted on low-thermal-conductance supports, these keeping the skin and insulation at a minimum of two inches from the main structure. The aluminum sheet acts as a micrometeoroid bumper and has a minimum average thickness of 0.004", to meet shield requirements.

The aluminized mylar used as the thermal shielding, being 0.0005 inch in thickness, is formed into various size and shaped blankets of 25 layers each. These are secured to the standoffs, on the outer surface of the structure. Where the blankets meet, the mating edges are sealed with mylar tape. Even though the seams are sealed with tape the blanket layers are vented to space. At the area about the Ascent engine propellant tanks, a light tubular framework is installed over the tanks to enable firm securing of the blankets as well as keeping it away from the tanks.

The aluminized mylar blankets will insulate the entire ascent stage structure against temperatures up to 350°F. On the RCS thruster assembly support truss members, where the members are subjected to temperatures above 350°F, due to engine radiation, added insulation is installed over the mylar blankets. This consists of an additional 25 layers of H-film. H-film is aluminized polyimide with an insulating capability of up to 1000°F. (It should be noted that the mylar and H-film can be readily identified by color; aluminized mylar being silver, the H-film being gold in color) additional H-film blankets are utilized in other areas, of the Ascent Stage, where it will be subjected to temperatures above 350°F.

After the entire Ascent Stage has been blanketed with the insulation the meteorite shield is placed over it, utilizing the same standoffs for its attaching points.

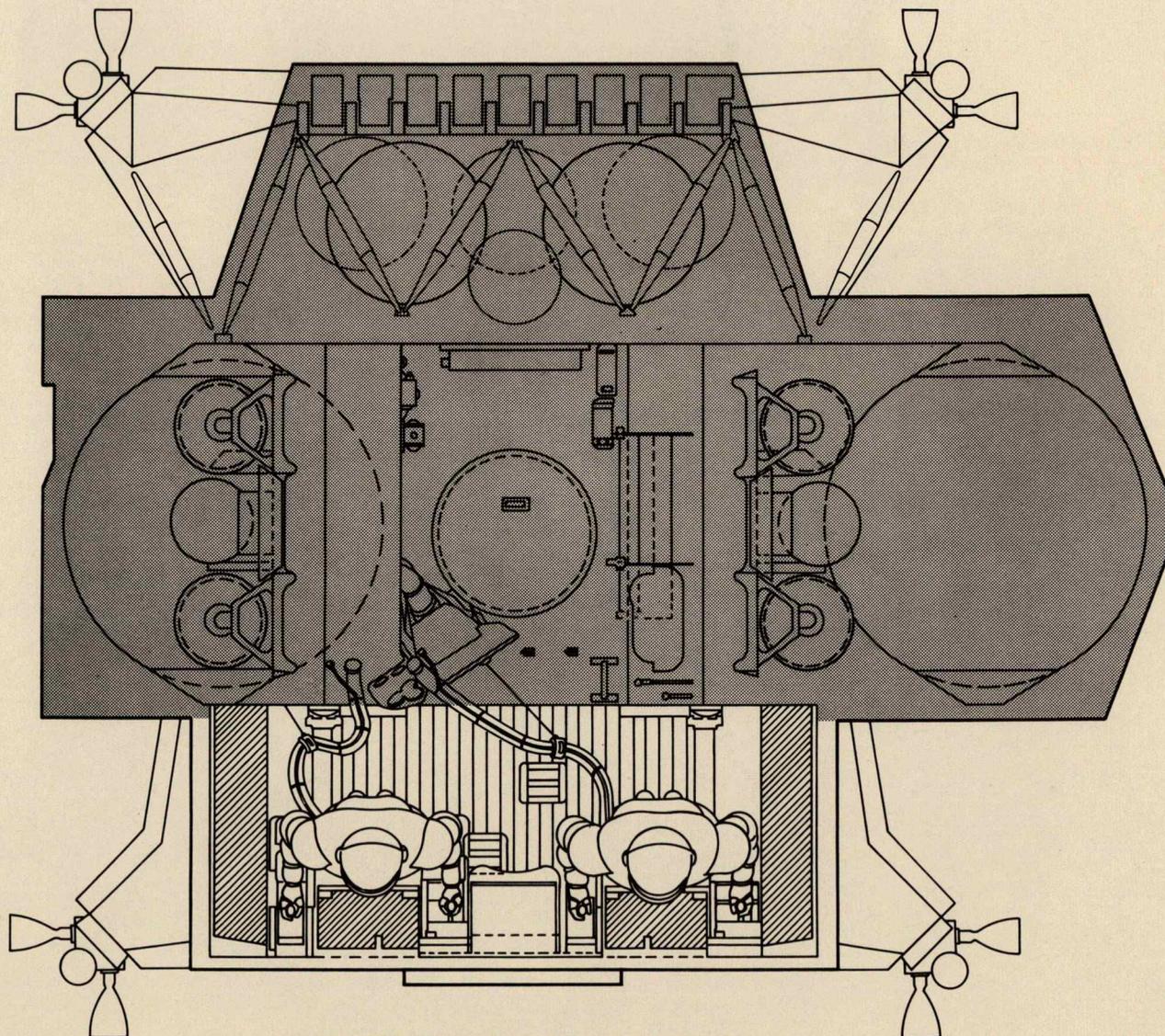
During earth prelaunch activities, various components and areas must be readily available; therefore, adequate access panels, in the outer skin and insulation, are readily available within these areas for easy access.

#### CREW COMPARTMENT

Forward Cabin Area: As previously stated, the crew compartment is the frontal area of the Ascent Stage, being approximately 92 inches in diameter and 42 inches in depth, creating an adequate work area for the two astronauts. (Figures 11 and 12.) This area having the flight stations with the instrument panels, armrests and body restraints, landing aids, two front and docking windows, alignment optical telescope and switch/circuit breaker panels. Flight stations are 44 inches apart; each astronaut has a set of controllers and armrests (Figure 13). The armrests have adjustments to accommodate all required percentile anthropometric sizes when the proper shoes are worn. A design reference point (design eye) orients flight station geometry for the required balance between external visibility, visual and physical access to controls and displays. Instrument panels, windows, glare shields, controllers, armrests and landing aids are oriented with respect to this design reference point. The flight station is provided with the necessary floor to overhead height, body clearance and armrest adjustment to accept all astronauts in the 10 to 90 percentile anthropomorphic body size. An astronaut need not be indexed at the design eye in order to effectively perform his assigned tasks; this requires that no adjustment with respect to the floor, is operationally employed for this purpose. The docking design eye orients the overhead docking window with respect to the Commander's flight station viewing angle. The main instrument panels are cantered and centered between the two flight stations to permit sharing and easy scanning by the astronauts. (Figures 14 and 15)

The optical alignment station is in the center aisle between the individual flight stations, for use of the alignment optical telescope (OAT). A single step-up adjustment is used in order to accommodate the range of percentile astronauts to the eyepiece and AOT controls (Figure 16).

The PLSS donning station (Figure 17) is also in the center aisle but slightly aft of the optical alignment station. A removable, height adjusting PLSS supporting harness, permits donning and doffing of the PLSS backpack. There is a recharge station on the -Y side of the equipment tunnel for recharging the PLSS water and oxygen, (Figure 18) completely accessible from the forward cabin. Tunnel design and equipment permits space for resting or sleeping (Figure 19).

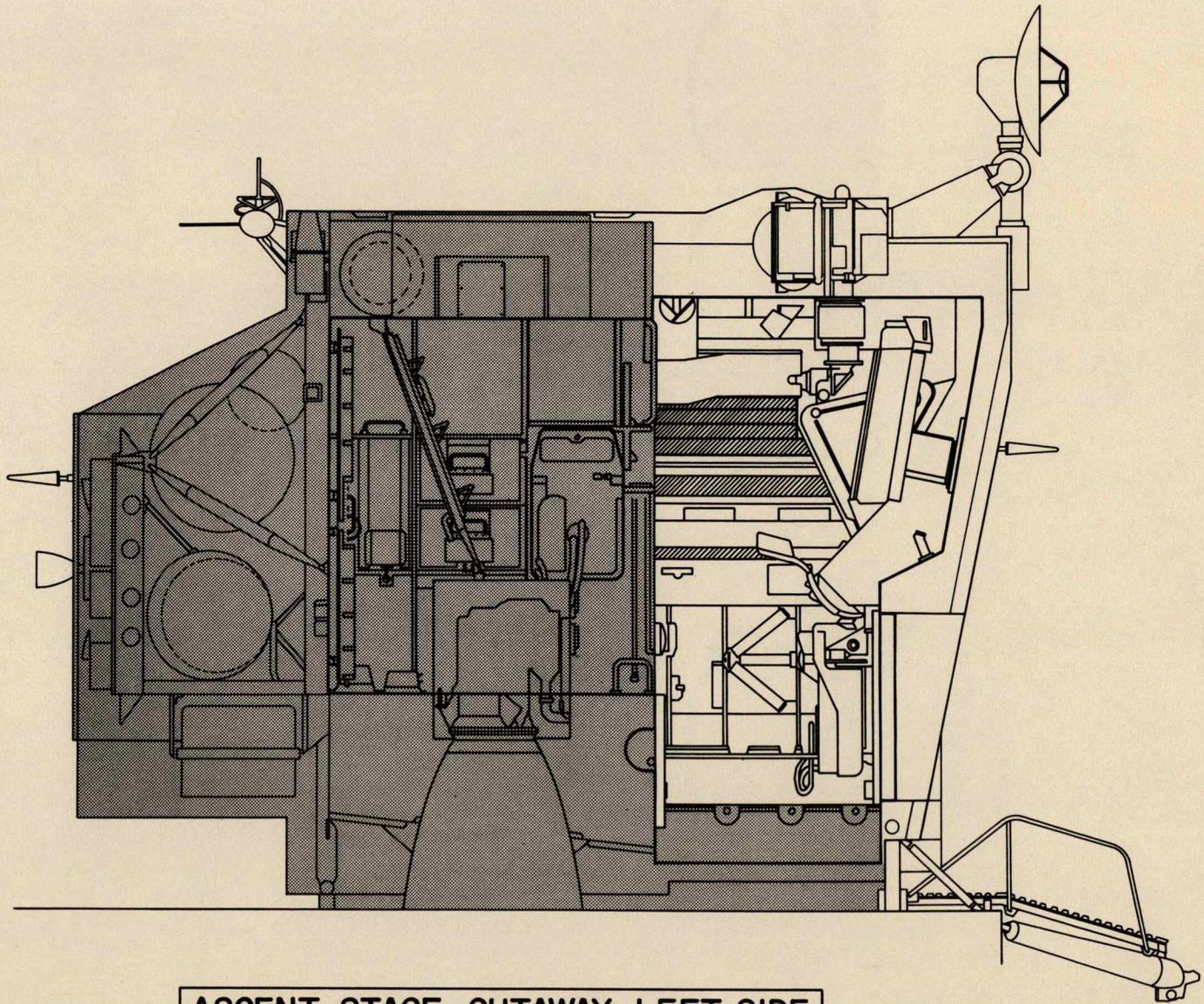


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Figure 11

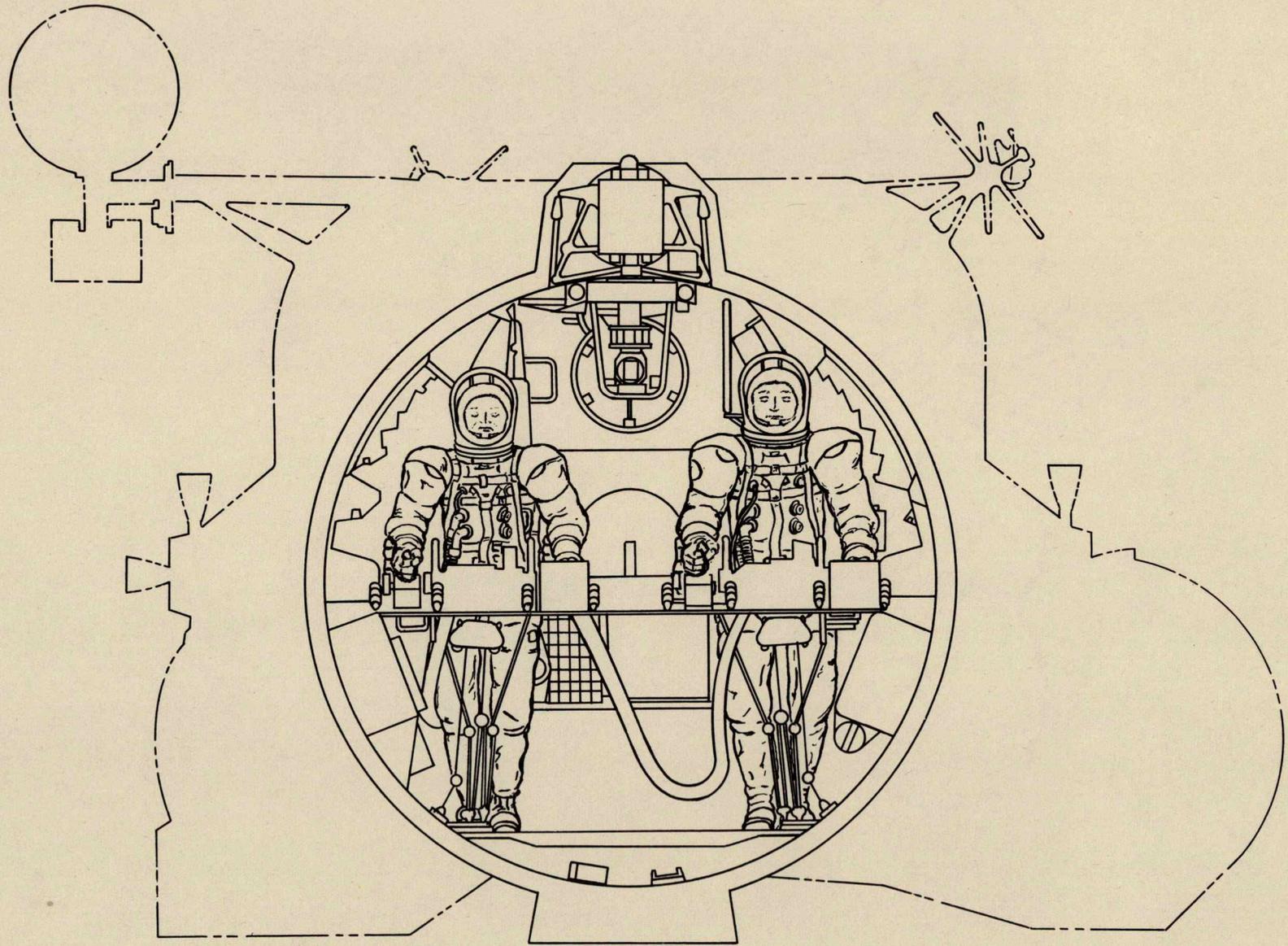
ASCENT STAGE PLAN VIEW  
(CREW COMPARTMENT)

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ASCENT STAGE CUTAWAY-LEFT SIDE  
(CREW COMPARTMENT)

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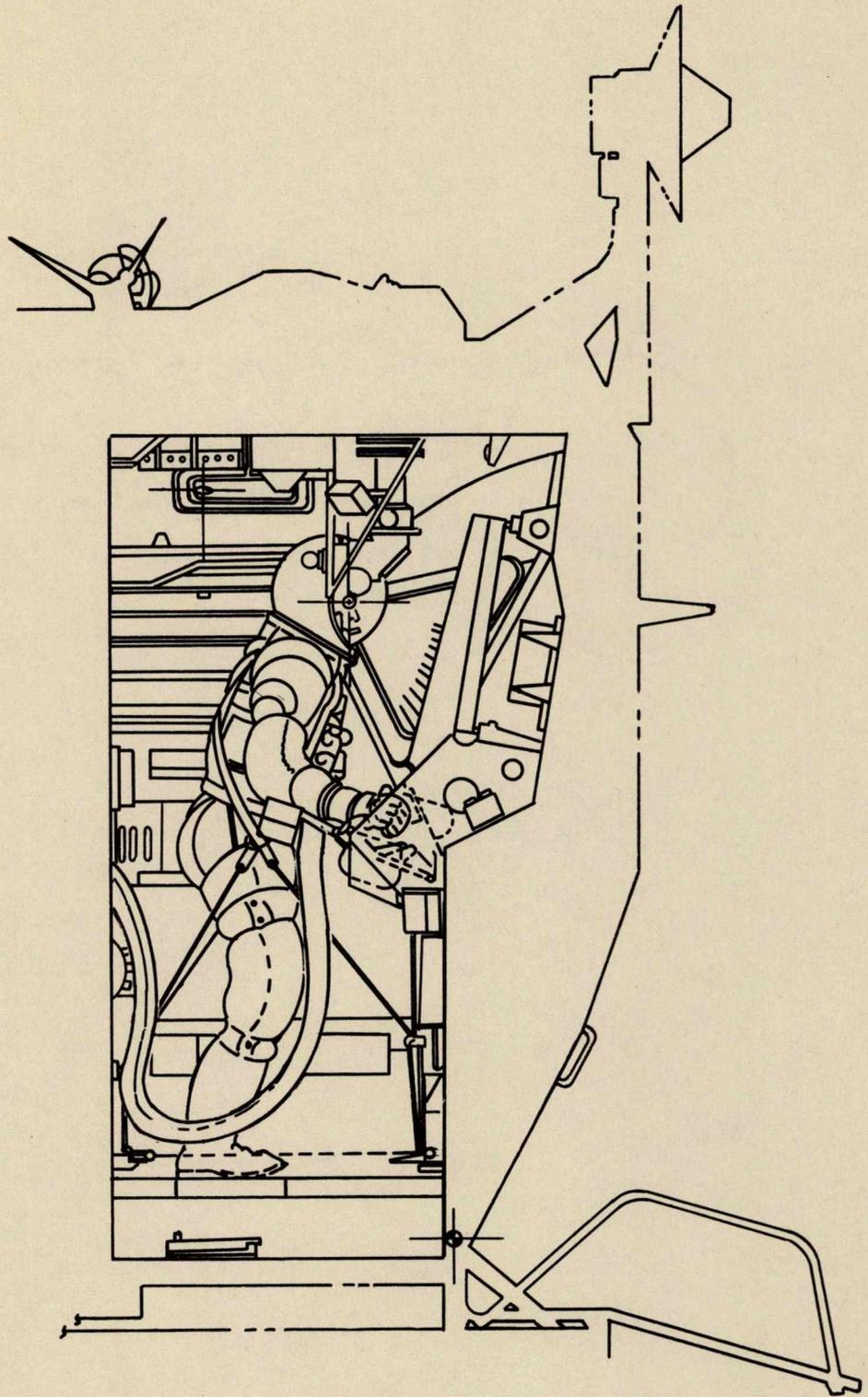


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Figure 13

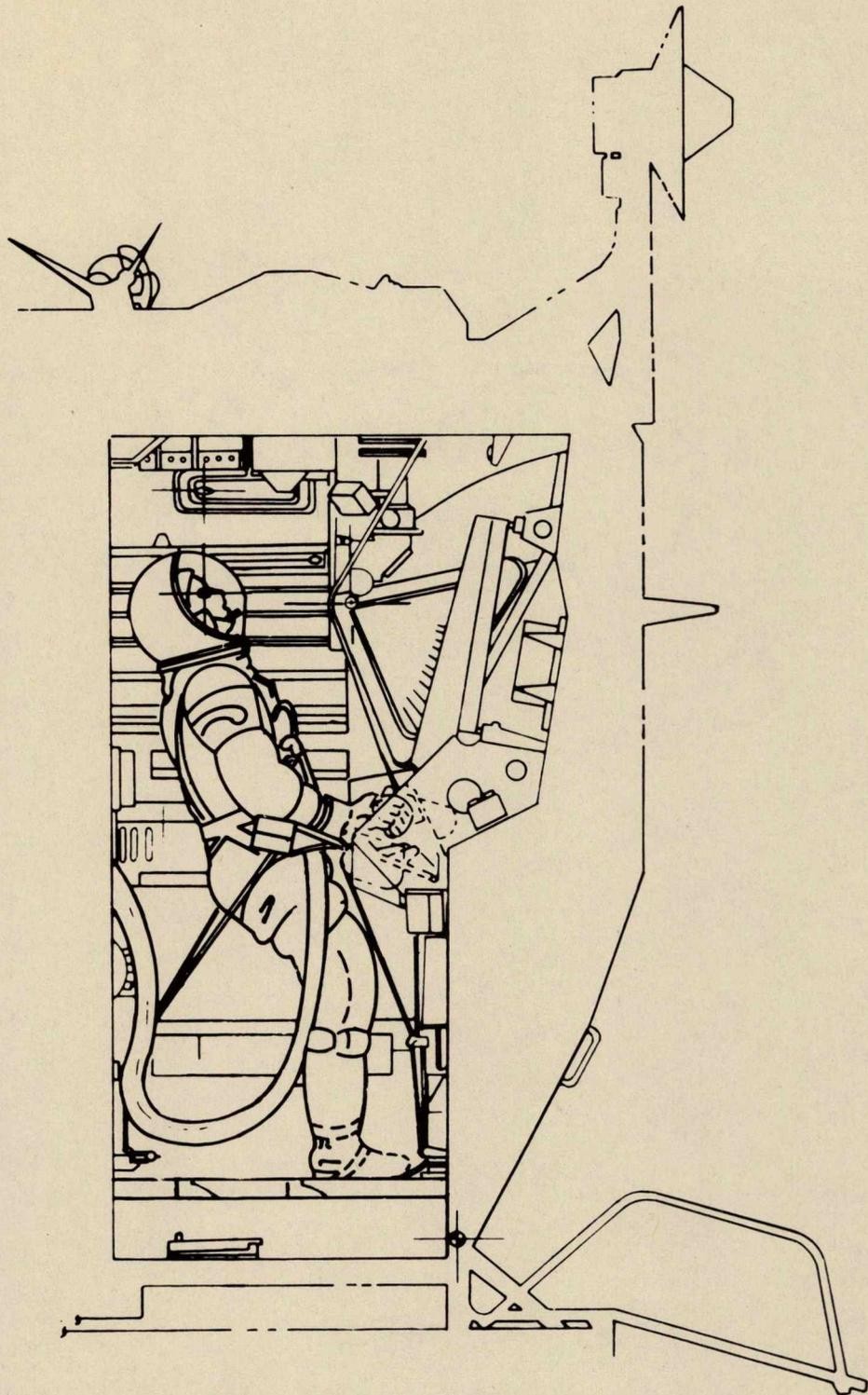
FLIGHT STATION (LOOKING AFT)

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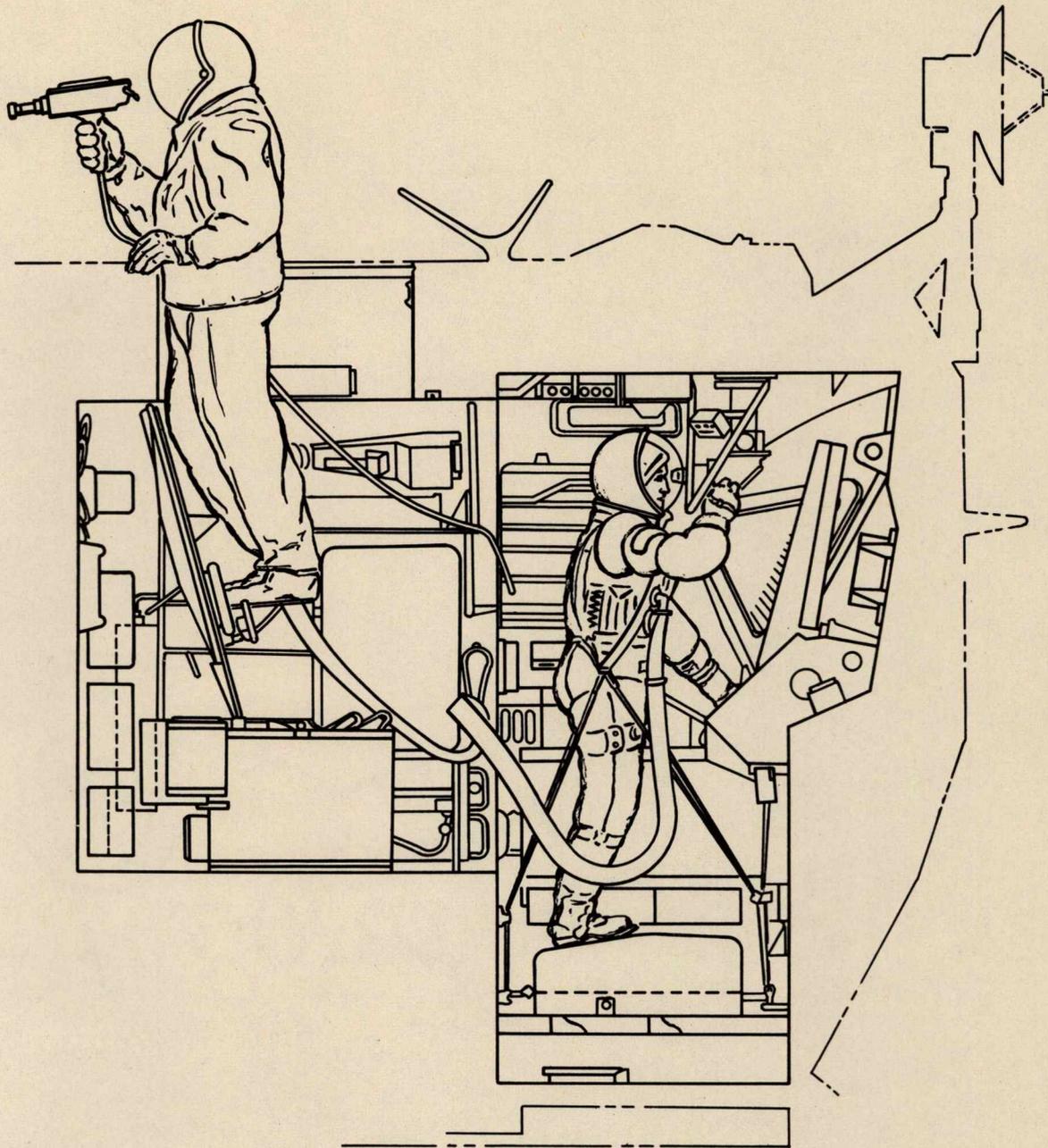
ASTRONAUT IN FLIGHT POSITION

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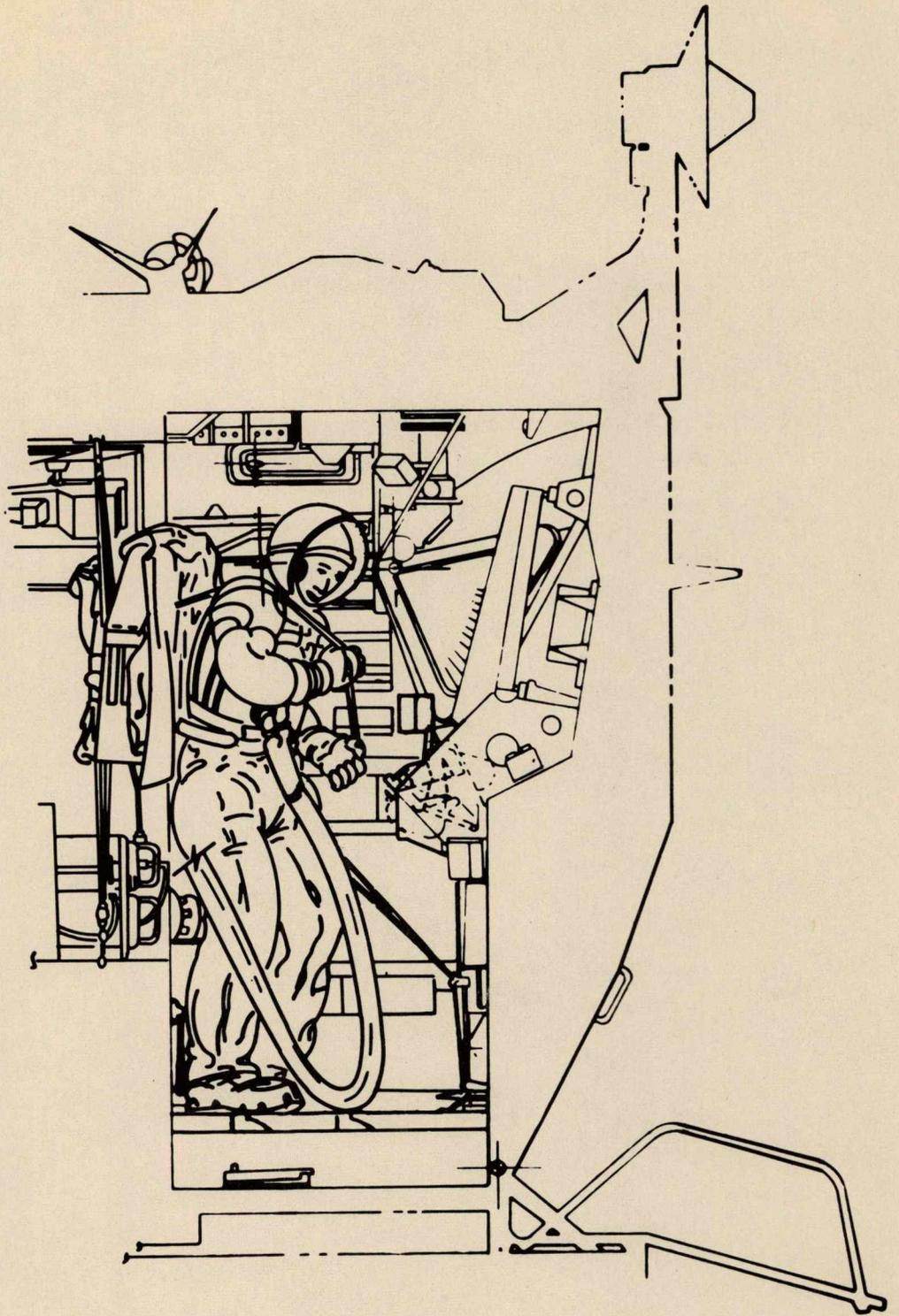
**ASTRONAUT IN DOCKING  
WINDOW POSITION**

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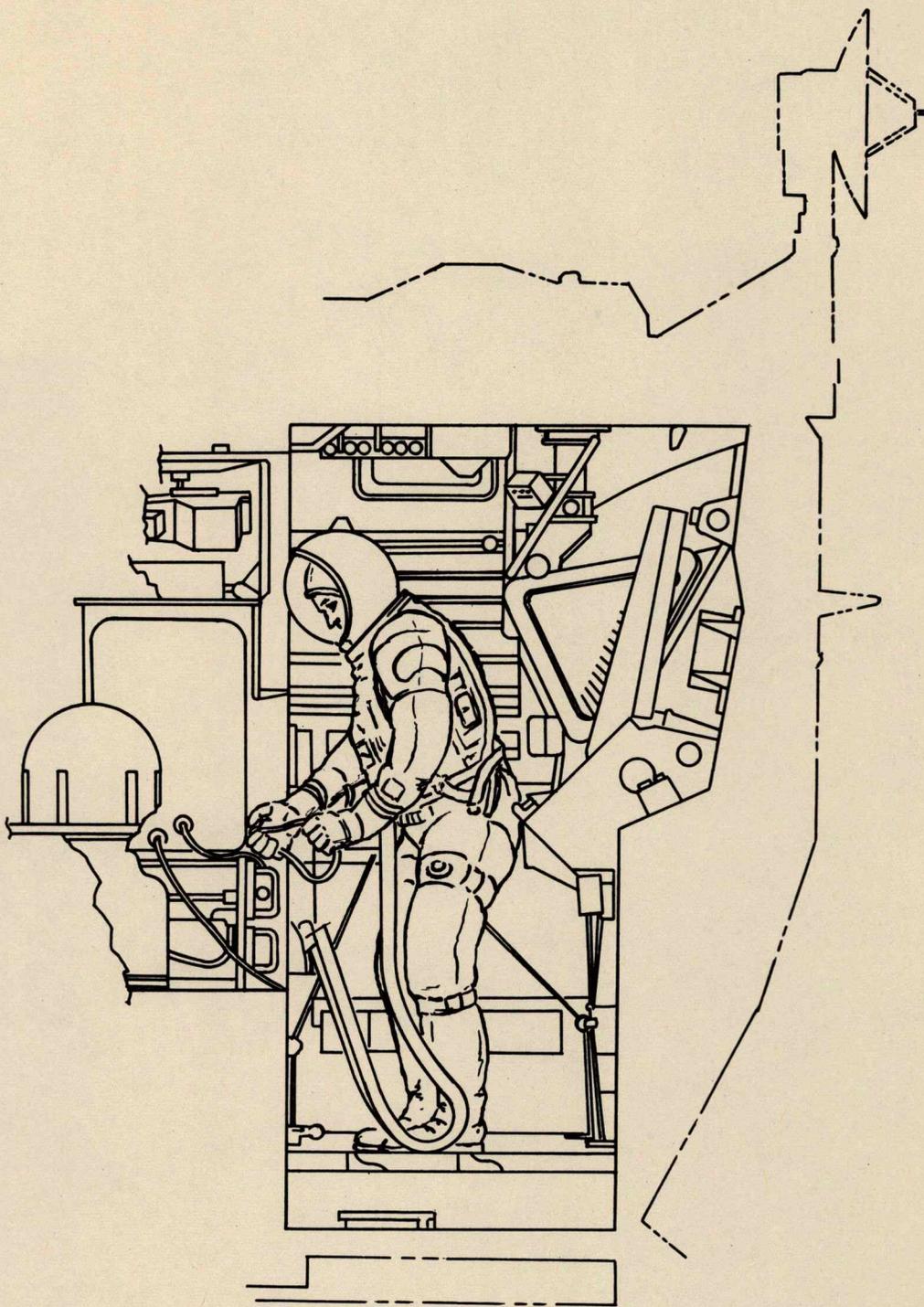
ASTRONAUTS USING AOT AND TV CAMERA

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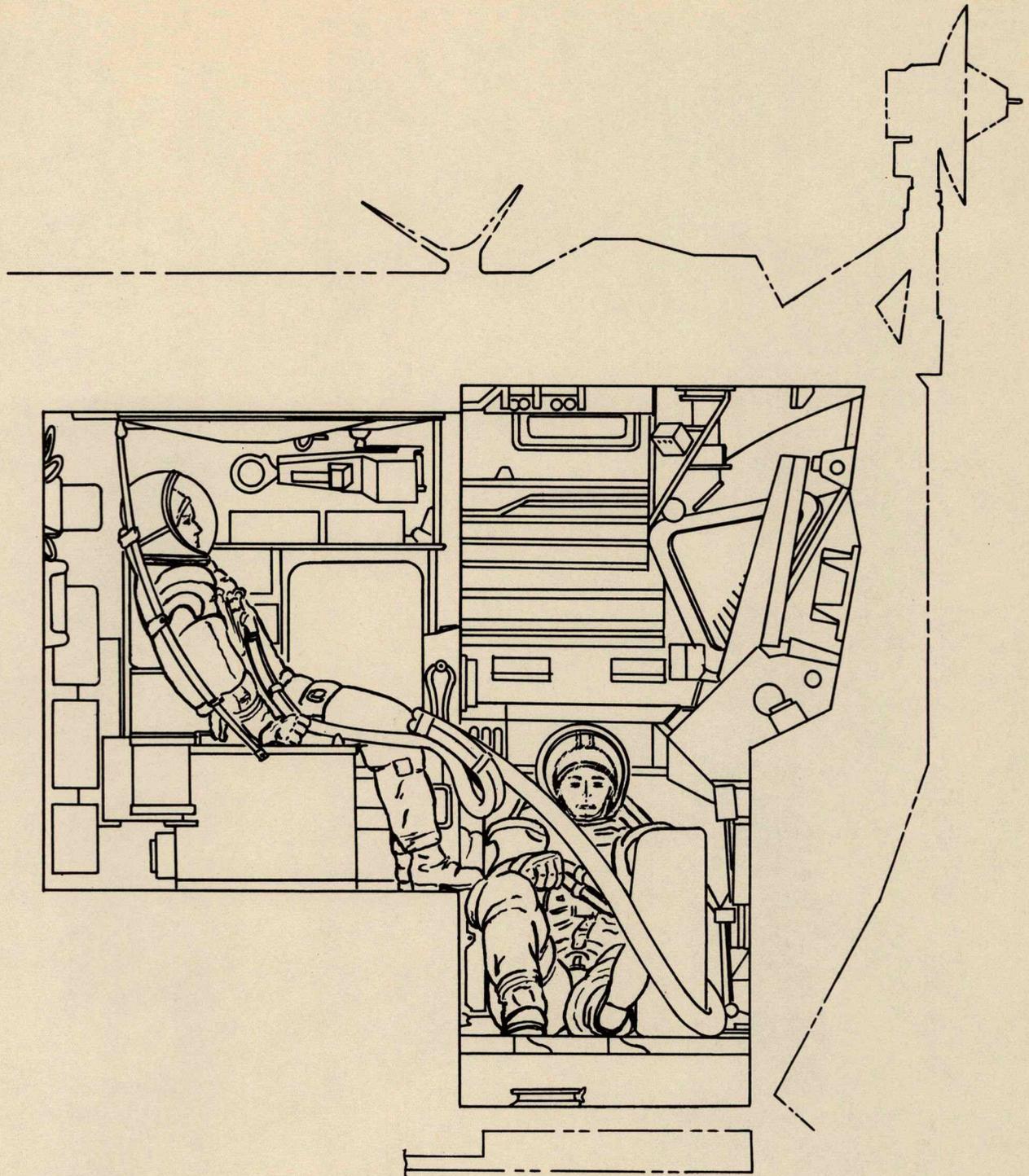
**DONNING STATION**

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JAN 67



RECHARGE STATION

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JAN 67



**ASTRONAUTS-REST POSITIONS**

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JAN 67

Control and Display Panels: The control and display area consists of twelve consoles and panels: (Figure 20) two main display panels (1 & 2), cantered forward  $10^{\circ}$ ; two lower center panels (3 & 4), sloping down and aft  $45^{\circ}$  towards the horizontal; two bottom side panels (5 & 6); two lower side consoles (8 & 12); two center side consoles (10 & 14), and two upper side consoles (11 & 16).

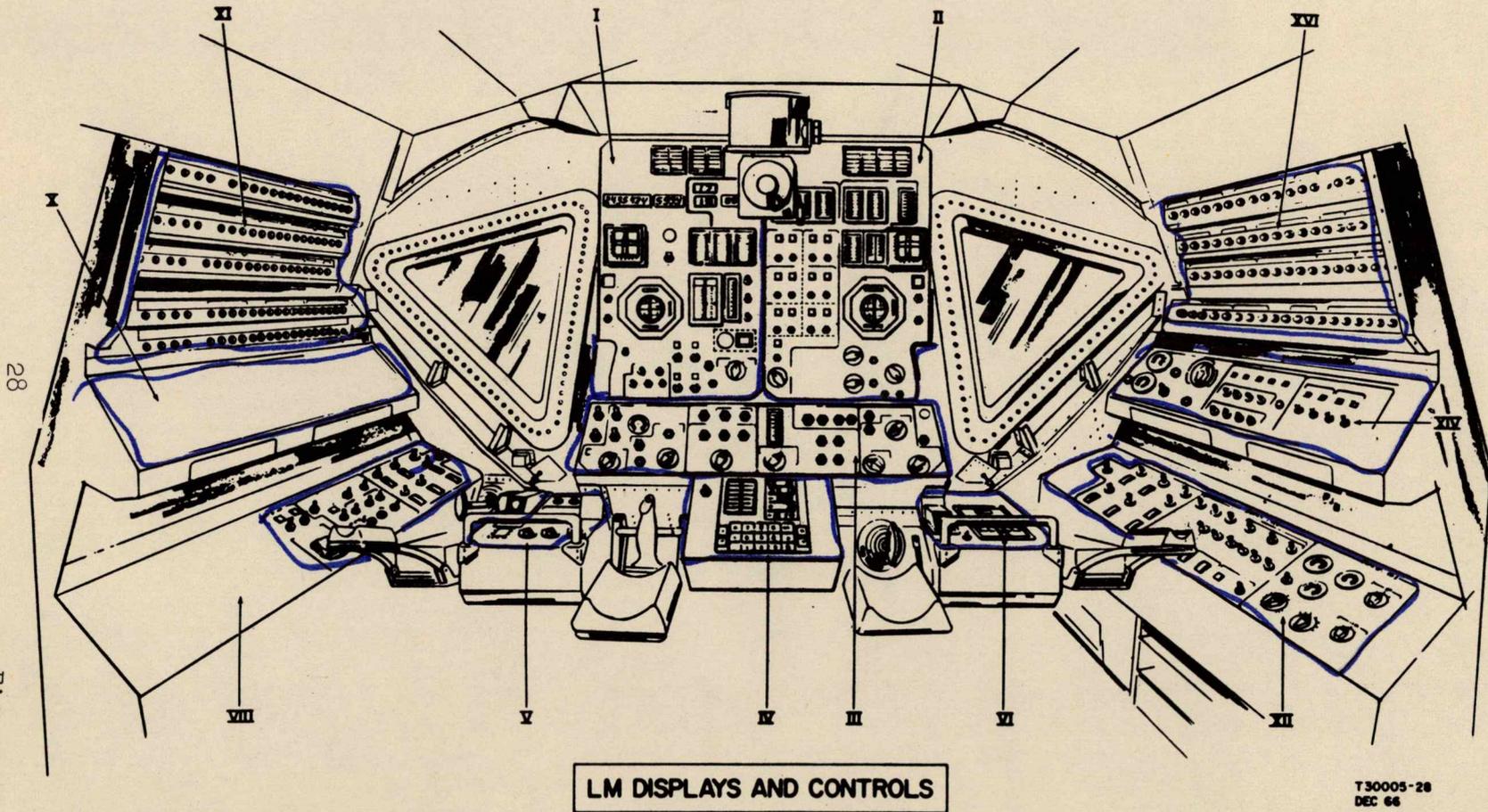
The two main display panels are constructed of two 0.015 face sheet of aluminum alloy, spaced 2 inches apart; they are reinforced by 0.015 channels. This forming a rigid box beam construction with a favorable strength-to-weight ratio and a relatively high neutral frequency. Each panel being supported to the structure by four shock mounts. Panel instruments are bezel-mounted to the back surface of the panels 2 inches along the case from the dial face, thereby achieving an attaching point approximately near the center-of-gravity of the instruments. The instrument cases are cushioned where they protrude through the panels dampening vibration tendencies. All dial faces are flush with the forward panels giving a clean display area which can be scanned readily by both astronauts. The two lower panels (3 & 4) are within easy reach and scanning for the astronauts. The two small panels (5 & 6) are in front of the astronauts at waist height. These panels contain the controls for all integral flood and signal lighting, as well as external lights, abort guidance and event timer.

At the left side of the Commander is a three-tiered console (Figure 21). The console runs fore and aft, from the front face assembly to the aft bulkhead (+Z27). The lower tier is cantered up  $15^{\circ}$  from horizontal; the center tier is cantered up  $36.5^{\circ}$  from the horizontal; the upper tier has a four angled surface containing circuit breakers, each row is cantered  $15^{\circ}$  to the line of sight. This permits a line of sight so that the white band on the circuit breakers may be readily seen when they pop.

The Systems Engineer has a three-tiered console on his right side, similar to that of the Commander's (Figure 22). All tiers are cantered at the same angle as the Commander's for ease of scanning and operation.

Compartment Deck: The crew compartment deck is approximately 36 x 55 inches, which is a seemingly small area but due to the curved construction of the compartment there is sufficient room for astronaut maneuverability. (Figures 21 and 22)

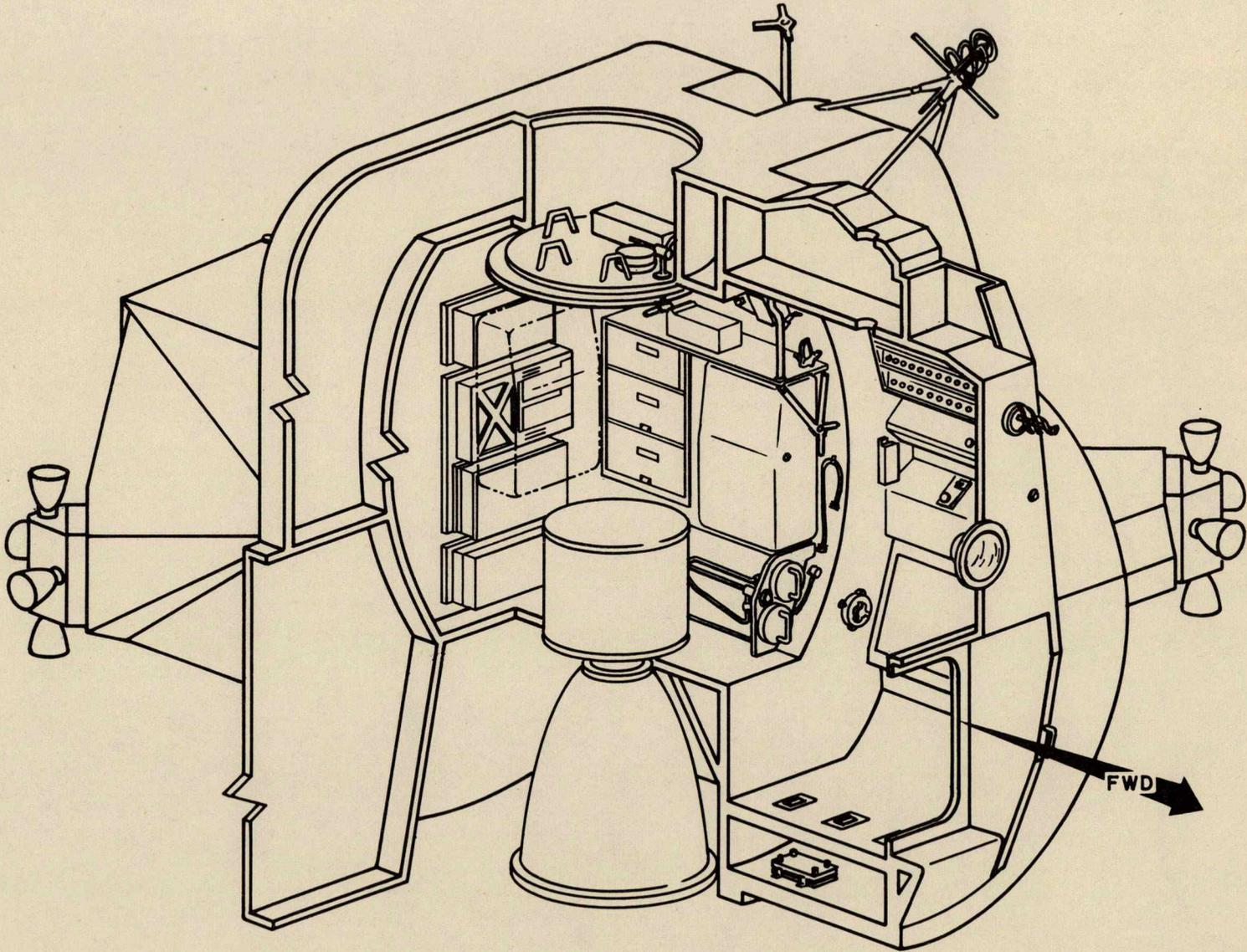
The deck construction is of aluminum honeycomb bonded to two sheets of aluminum alloy. The single construction is secured to the compartment's lower structure. Velcro-hook is bonded to deck's top



T 30005-28  
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Figure 20

28



ASCENT STAGE-LEFT SIDE

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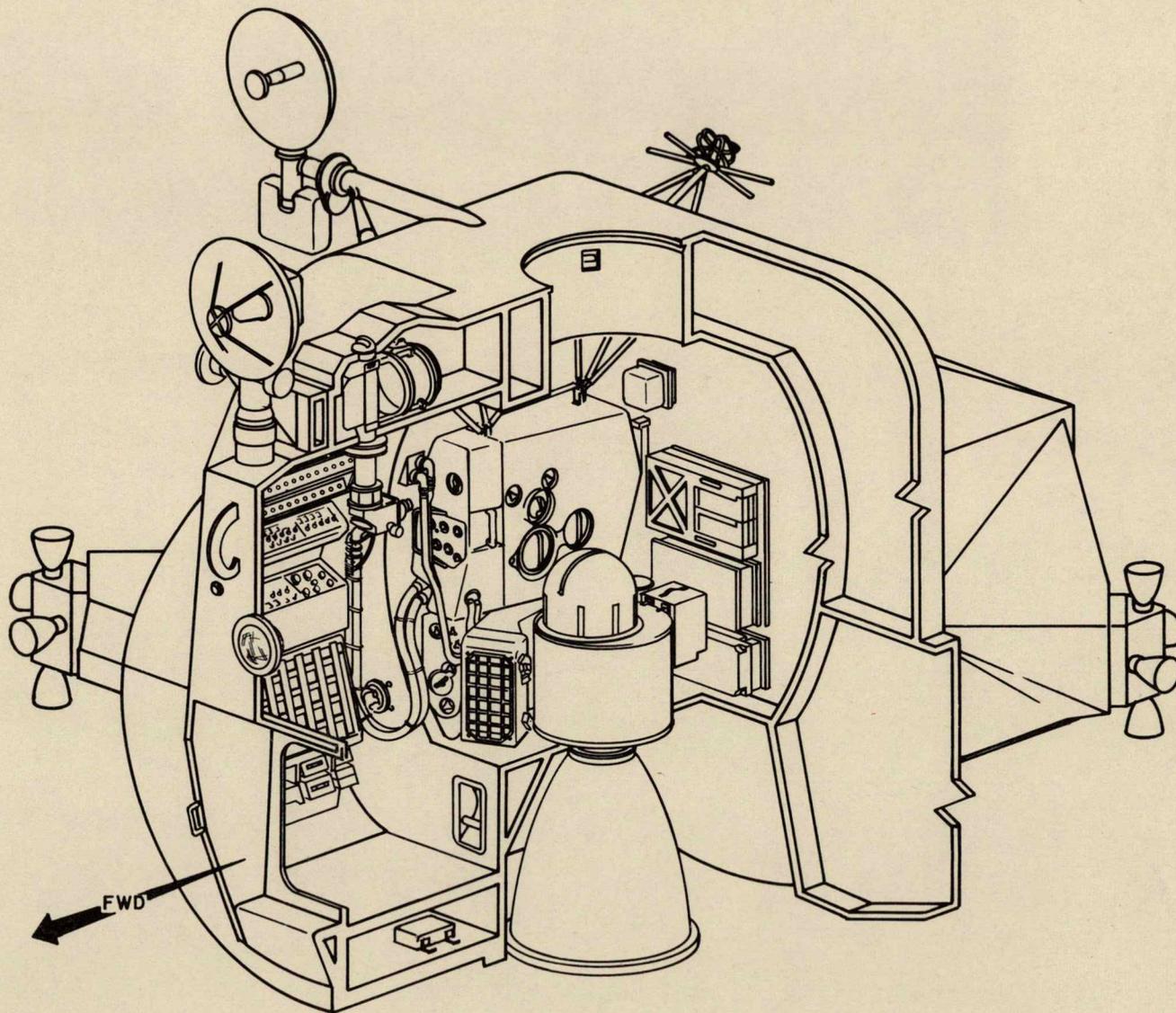


Figure 22

ASCENT STAGE-RIGHT SIDE

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surface, this, in conjunction with the velcro-pile on the soles of the astronaut's boots, provides a restraining force to hold the astronaut to the deck during zero "G" flight phases.

Adequate hand grips are recessed in the deck construction, to aid the astronauts, during egress and ingress maneuvers through the forward hatch.

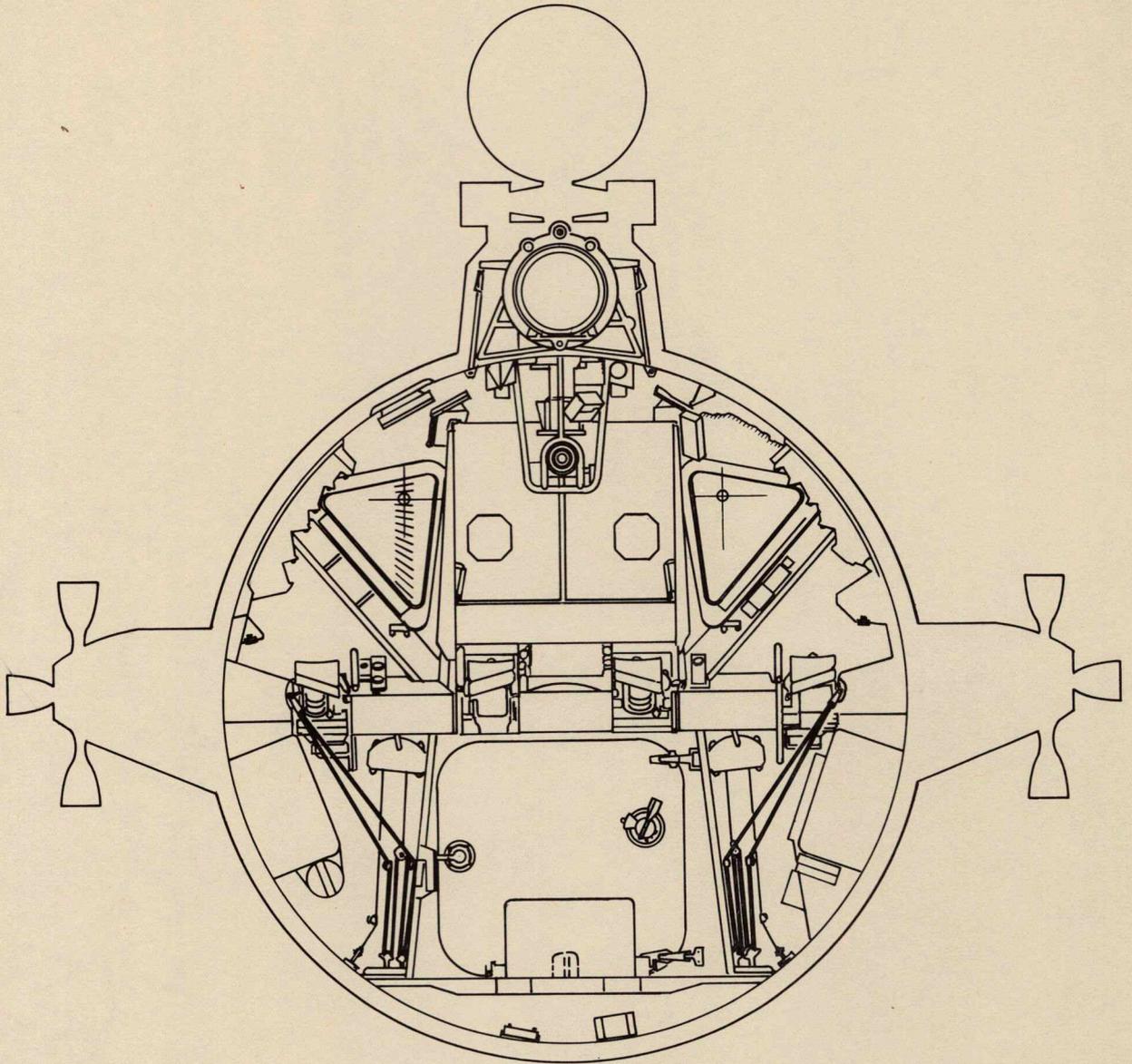
#### INGRESS/EGRESS HATCH

The forward hatch (Ingress/Egress) is used for transfer of the astronauts and scientific equipment to and from the LM and lunar surface. The hatch is located in the front face assembly just below the lower display panels and controls. Hand grips are provided on the forward side of the front face assembly and also recessed in the crew compartment deck, to aid the ingress and egress of the astronauts. (Figure 23)

The hatch, being approximately 32 inches square, is hinged to swing inboard when opened. A simple cam latch assembly is used to hold the hatch in the closed position; this forces a lip about the outer circumference of the hatch to enter a preloaded elastomeric silicone compound seal secured to the hatch frame. Cabin pressurization forces the hatch lip further into the seal ensuring a pressure tight contact. (Figure 24). A fixed handle is provided on the outside of the hatch for latch operation while the torque wrench (NAA Part V16-601145-11) is required to operate the latch from within the LM.

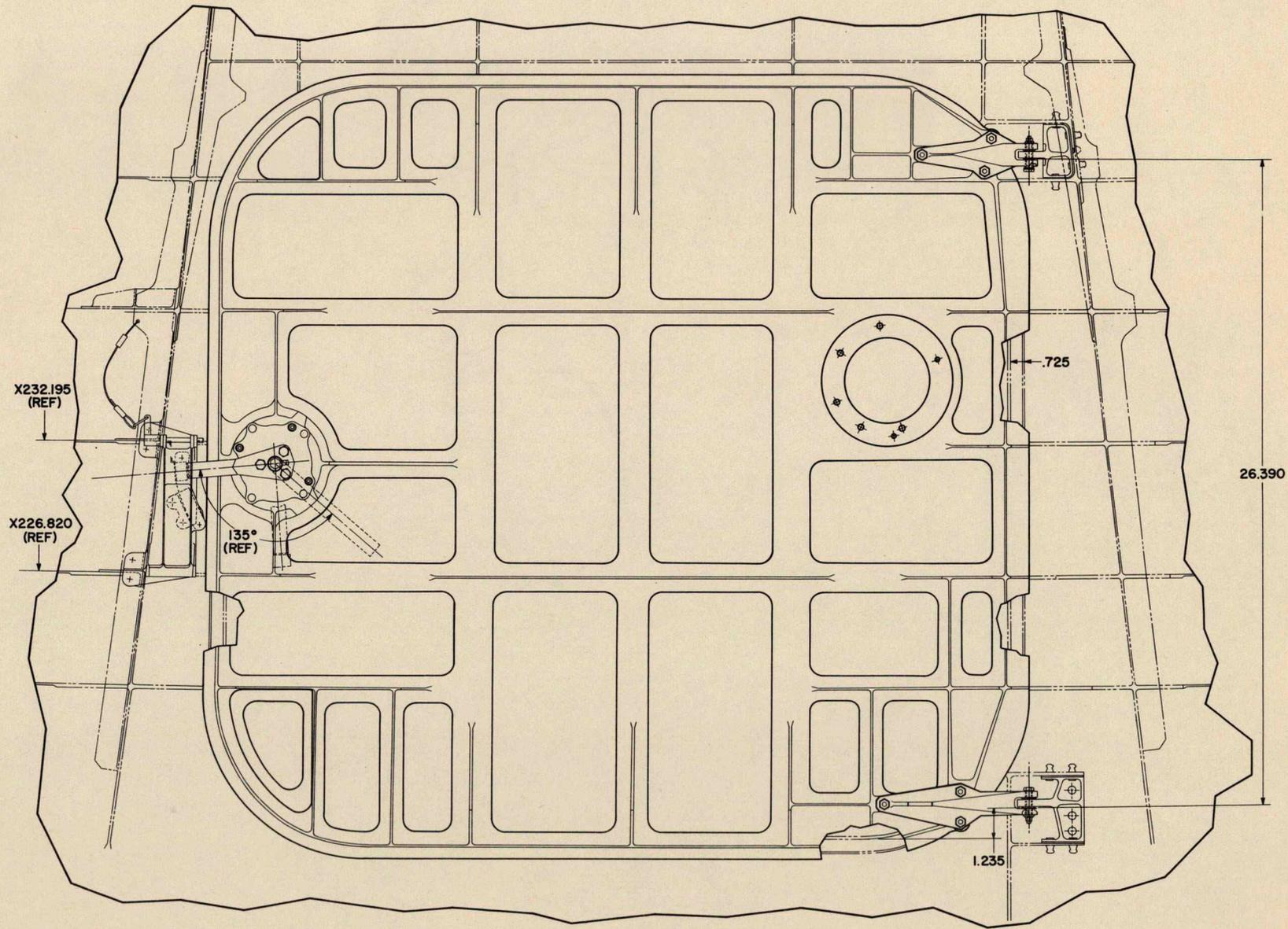
To open the hatch, it is necessary to depressurize the cabin completely. This is accomplished by opening the combination pressurization dump/relief valve within the hatch structure. A handle on the valve will open it, dumping cabin pressure and automatically shutting off cabin pressurization and turning on suit pressure. When cabin pressure reaches zero, the hatch can be opened by inserting the torque wrench and rotating the latch. The hatch can then be swung inboard. A dump valve handle is also installed on the outside of the hatch as well as the latch handle. Depressurization of the cabin and opening of the hatch can be accomplished by an astronaut, from the outside if it becomes necessary to do so.

It should be noted; in the event the torque wrench is mislaid and the hatch must be opened it can be accomplished utilizing an emergency procedure. First depressurize the cabin using the normal procedure. With pressure at zero; pull the ball-lock pin free of the latch assembly, using the cable as a puller. When free swing the latch plate assembly down, this will free the latch roller allowing the hatch



**CREW COMPARTMENT  
(LOOKING FORWARD)**

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INGRESS/EGRESS HATCH

33

Figure 24

to be opened. To close the hatch reverse the procedure being sure the ball-lock pin is properly inserted holding the latch plate in place.

## WINDOWS

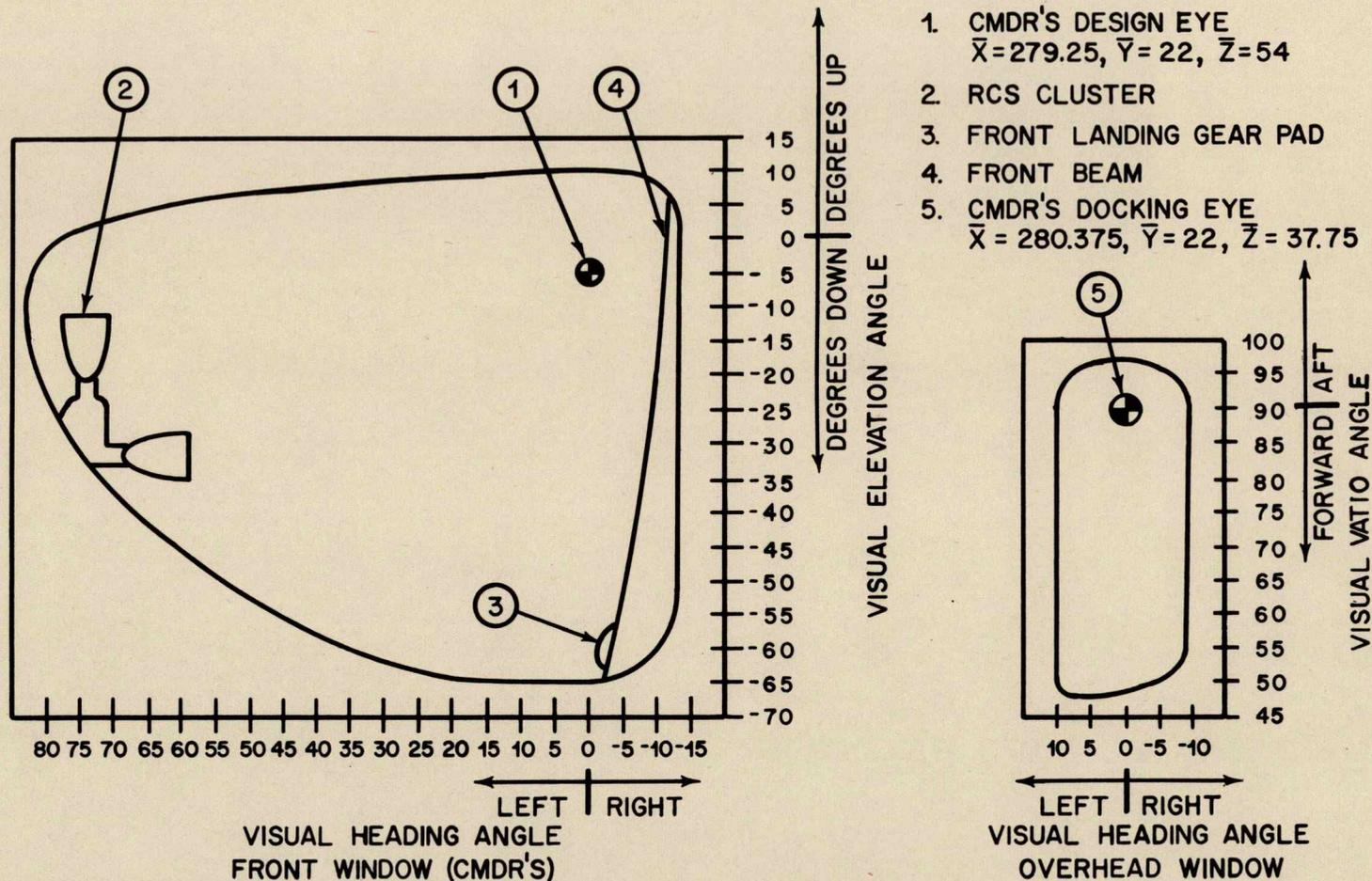
Two triangular cabin windows in the front face assembly of the forward cabin section (crew compartment), provide visibility during lunar descent, lunar landing, and the rendezvous and docking phases of the mission. (Figure 23 shows location) Both windows have approximately 2 square feet of viewing area; they are cantered down to the side to permit adequate peripheral and downward visibility. (Figure 25) Each window consists of two separated panes, vented to space environment. The outer pane is made of vycor glass, coated for thermal and radiation protection; a red-blue metallic oxide being applied to the outer surface for this purpose. The inner window pane is made of a structural glass (Chemcor) designed to carry pressure loads imposed on it. The inner pane is sealed with a dual Raco seal and bolted to the structure's window frame, through an edge member bonded to the glass. The outer surface of this window is also coated with the red-blue metallic oxide. In addition, over this coating, a defogging coating is applied for thermal control. The inner surfaces are also coated; a high efficiency anti-glare metallic oxide being applied to these surfaces. (Figure 26)

The third window is in the curved overhead bulkhead of the crew compartment, above the Commander's flight station on the left side, provides visibility for docking maneuvers. The window consists of two panes, being constructed of the same material as those of the forward. The panes are coated in the same manner with the thermal-radiation protection, anti-glare and defogging materials (Figure 27).

### Window Coatings:

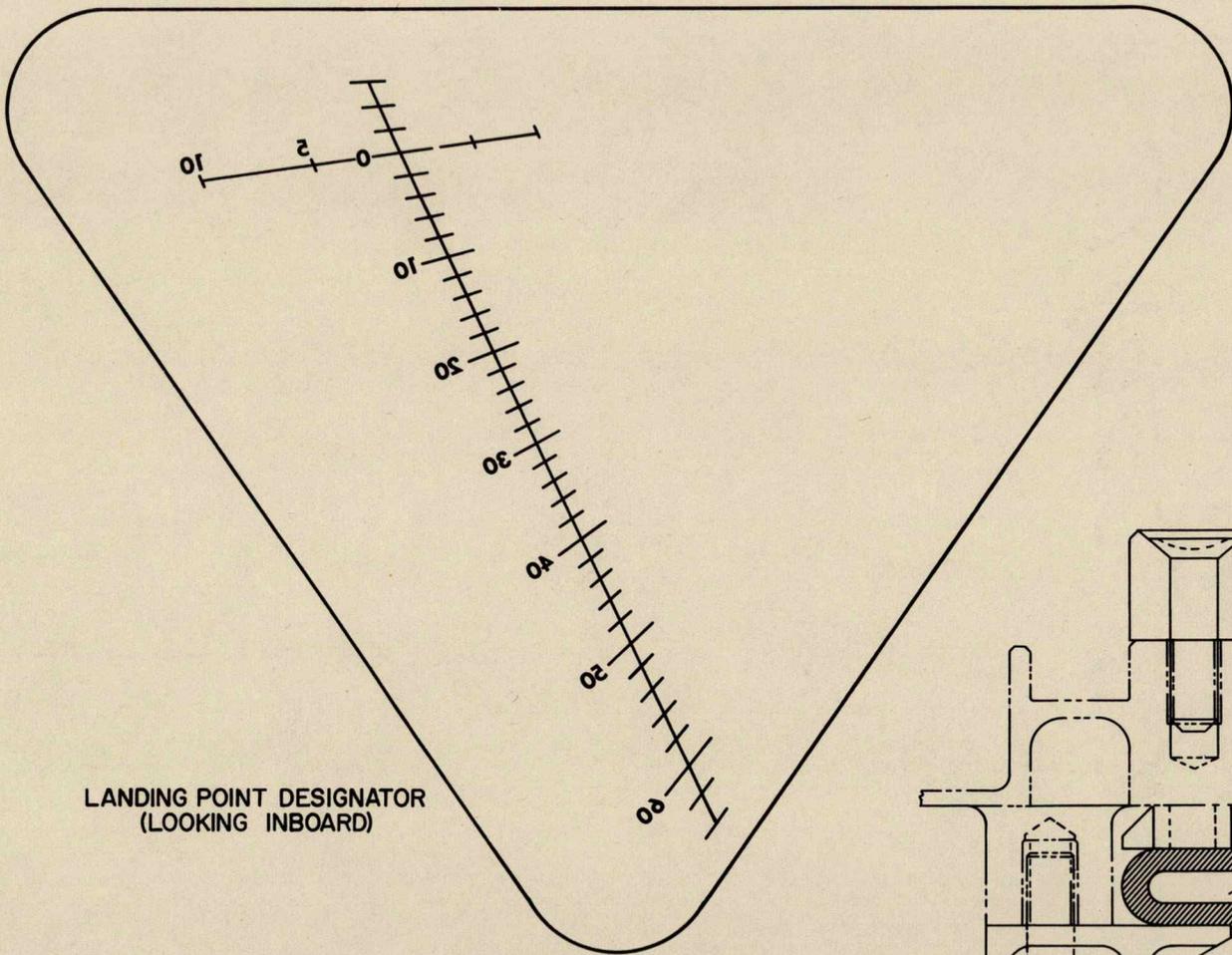
Multi-layer blue-red -- This is a metallic oxide applied to the outer surface of all window panes, by means of vacuum sputtering process at a temperature of 250°C. 36 coats are applied which in turn reduces infra-red and ultra-violet light transmission in wavelengths above and below normal visibility. (Note Wavelength Chart, Figure 28)

High Efficiency Anti-Reflection -- This is also a metallic oxide applied to the inner surface of all window panes utilizing the same process as above. The coatings reduce the mirror effect of the windows as well as increasing their normal transmission efficiency.

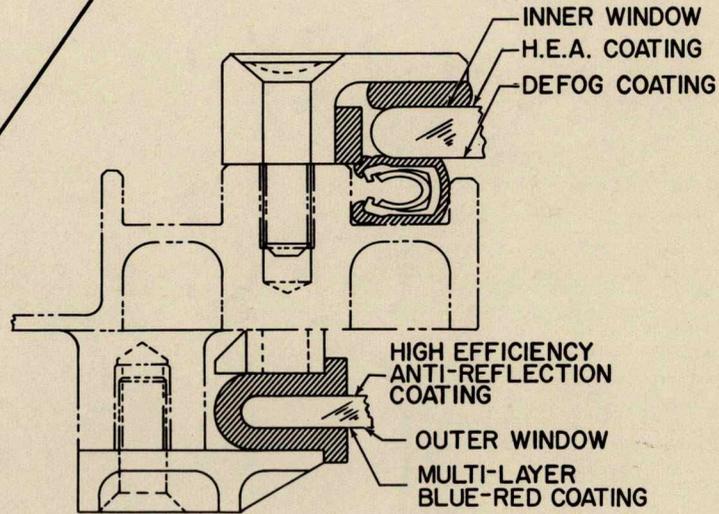


**VISIBILITY DIAGRAM  
FROM COMMANDER'S EYE**

T30915-39  
JAN 67

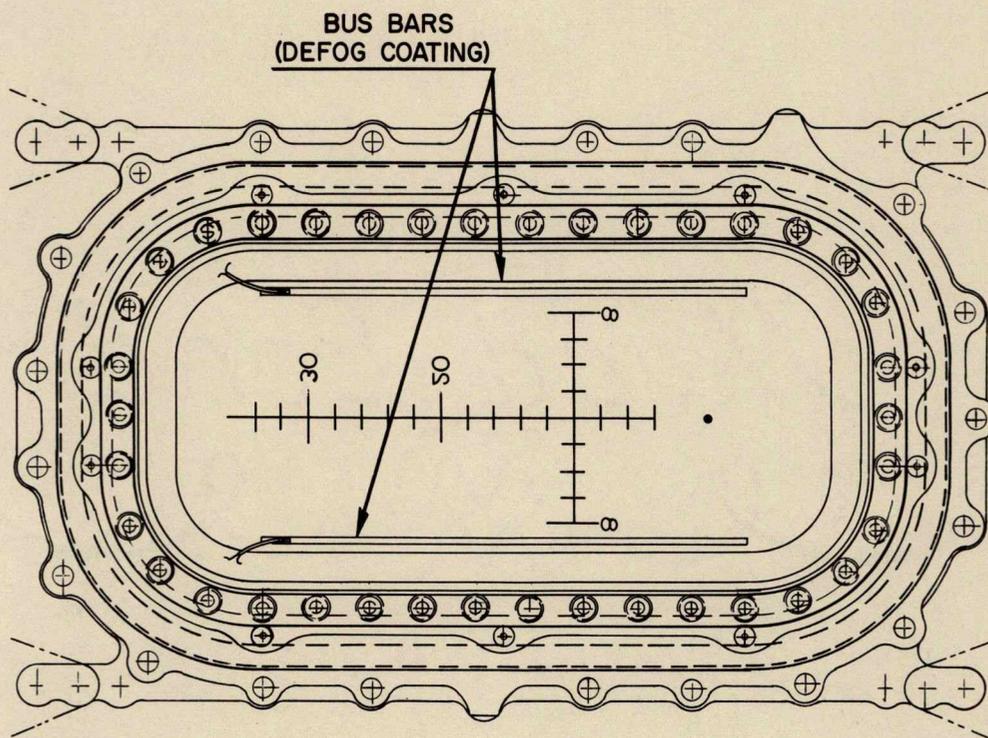
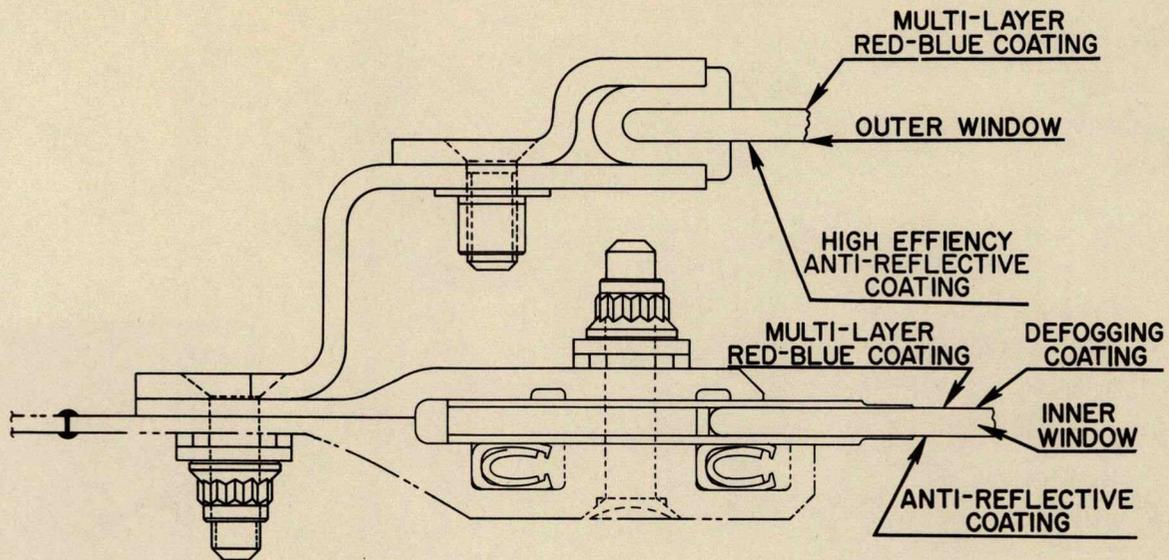


LANDING POINT DESIGNATOR  
(LOOKING INBOARD)



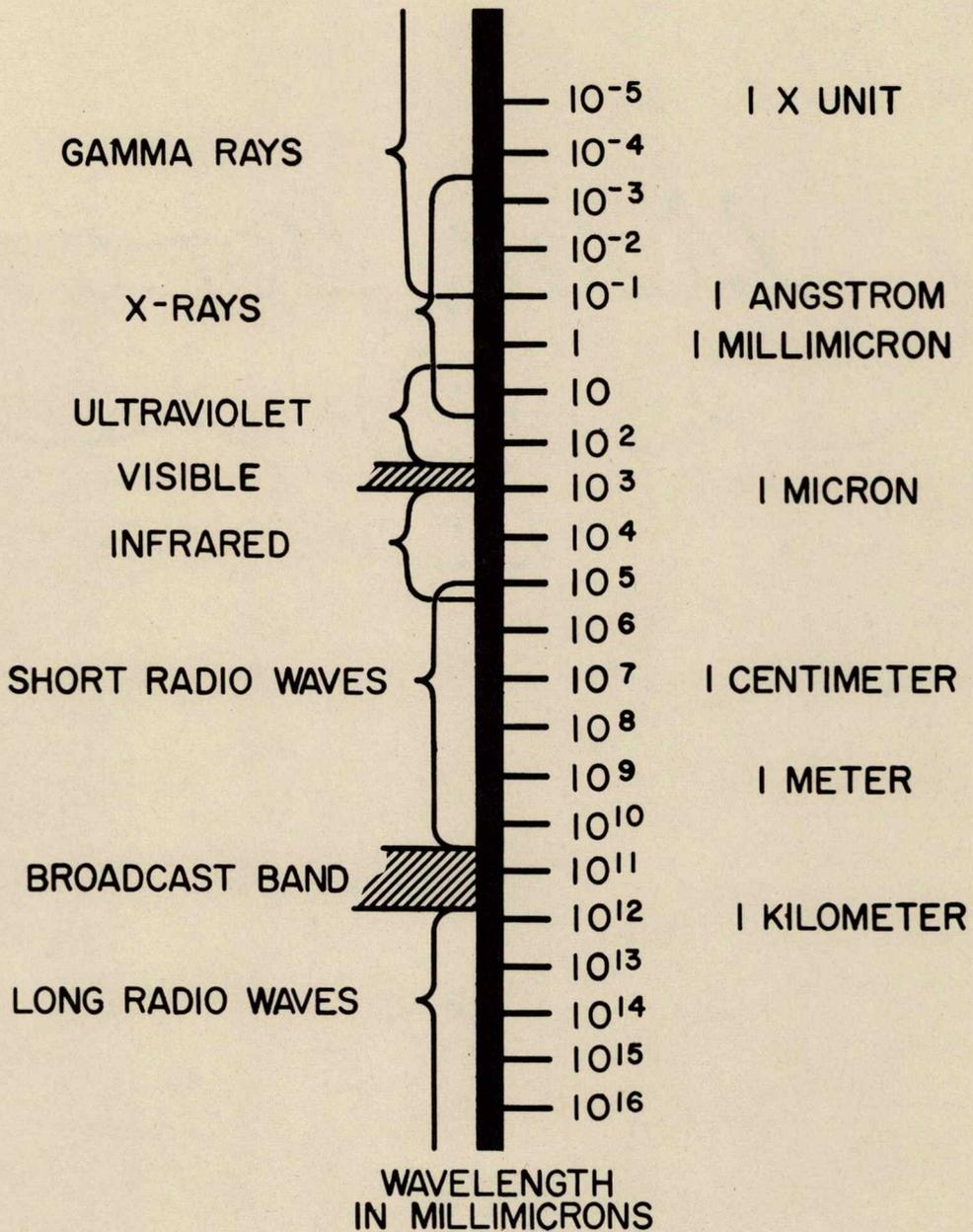
**FRONT FACE WINDOW**

T30915-38  
JAN 67



**DOCKING WINDOW**

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**LIGHT TRANSMISSION  
IN WAVELENGTHS**

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Defogging -- This coating is also a metallic oxide sprayed on the outer surface of the inner windows over the multi-layer red-blue coating. On the front triangular windows the coating is applied in varying densities, as to heat requirements. After spray coating, the oxide is baked onto the panes at a temperature of 450°C when silver buss bars are incorporated to the surface. A 115V ac current is applied to the front window to generate the heating effect while 28V dc is applied to the docking window.

Landing Point Designator and Docking Target -- A Landing Point Designator, as shown in Figure 26, will be applied to the inner surface of the Commander's window, by a silk screen process. A docking target is to be applied to the docking window, in the same manner, as soon as it is developed by engineering.

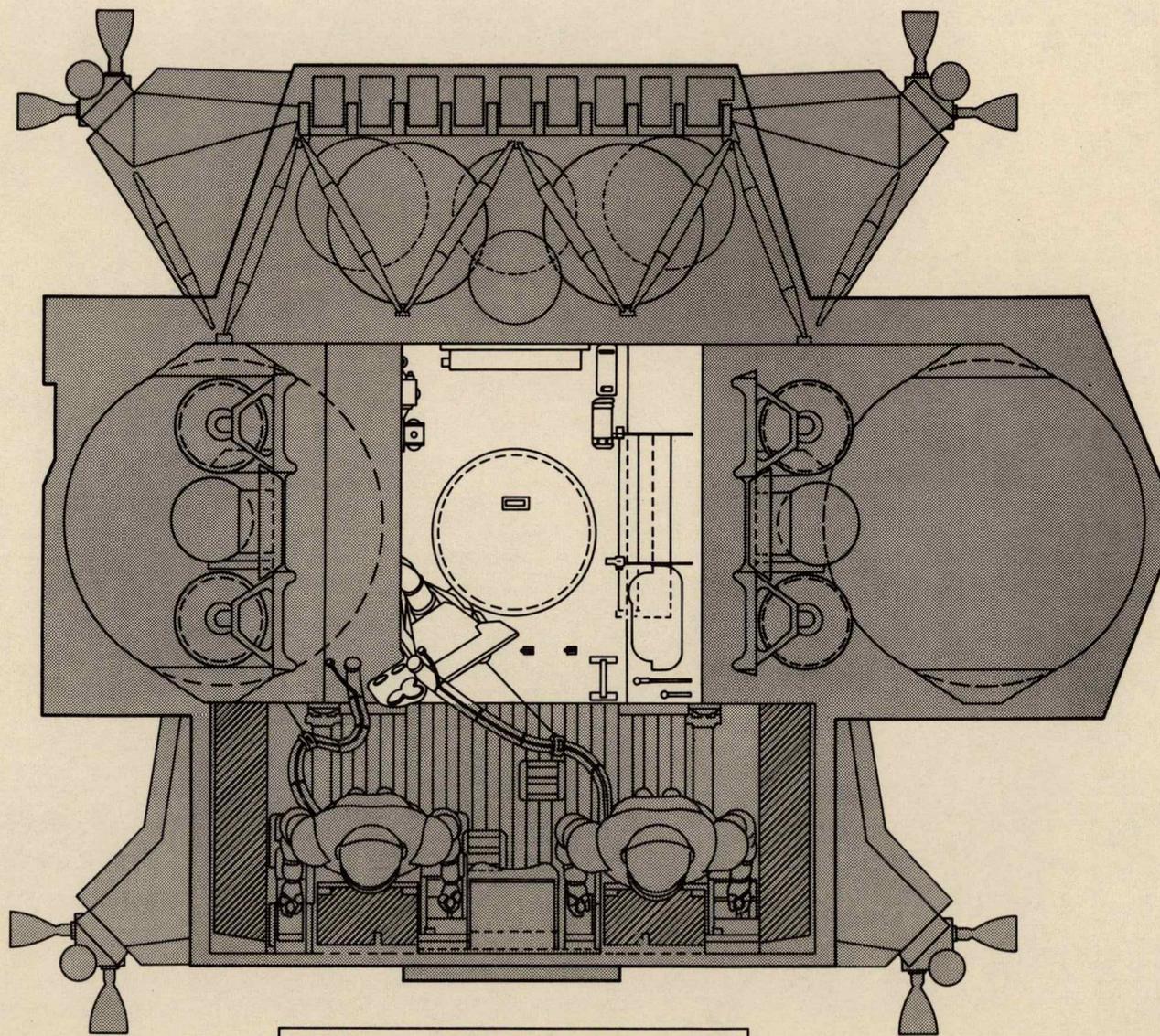
#### MIDSECTION:

The Midsection of the LM (Figures 29 and 30) affords an accessible compartment, just aft of the crew compartment, wherein major subsystem's components and stowage areas are mounted. The lower deck of the compartment is approximately 18 inches above the deck of the crew compartment allowing an overall area of 54 inches deep, 45 inches wide and 60 inches high. The combination of both crew and midsection compartments constitutes the pressurized work area of the LM. The compartment interior is so arranged that easy access can be gained, by the crew, to all equipment and areas within.

The right side of the Midsection (Figure 22) contains the major portions of the ECS controls and a major portion of the heat transport section, water-glycol plumbing. Valves and controls for operation of the ECS equipment are readily accessible from the forward cabin section. The left side of the Midsection (Figure 21) contains PLSS lithium hydroxide recharge canisters and the containers for lunar samples. Approximately 9 cubic feet in the lower side consoles is used for the stowage of crew provisions.

To minimize cable runs, several electronic units that do not require access by the astronauts are located in the Midsection. These include the Guidance and Navigation Computer, Power and Servo Assembly and the PLSS Battery Charger.

The cylindrical ascent engine cover, is secured to the center of the lower deck protruding an additional 18 inches into the compartment area. As well as covering the upper portion of the engine it is

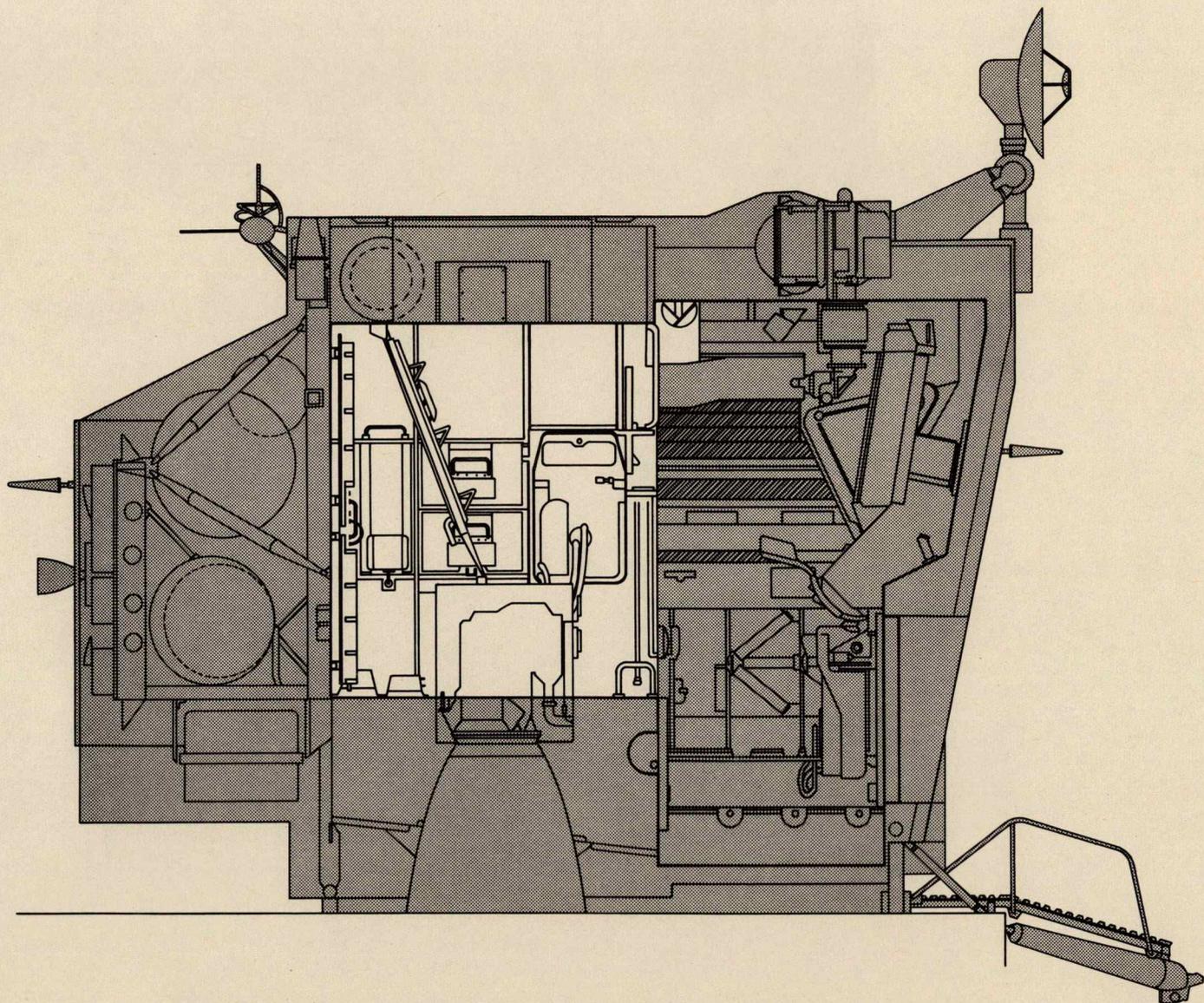


ASCENT STAGE PLAN VIEW  
(MIDSECTION)

T30915-9  
JAN 67

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Figure 29



ASCENT STAGE CUTAWAY-LEFT SIDE

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Figure 30

also utilized as a step for the astronauts, when scanning the lunar surface (Figure 26). A latching assembly is provided, on top of the cover, to secure the docking hatch in the open position at an angle of 70° from horizontal.

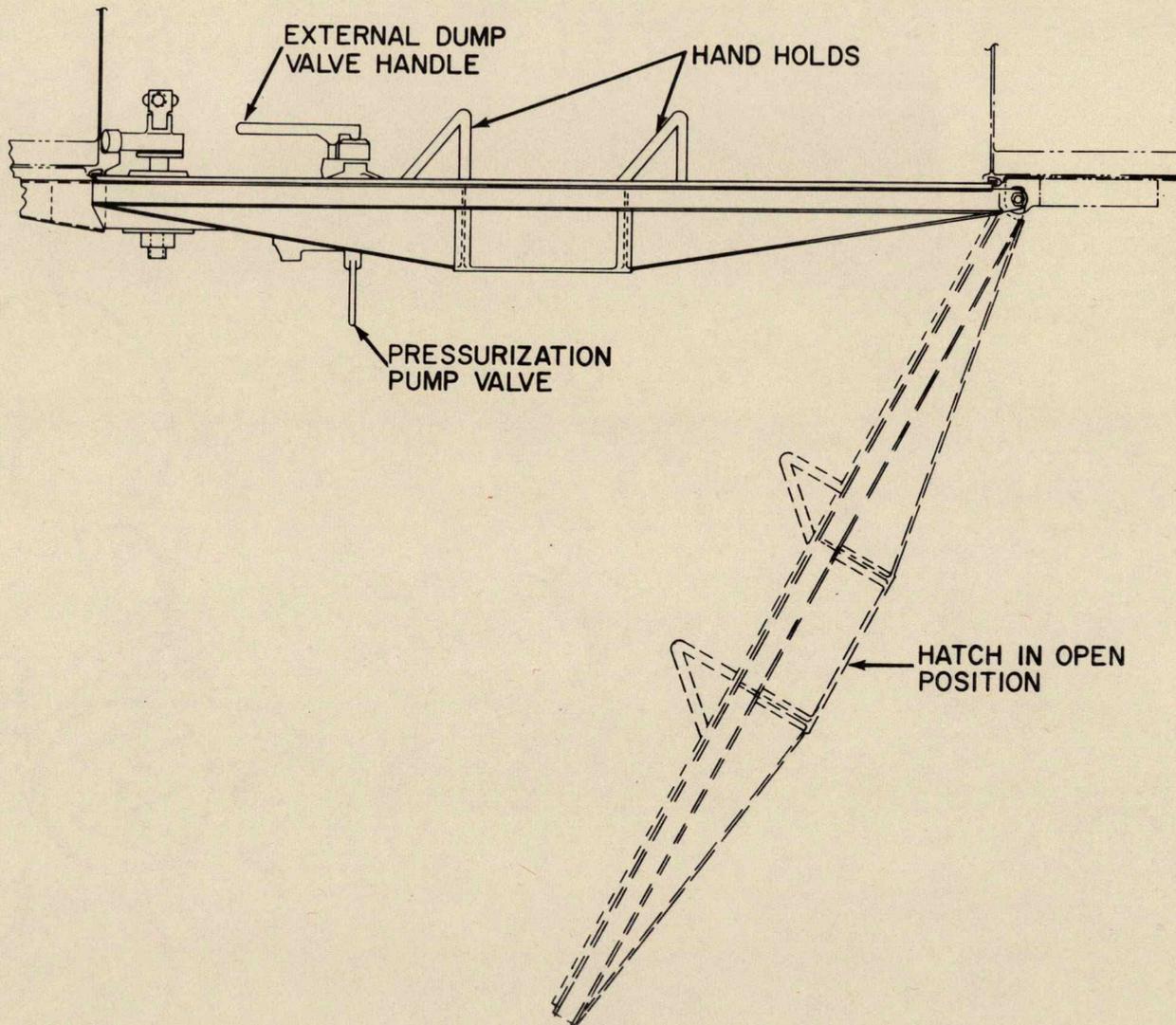
A ring secured to the outer deck of the Midsection structure, is compatible with the clamping mechanism in the CSM; it insures structural continuity for transmitting midcourse correction and lunar orbit injection loads. The ring is concentric with the X-axis, which is also the nominal center-line of the thrust of the ascent and descent engines. The drouge portion of the docking mechanism is secured below this ring during the docking operation to mate with the CSM-mounted probe. It is also stored within the tunnel area when stowage is required, out of the crew compartment. The CSM-LM umbilical cables will also be stowed within the tunnel area.

#### DOCKING TUNNEL AND HATCH

The Midsection Tunnel (the docking and equipment tunnel) at the top centerline of the Midsection, is used for docking after rendezvous in earth orbit, for transfer of the two astronauts to the LM from the CSM and return including the scientific payload. This tunnel is compatible with its counterpart in the CM when in the docked mode; it allows for transfer of an astronaut without exposure to space in either a pressurized or unpressurized extravehicular mobility unit. The length of the tunnel, from hatch to docking ring, is approximately 18 inches.

The upper (docking) hatch is attached to the Midsection upper deck structure on the X-axis, above the ascent engine cover. The hatch is approximately 36 inches in diameter which provides adequate area for crew transfer, based on head first passage. Hand grips, in the aft tunnel section and at top of the hatch are used for aiding in crew and equipment transfer while in the docked configuration. (Figure 31) The hatch is hinged at the aft end allowing it to be opened down and aft. The latch and silicone seal is of the same type as those used on the Ingress/Egress hatch, operating in the same manner. An additional pressure relief/dump valve is also incorporated within the hatch structure and utilized in the same manner as the other.

The hinge assembly of the hatch is constructed slightly different from those of the forward hatch. The fulcrum point of the hinge is slotted allowing the hatch to lift off the seal when in the closed configuration. This function allows the CSM to more readily repressurize the LM at the first docking maneuver. After docking CSM pressure



43

Figure 31

**DOCKING HATCH**

T30915-12  
JAN 67

is used to pressurize the docking tunnel area. At a slight build-up of pressure the hatch will lift off the seal allowing the pressure to flow into the LM. After the LM pressure is equalized to that of the CSM docking procedure is completed and the crew will transfer to the LM. After transfer LM's ECS will be activated and the hatch will function in the normal manner.

When the hatch is opened fully, the forward end of the hatch rests on the ascent engine cover. A locking device, secured to the cover, will hold the hatch in the open position thus allowing it to be held rigid when the crew uses the hand grips.

#### MISCELLANEOUS INFORMATION

Various antennas for radar and communications systems are attached to the outer structure of the Ascent Stage (Figure 1). Those found on the structure are:

Rendezvous Radar Antenna - Attached to a movable mounting secured to the curved bulkhead top side of the crew compartment just above the front face assembly.

Scimitar Antennas (DFI) - One is attached to the front face assembly between the two triangular windows; the second is secured to the aft side of the aft equipment bay.

Two S-Band Antennas - One installed on the front face assembly, the other on the aft side of the Midsection.

S-Band Steerable Antenna - On extended truss members secured to the upper right structure of the Midsection.

Two VHF Antennas - Both antennas are secured to the upper portion of the Midsection structure, left forward and right aft.

EVA Antenna - Secured to the aft side of the Midsection.

Docking Target: A three-dimensional alignment target is recessed into the LM Midsection structure so as not to protrude into the launch configuration clearance envelope or the post-excursion contact maximum envelope. The target has contrasting colors, one of which is radio-luminescent green the other orange. The target, a three-dimensional standoff at approximately  $-Y46.3$  and  $-Z0.203$ , is 17.68 inches in diameter at the base and is constructed to indicate centering of the cross-members within the target circle when viewed at intercept parallel to the  $-X$  axis and perpendicular to the  $Y$  and  $Z$  axis. (Figure 1)

In addition, also to aid in the rendezvous and docking maneuvers, various docking lights are installed on the Ascent Stage structure. (Light similar to those of aircraft navigation lights). The lights being placed as follows:

Port Side	Color Red	on the oxidizer tank area
Starboard Side	Color Green	on the fuel tank area
Underside	Color Yellow	
Forward	Color White	on the front face assembly
Aft	Color White	on top side of aft equipment bay

### DESCENT STAGE

#### GENERAL DESCRIPTION

The Descent Stage is the unmanned portion of the LM. It consists of the equipment necessary for a landing on the lunar surface and also serves as a platform for liftoff of the Ascent Stage after completion of the lunar stay. The structure provides attachment and support points for securing the LM within the S-1B Booster.

The Descent Stage structure is able to withstand its load limits without deformation. Its structural configuration fulfills the requirements of the following functions:

Serves as a support for the LM spacecraft LM Adaptor (SLA)

Provides support for all Descent Stage equipment.

Provides for installation and structural support of lunar scientific equipment and applicable operational transducers, signal conditioners, and lines.

Provides for installation and structural support of the landing gear in retracted and deployed positions.

Provides for installation and support of the descent engine, descent propellant tanks and lines, and helium pressurization section tanks and lines.

Provides for installation and structural support of the ECS water tank and lines.

#### STRUCTURAL CONTEXTURE

The Descent Stage primary structure is constructed of aluminum alloy, chem-milled webs, extruded and milled stiffener and milled capstrips. All joints are fastened with standard mechanical fasteners. The main structure consists of two pairs of parallel beams arranged

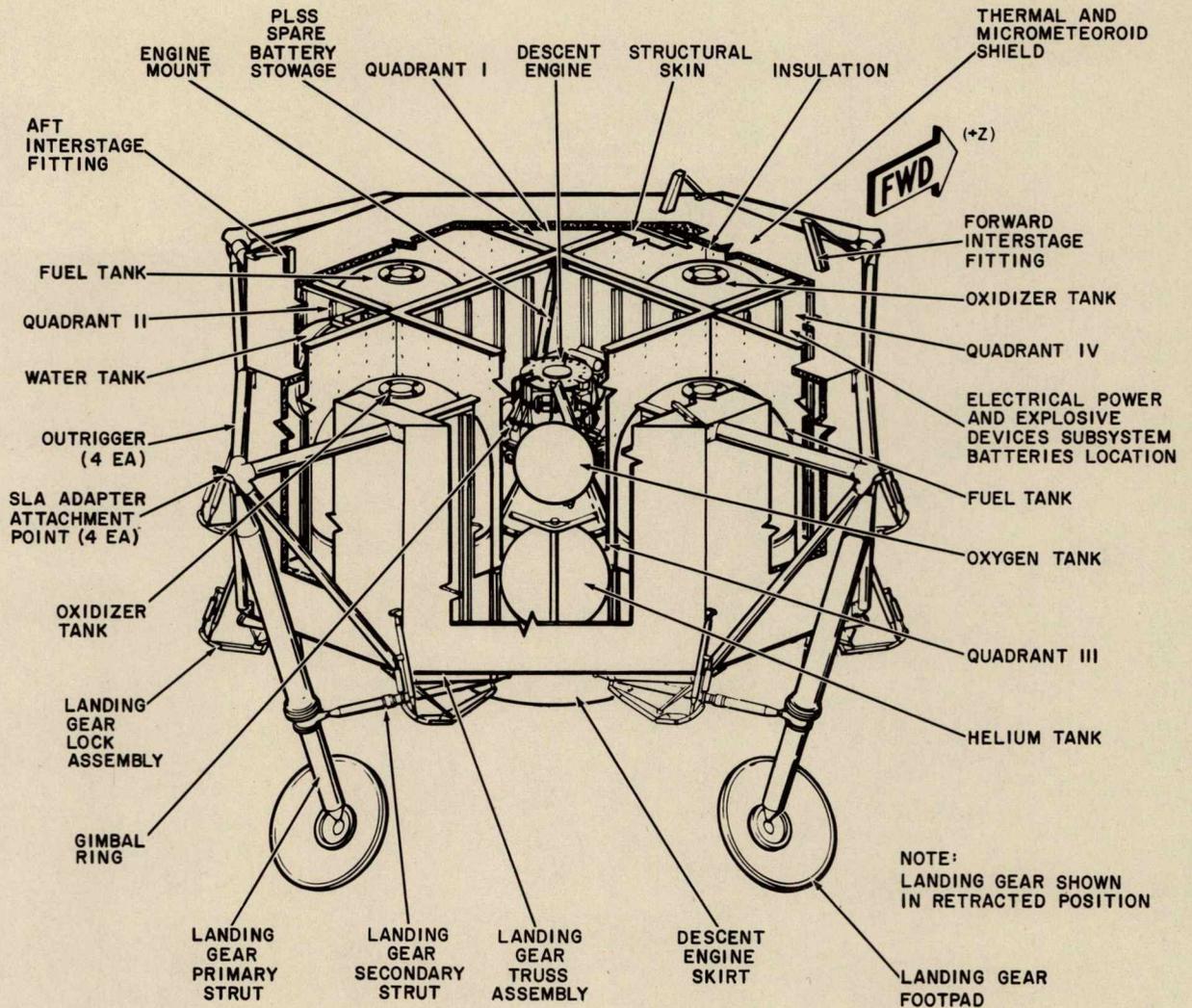
in a cruciform, with a structural upper and lower deck. (Figure 32). The beam webs are at station  $\pm Y27.0$  and station  $\pm Z27.0$ . The lower deck is at  $+X131.14$  and the upper deck, at  $+X196.0$ . The ends of the beams are closed off by end closure bulkheads at  $\pm Z81.0$  and  $\pm Y81.0$ . A four-legged truss assembly (outriggers) are attached at the ends of each pair of beams. These serve as a support for the LM in the SLA and as the attachment point for the main strut of the landing gear. The truss members are constructed of aluminum alloy tubing.

The five compartments formed by the Descent Stage main beam assemblies house the major components of the descent engine. The center compartment houses the descent engine supported by eight tubular truss members secured to the four corners of the compartment and the engine gimbal ring. The two compartments along the  $\pm Y$  beams house the oxidizer tank; the  $\pm Z$  beam compartments house the fuel tank. The tanks are integral with the lower deck and are supported by a collar on the top deck.

The quad areas of the Descent Stage close in the areas between the main beam giving the Stage its octagon shape. These areas utilize a minimal amount of structure as all components housed in these areas are secured to the main beam structure. The structure, within the areas, are used to hold and secure the thermal insulation and outer skin only. The Quad II area is the only area with additional structural support this being utilized to support the scientific equipment required for lunar exploration. All mounts and brackets, supporting the components within the Quad areas, are constructed of fabricated aluminum alloy brackets and aluminum alloy tubular truss members. These being secured to the main structural support members.

The entire Descent Stage structure is housed in a thermal shield consisting of 25 layers of aluminized mylar mounted on low-thermal-conductive supports, over which an outer micrometeoroid shield of aluminum alloy is installed. In area subjected to temperatures above  $350^{\circ}\text{F}$ , 25 layers of H-film will be used in addition to the mylar.

The top deck and side panels of the Quad areas are in direct line with the down firing engine, of the RCS thrust clusters. Plume impingement of these areas is inevitable therefore additional insulation is required. A combination of Inconel sheet and mesh plus nickel steel foil is used for this purpose. These are installed in three layers of Inconel mesh alternated with the nickel steel foil. A top layer of Inconel sheet covers the entire area. The full layer is installed along the edge, made by the top deck and side panel, and gradually tapering off in the amount of laminations in the inboard and down directions. This type of insulation will protect the area to temperatures up to  $1000^{\circ}\text{F}$ . This insulation is installed over a combination of 25 layers each of aluminized mylar and H-film.



**LM DESCENT STAGE**

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The bottom of the Descent Stage as well as the engine compartment is subjected to very high temperatures due to radiation from the engine and its plume, therefore a separate base heat shield is installed to protect the area. The base heat shield, protecting the Descent Stage lower deck and engine compartment, is a composite of alternate layers of nickel steel foil, fibrecil and refracil supported by standoffs. A special support ring of columbian, titanium and refracil encircles the engine skirt holding the insulation at an adequate distance from it. Within the engine compartment area an additional protective layer of titanium is added over the basic heat shield.

A specially shaped blast shield of titanium is secured to the upper edge of the engine compartment, creating an upper deck covering the entire engine compartment. The shield is used to deflect ascent engine blast, at lunar launch. The ascent engine being just above and on the same centerline as that of the descent engine, the shield is designed to deflect the blast outward.

#### SUBSYSTEM SUPPORTS: (QUAD AREAS)

Compartments formed by the Descent Stage structural arrangement houses equipment required by the subsystems (Figure 29). The descent engine propellant oxidizer tanks are installed in the compartments formed by the  $\pm Z$  beams; the compartments formed by the  $\pm Y$  beams house the fuel tanks.

The  $+Z$ ,  $-Y$  Quadrant (Quad I) is used to house the erectable S-band antenna and the PLSS batteries. The canister holding the S-band antenna is secured to a bracket mounted on the  $+Z$  beam. The canister is accessible to the astronaut, while on the lunar surface, by removing an access panel in the outer skin and insulation. The three PLSS batteries are readily removable from brackets mounted on the  $-Y$  beam. Access also gained by a removable panel in the outer skin and insulation.

The  $-Y$ ,  $-Z$  Quadrant (Quad II) will house the ECS water tank, which is secured to both the Y and Z beams by tubular truss members. The lower portion of the area having added structural members forming a storage compartment. This compartment being utilized for storage of the scientific equipment required during lunar stay. The equipment being accessible to the astronaut by a removable hatch cover. The landing radar antenna is supported on additional structure externally, below the area's lower deck. Supporting electronic components, for the radar, are mounted within the compartment area on the  $-Z$  beam.

The -Z, +Y Quadrant (Quad III) houses the supercritical helium and the ambient helium tanks of the descent engine system as well as some of the controls. A gaseous oxygen tank, for the ECS, is also mounted within the area. Tubular truss members are used to mount the supercritical helium tank to both Z and Y beams. The truss member securing the ambient helium tank is supported on the +Y beam and those of the Gox tank to the -Z beam. Brackets mounted on the -Z beam are used to secure the descent engine controls.

The +Y, +Z Quadrant (Quad IV) has brackets mounted to the +Y beam supporting the EPS and ED batteries. A mount for the interstage hard line disconnects and the umbilical cable cutter are also mounted on the +Y beam. A mounting bracket for the S-band antenna cable is secured to the +Z beam, the cable being accessible by removing an access cover in the outer skin and insulation.

All the fill, drain and vents for the fuel, oxidizer, helium, water, and GOX are mounted externally about the Descent Stage structure. Electrical connections for prelaunch testing are also mounted externally. These are all clearly marked and identified by decals at their locations.

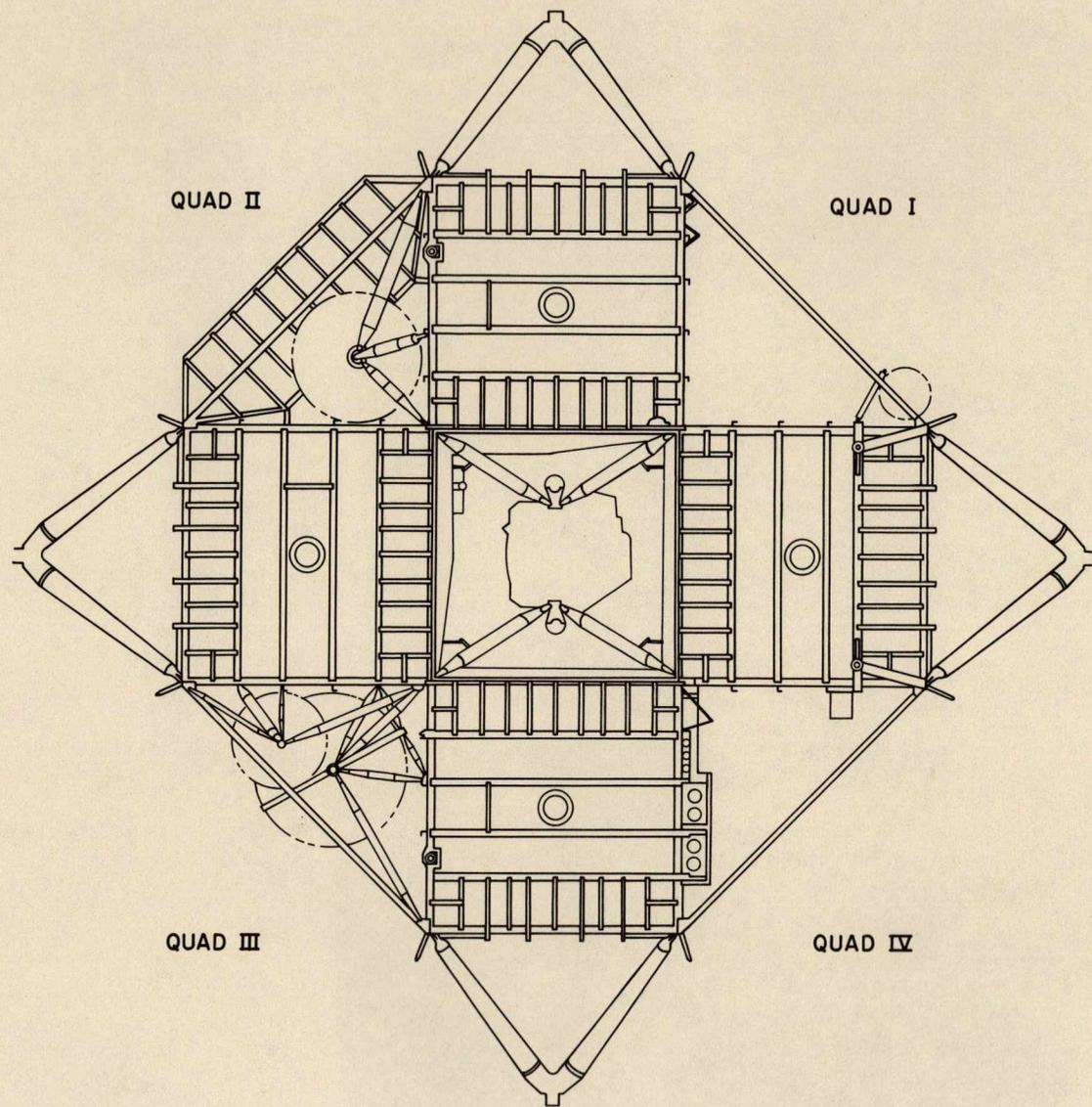
#### OUTRIGGERS

The outriggers are tubular truss members which support the four landing gear assemblies. They are secured to the outboard side of the end bulkheads of the cruciform structure (Figure 33). Their mounting points being integral with the upper and lower ends of the main beam assemblies. This allows the load forces of landing to be transmitted to the main beam structure.

The primary strut of the landing gear assemblies are hinged at the apex of the triangular construction of the tubular truss members. This point also serves as the supporting mount for the LM to the SLA structure, prior to separation.

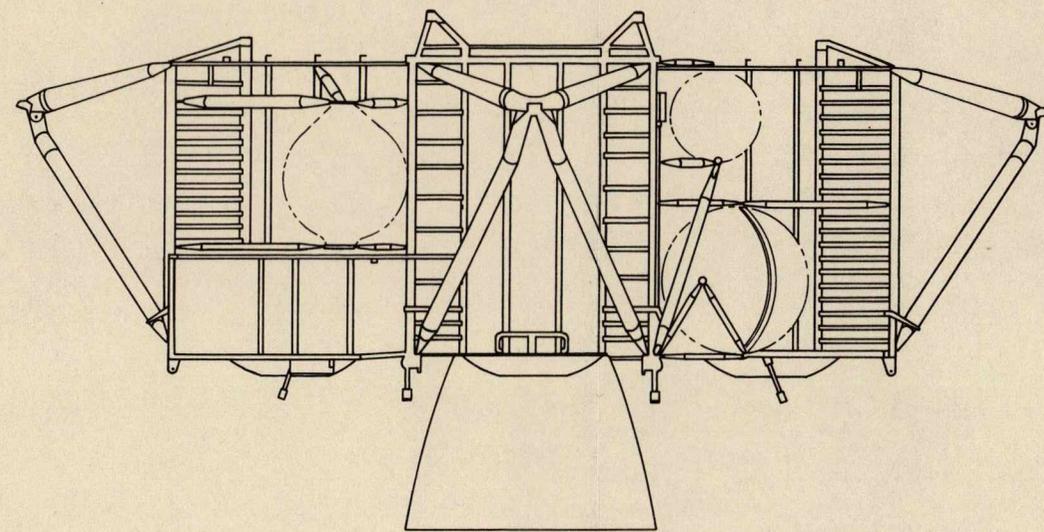
#### LANDING GEAR

The landing gear provides the impact attenuation required to land the LM on the lunar surface, prevent tipover on a  $\pm 5^\circ$  pitch and roll angle and support the LM during lunar stay and Ascent Stage launch. The impact attenuation is accomplished at load levels that preserve the structural integrity of the LM. A boarding ladder with steps and railings is affixed to the forward (+Z) landing gear leg (Figure 1). The ladder extends from a platform below the Ingress/Egress hatch to bottom of the outer cylinder of the primary strut. It is used to climb to and from the Ascent Stage via the Ingress/Egress hatch. At

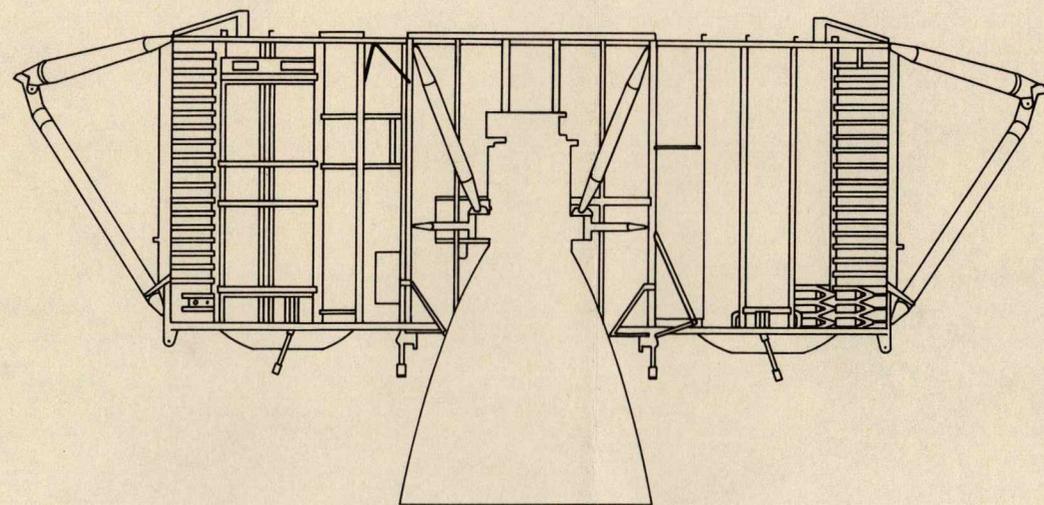


DESCENT STAGE STRUCTURE TOP VIEW

T30915-15  
APR. 66



LOOKING FWD



LOOKING AFT

DESCENT STAGE STRUCTURE SIDE VIEWS

T30915-22  
APR. 66

earth launch, the landing gear is stowed in a retract position; it remains retracted until a time in the mission profile calls for gear deployment by the astronauts. The landing gear uplocks are then explosively released and a spring in each drive-out mechanism extends the landing gear. Once extended, each landing gear is locked in place by the two downlock mechanisms.

The landing gear is of the cantilever type. It consists of four sets of legs connected to the outriggers extending from the ends of the Descent Stage structural beams. The legs extend from the front (+Z), rear (-Z), and both sides (+Y and -Y) of the LM. Each landing gear consists of the following: (Figures 34 and 35)

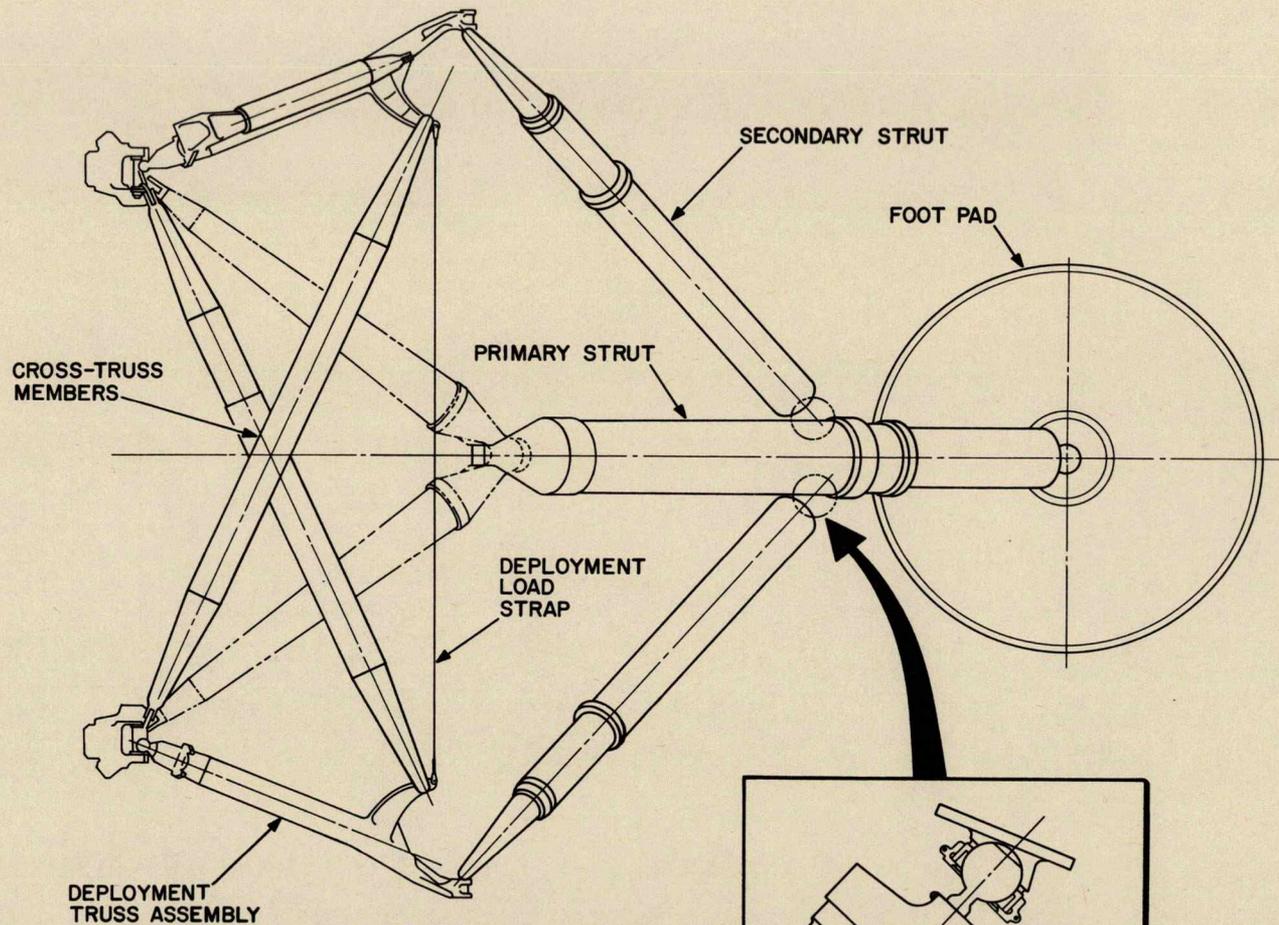
- One Primary Strut
- Two Secondary Struts
- One Foot Pad
- One Uplock Assembly
- Two Deployment Mechanisms
- Two Downlock Assemblies
- One Crosstruss Assembly
- One Lunar Surface Sensing Probe

**Primary Strut:** The Primary Strut consists of a piston-cylinder single strut device, similar to that of an aircraft strut. The strut is designed to absorb compression loads of landing. The Primary Strut upper end attaches to a swivel joint on the outrigger fitting and the lower end provides a ball joint support for the foot pad. (Figure 35)

**Secondary Strut:** Each Secondary Strut consists of a piston-cylinder device, similar to that of the Primary Strut, which is capable of absorbing both compression and tension loads. The outboard end of each strut attaches to the Primary Strut outer cylinder, by means of a ball-socket joint. The inboard end is bolted to a swivel on the deployment truss member.

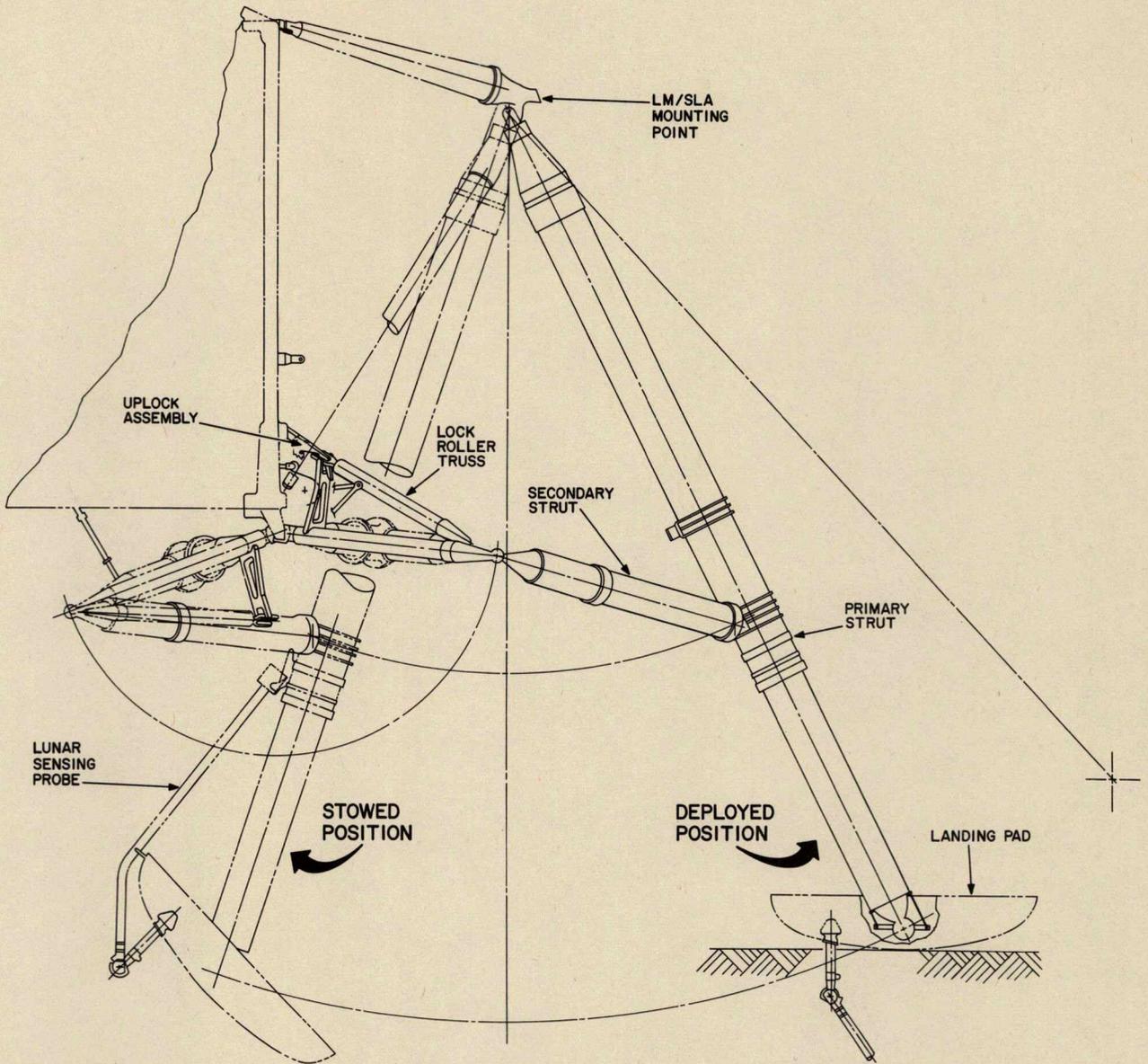
**Shock Absorbing Medium:** All struts, Primary and Secondary, have crushable aluminum honeycomb metal cartridges within to attenuate the landing loads. The aluminum honeycomb has the shock absorbing capability of accepting one LM lunar landing. This may include one or two bounces but once the weight of the LM is on the gear the absorbing medium is used up.

**Foot Pad:** The landing pads are so designed as to provide vehicle floatation on a minimum bearing surface of 12 psi under the maximum landing gear reaction force. Each Foot Pad is pivoted in a ball-socket at the end of the primary strut. The pads are



LM LANDING GEAR  
(TOP VIEW)

T30915-43  
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**LM LANDING GEAR**

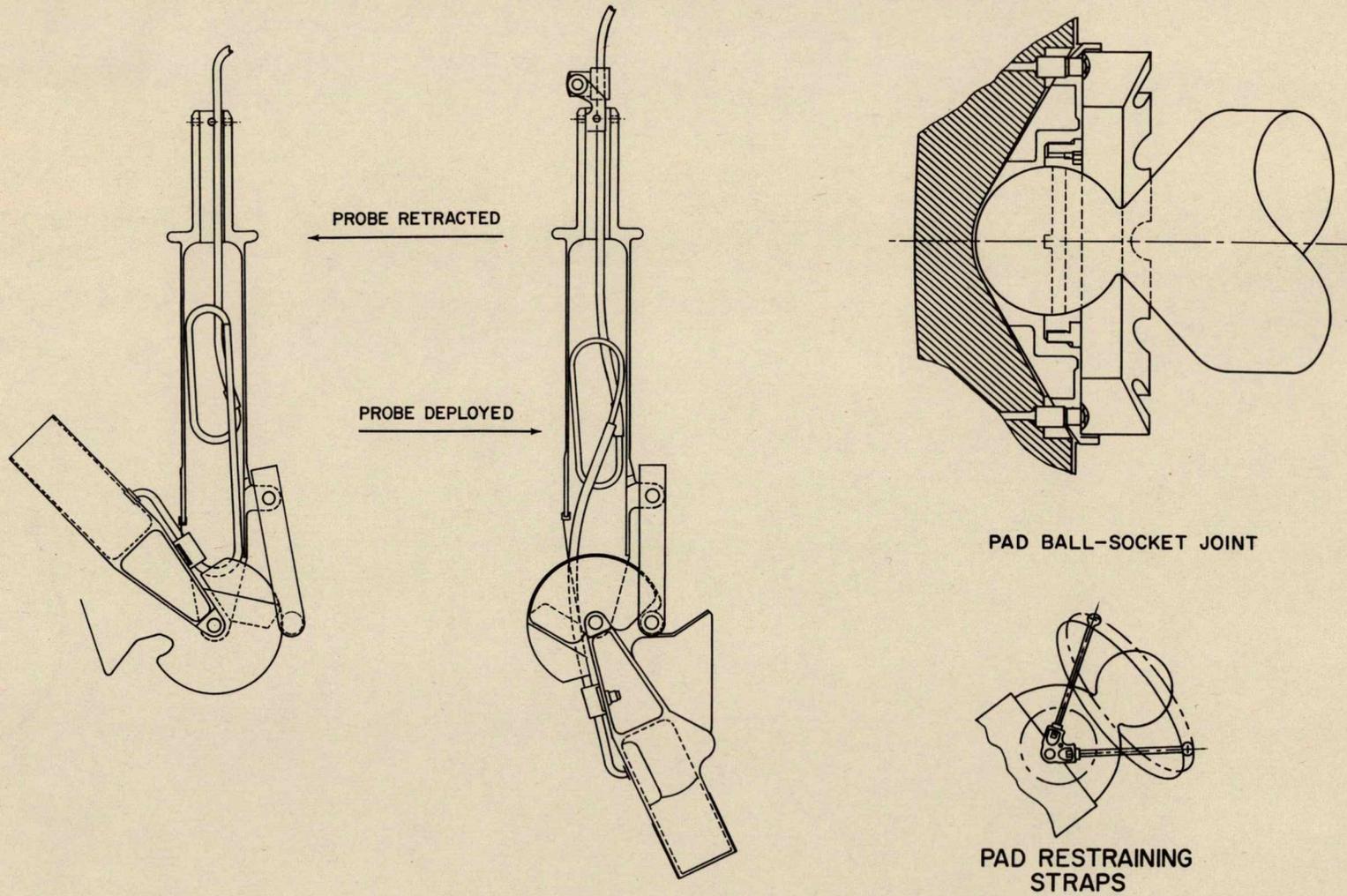
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held in a fixed position, on the strut, by four restraining straps which will bend or shear on contact with the lunar surface allowing the pad to accept the irregularities of the surface. (Figure 36) The pads also contain the crushable honeycomb to give additional shock absorption.

Uplock Mechanism: One uplock device is attached to each landing gear assembly, between the Descent Stage structure and the Primary Strut (Figure 51). The uplock device, which is explosively actuated, is installed with sufficient preload tension to restrain the landing gear in the stowed position under all conditions of shock and vibration. The uplock device is a metal tie rod that restrains the landing gear in its retracted position, deflecting it slightly to achieve a 400 to 600 pound tension on the uplock. A manually operated switch on the explosive device panel activates the initiators on all uplocks, permitting unlocked gear assemblies, to deploy. Two Apollo standard initiators plus two cartridges are installed in each uplock device. Either initiator and cartridge or the combination of the two each, will supply sufficient pressure to drive the blades of the cutter severing the metal uplock strap, permitting the landing gear to extend (deploy).

Deployment Mechanism: The Deployment Mechanism of each landing gear consists of a deployment truss, deployment springs and connecting linkage plus the crosstruss assembly overcenter strap (Figure 34 and 35). As the uplock is severed; the two clock-spring type deployment springs start to roll up (Figures 37 & 38) pulling on the connecting linkage and deployment truss driving the gear from the stowed position to the fully deployed (gear lock down) position. An additional drive out force is exerted through the cross-truss members to the deployment truss by the stored up tension forces built up in the overcenter strap. As the gear deploys the strap tension is relieved by the twisting of the cross-truss members. The combination of the spring forces and the strap can deploy the gear from a standstill to a full gear down and lock position.

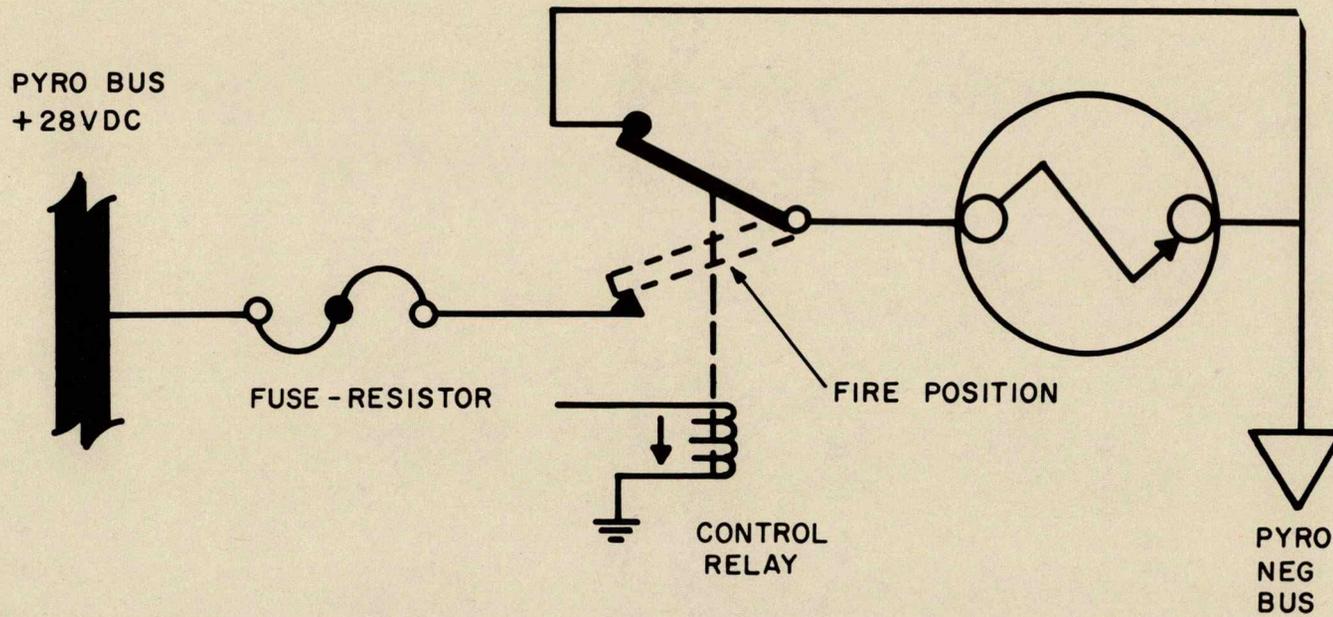
Down Lock Mechanism: The landing gear deployed (gear locked down) mechanism, consists of two spring-loaded locks per landing gear assembly (eight in all). The mechanisms are capable of sustaining balancing loads imposed on the deployment frame during lunar landing (Figures 37 & 38). The landing gear downlocks secure the deployment truss in the deployed configuration. Downlock springs (one for each downlock) retains the downlock in a secured position under all vibration and shock loads.



FOOT PAD AND SENSING PROBE

T30915-45  
MAR 67

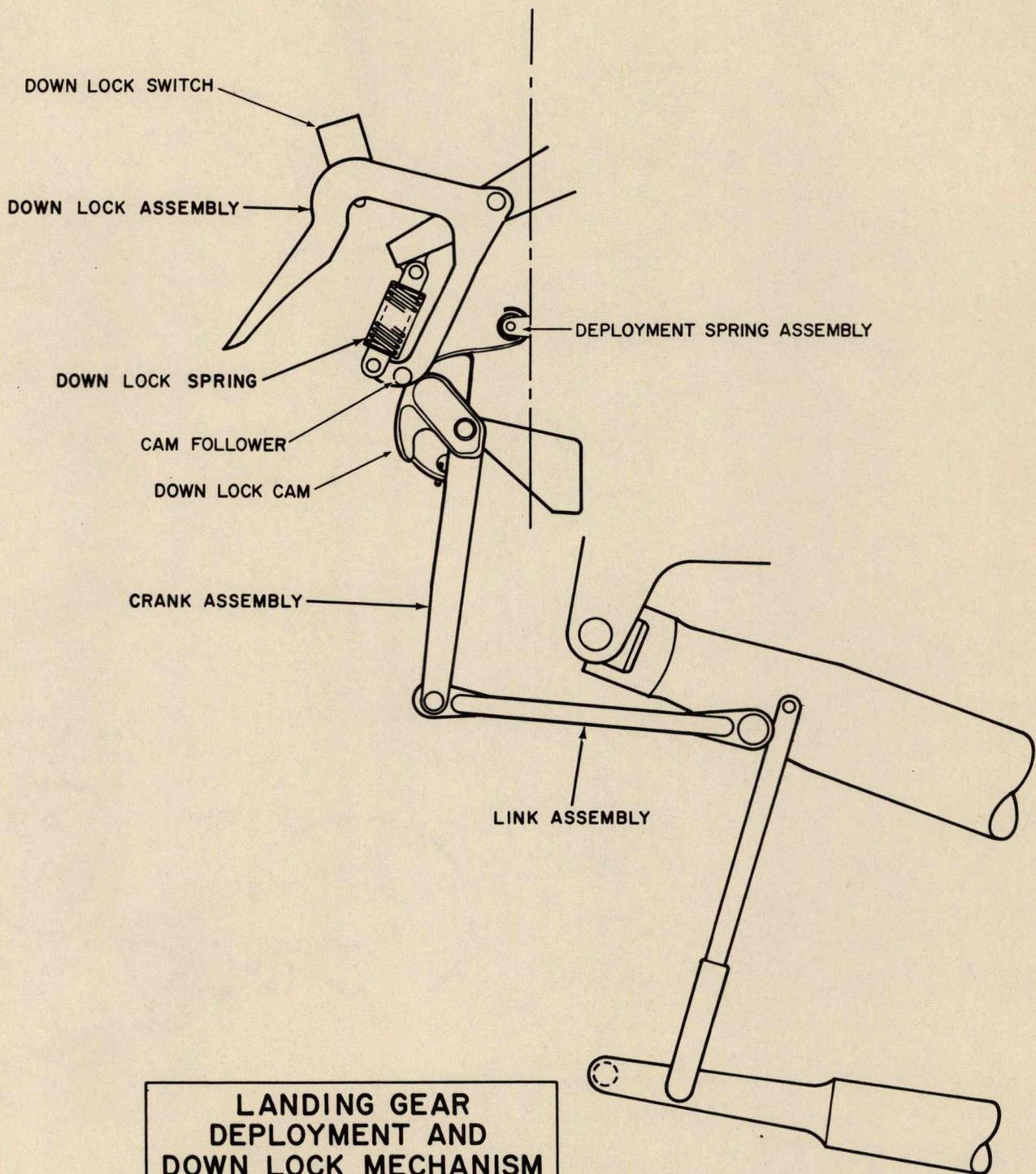
56



INITIATOR GROUND LOOP CIRCUIT

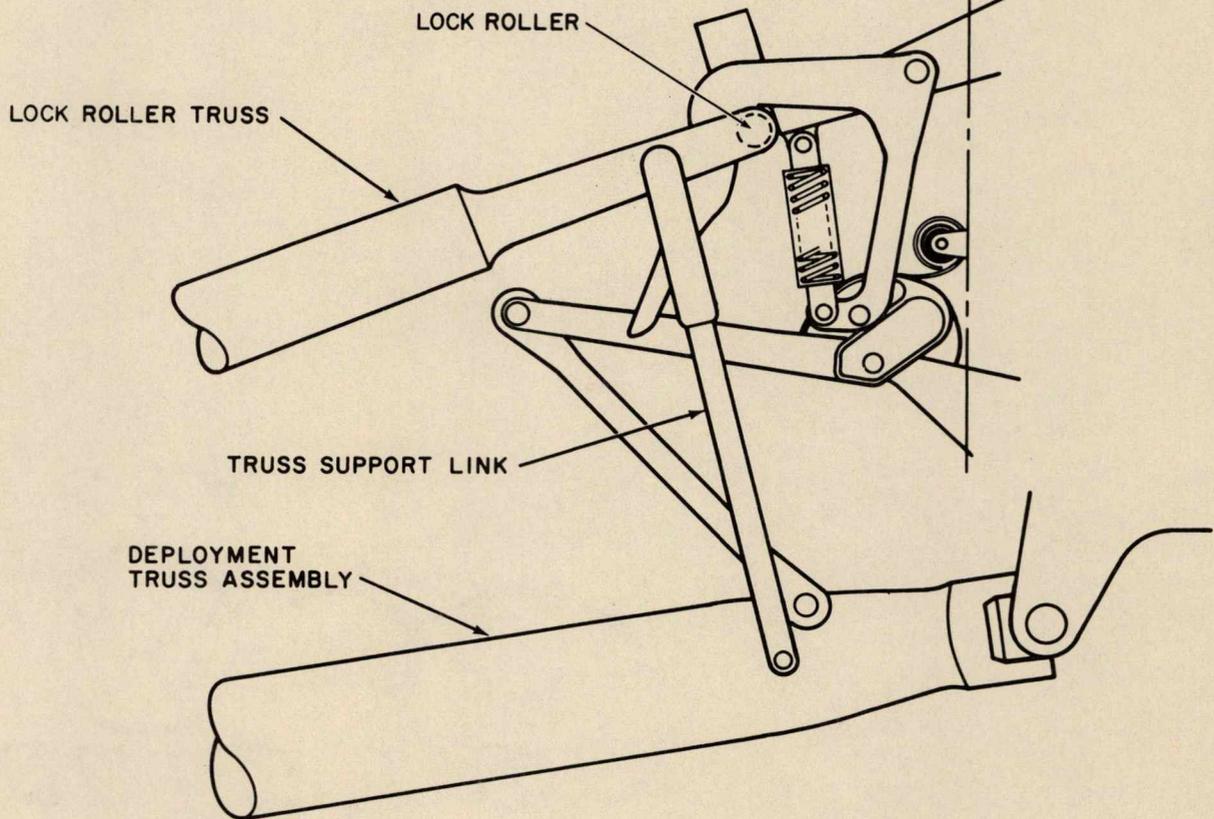
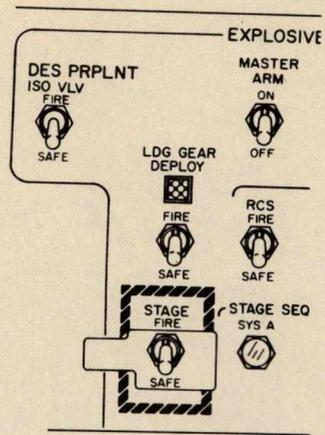
Figure 51

T30915-54  
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**LANDING GEAR  
DEPLOYMENT AND  
DOWN LOCK MECHANISM  
(STOWED POSITION)**

T30915-18  
FEB 67



**LANDING GEAR  
DEPLOYMENT AND  
DOWN LOCK MECHANISM  
(DOWN AND  
LOCKED POSITION)**

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With the gear assembly in the stowed position, the locks are held open by cam on the deployment mechanism and a follower on the lock (Figure 37). On gear deployment, as the gear reaches full deploy position, the latch roller on the deployment truss assembly will strike the fixed stop. Simultaneously, the lock cam rotates and at full deploy the follower will drop off the cam ramp allowing the spring to snap the lock over the latch roller securing it against the stop (Figure 38). The lock assembly being in an over-center locked configuration cannot be opened under any conditions.

Each downlock contains two independent electric switches that are actuated when the downlock is in the landing gear locked down position. The "LDG GEAR DEPLOY" status flag indicator on the explosive device control panel, presents a barberpole indication when the landing gear is in the stowed configuration and the locks (Figure 37) are open. On deployment when all landing gear assemblies have been downlocked and at least one switch on each of the eight downlocks has been actuated, the flag will change from barberpole to gray (Figure 38).

Landing Gear Miscellaneous Information: On a lunar landing the landing gear assemblies have the capability of accepting surface irregularities (protruberances, depressions and surface sinkage) up to 60 cm (approximately 24 inches). An effective slope at touchdown point should not exceed  $12^{\circ}$  being derived from the above. The landing pads can pivot to accept minor irregularities of the surface as well as a minimum bearing of 12 psi. The landing speed envelope, of the gear assemblies, is from 7 feet per second vertical with a maximum 4 feet per second horizontal speed to a maximum 10 feet per second vertical with a zero feet per second horizontal speed.

Heat radiation from the descent engine will be dissipated by the heat reflective paint on the gear assembly, in addition insulating mylar blankets will be installed on areas subjected to high heat radiation. The landing pads will be insulated as well to prevent heat soak-back into the gear from the lunar surface, after landing.

#### LUNAR SURFACE SENSING PROBES

The lunar surface sensing probes are electromechanical devices, one being attached to each landing gear footpad. The probes are retained in the stowed configuration until deployment of the landing gear (Figure 35). During deployment, a mechanical interlock on the primary strut releases, permitting spring energy to extend the self-erecting probe (Figure 36). The probe will then extend vertically, parallel to the X-axis of the LM, approximately 53 inches below the bottom surface of the footpad.

On lunar descent and landing the LM hovers and descends slowly, a probe/probes will touch the lunar surface first. On contact with the surface a striker plate, on the lower end of the probe, will mechanically actuate the sensing switches initiating two signal lights (lunar contact) on the center display panel (Panel III). Any slight downward pressure on one or more of the probes will illuminate the lights, on release of the pressure the lights will extinguish. A constant downward pressure of 9 pounds will close the switches permanently keeping the lights illuminated. When the "LUNAR CONTACT" lights are illuminated, (indicating the LM is approximately 53 inches from the lunar surface) the descent engine is shut down. With time of shut down and engine decay the LM will land on the lunar surface within the landing gear descent speed envelope.

On deployment of the landing gear and release of the probes, extension to a full down position is less than two seconds. After contact with the lunar surface and during the last few feet of LM descent to the surface, the probes are so constructed as to either bend out of the way or shear off. Therefore, damage to the foot pads or other areas, by the probes, is prevented.

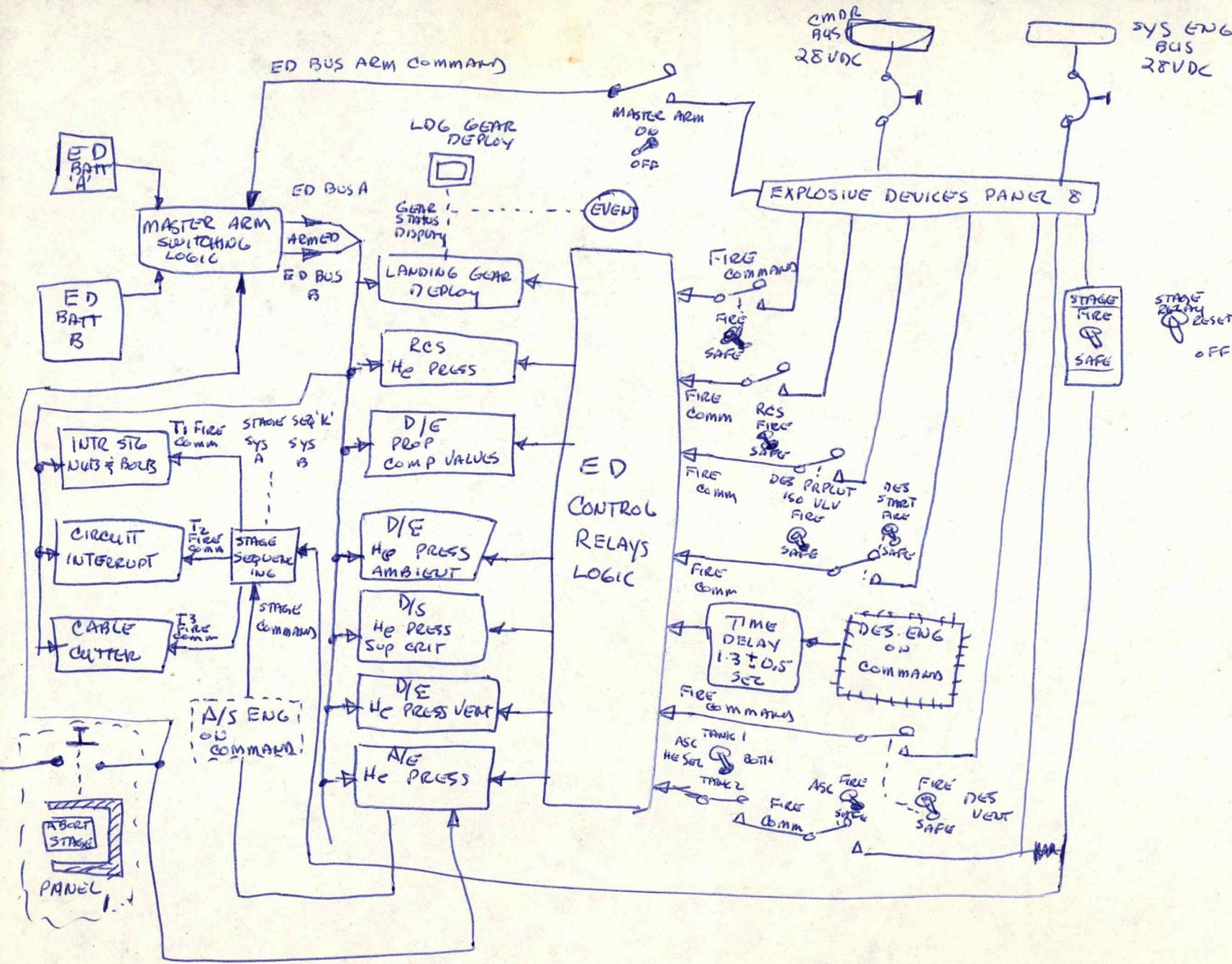
#### LUNAR SURFACE ACCESS AIDS

Access to the lunar surface, by the astronauts, is accomplished by means of a platform and ladder (Figure 1). The platform which is approximately 32 inches by 45 inches is mounted over the forward landing gear outrigger, directly below the Ascent Stage Ingress/Egress hatch. The platform is an aluminum alloy constructed shell filled with lock-foam core, giving it minimum weight yet a very rigid structure. The upper surface is corrugated and so constructed that the corrugations will fit the toes of the astronaut's boots. This plus a Velcro hook covering will prevent slipping while leaving or entering the LM. Hand grips and railing are also provided as an aid. An aluminum alloy ladder, secured to the Primary Strut of the forward landing gear, extends from the forward end of the platform to the end of the Primary Strut outer cylinder. The bottom step of the ladder being approximately 36 inches from a surface prior to the strut compressing due to a landing. An additional collapsible ladder is contemplated as on-board-equipment to aid the astronaut if the distance to the lunar surface is too great due to surface irregularities.

#### INTERSTAGE CONNECTIONS

The Ascent and Descent Stages are secured together (up until separation at lunar launch) by four interstage mounts. These mounts extend from the Ascent Stage lower structure and mate with four additional mounts extending above the Descent Stage upper deck. The

stages are secured together at the mounts by explosive nuts and bolts. The stages will be held together by the bolt until stage separation is required at which time the nuts and bolts are exploded by an electrical circuit allowing both stages to be free of each other. Operation and firing of the interstage nuts and bolts will be covered in the electro-explosive device section.



ED.

## ELECTROEXPLOSIVE DEVICES SUBSYSTEM

### INTRODUCTION

The Explosive Devices Subsystem (ED), also known as the Electro-explosive Devices Subsystem (EED), provides the Astronauts with the capability to operate or enable various LM equipment by simple explosive devices (Apollo Standard Initiators). Some of the functions the Apollo Standard Initiators (commonly called Pyrotechnic Initiators) initiate, are the Landing Gear Deployment; Helium Pressurization of the propellant tank for the RCS engines, Ascent engine and Descent engine; venting of the propellant tanks of the descent engine after landing on the lunar surface; also the functions of Ascent and Descent stage separation.

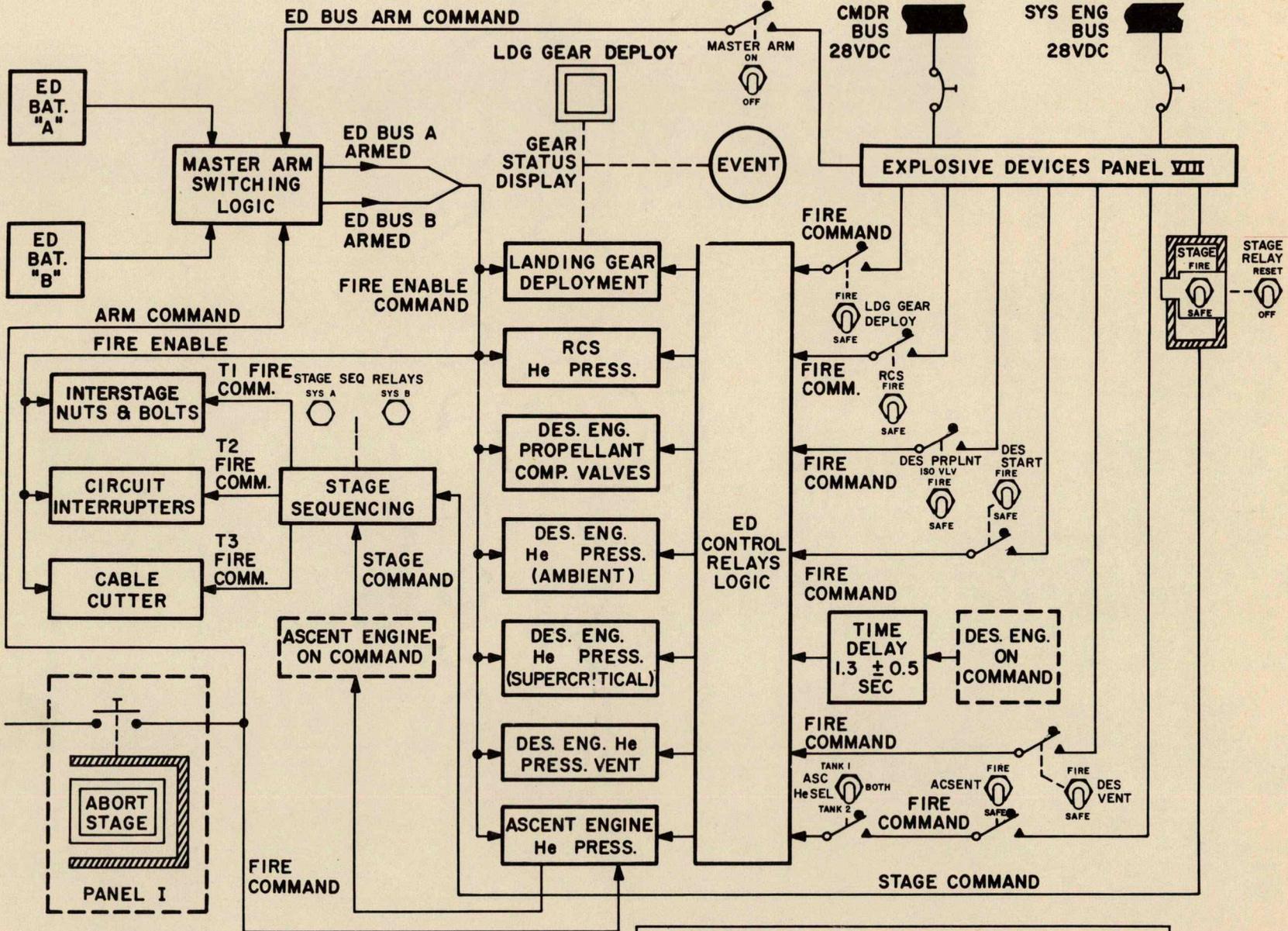
There are two complete and separate circuits for the Explosive Devices Subsystem, system "A" and system "B" (figure 39). Each of the circuits incorporates its own 24-volt DC battery, its own switches, relays, wiring, fuses and initiators. The redundant features, of the two systems, are incorporated throughout to provide safety, protection and positive operation.

Figures 40, 41 and 42 indicate the general locations of all the components comprising the ED subsystem. Electrical power for ED subsystem control components is supplied through circuit breakers, distributed between two circuit breaker panels on the Commander's and System Engineer's upper side consoles. Power for this is taken from both 28 volt DC main buses; the Commander's bus is used to power the control components of ED system "A" while the System Engineer's will power those of system "B". Three ampere circuit breakers are used to protect the circuit.

### FUNCTIONAL DESCRIPTION

The ED subsystem consist of two batteries, an "EXPLOSIVE DEVICES" control panel, two ED relay boxes and the initiators with the devices they initiate. Power to actuate the relays in the relay boxes is drawn from the main power supply (EPS Buses); power for the initiators is supplied by the Explosive Devices Batteries. Each battery supplies power to an identical redundant bus (in the ED relay box) for the initiation of all Explosive Devices on the LM controlled by its respective switches on the "EXPLOSIVE DEVICES" panel 8 (figure 43).

The "MASTER ARM" switch operates two master arm relays, one in system "A" and one in system "B". These relays provide an electrical connection between each battery and its ED bus. Each function switch

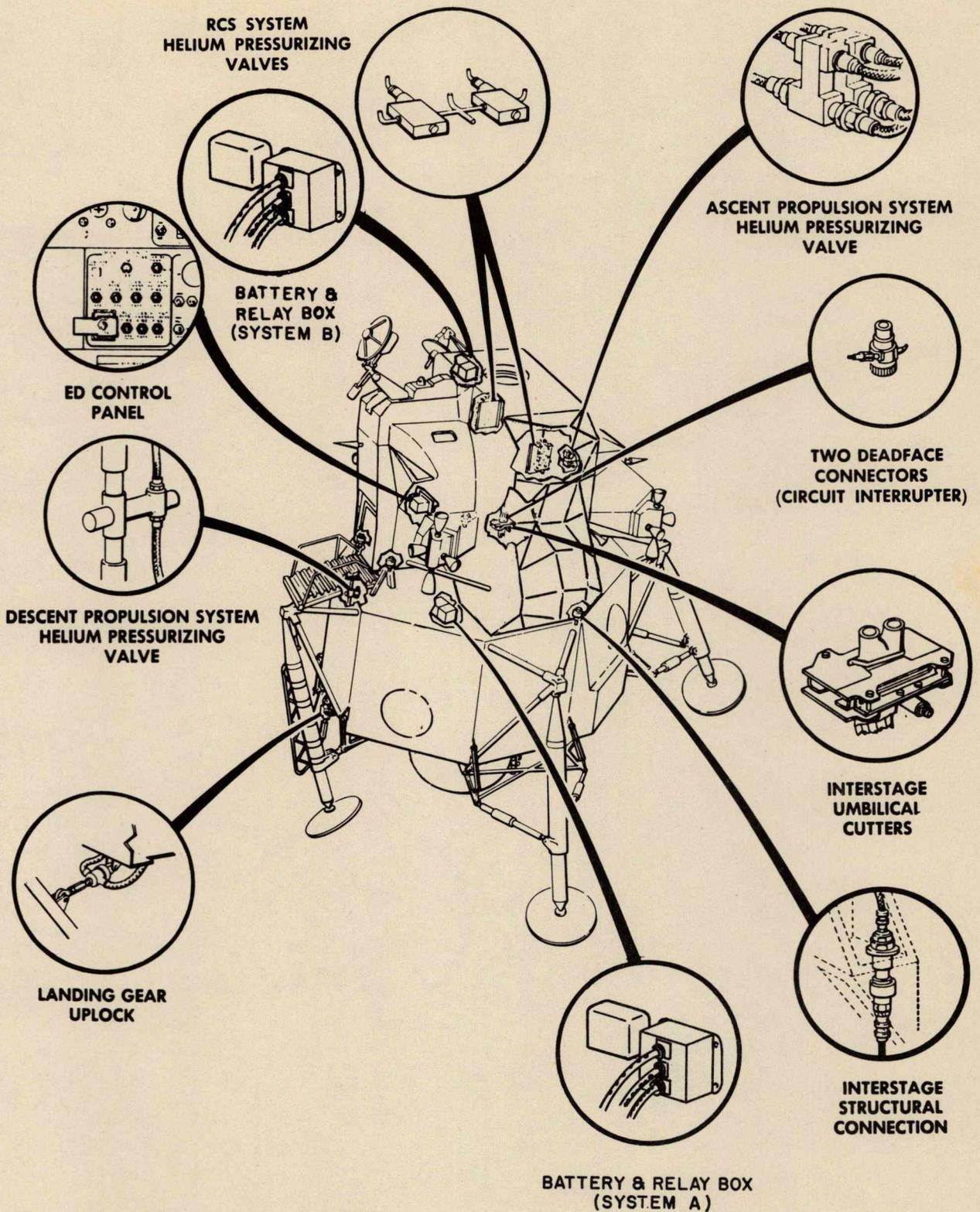


**EXPLOSIVE DEVICES BLOCK DIAGRAM**

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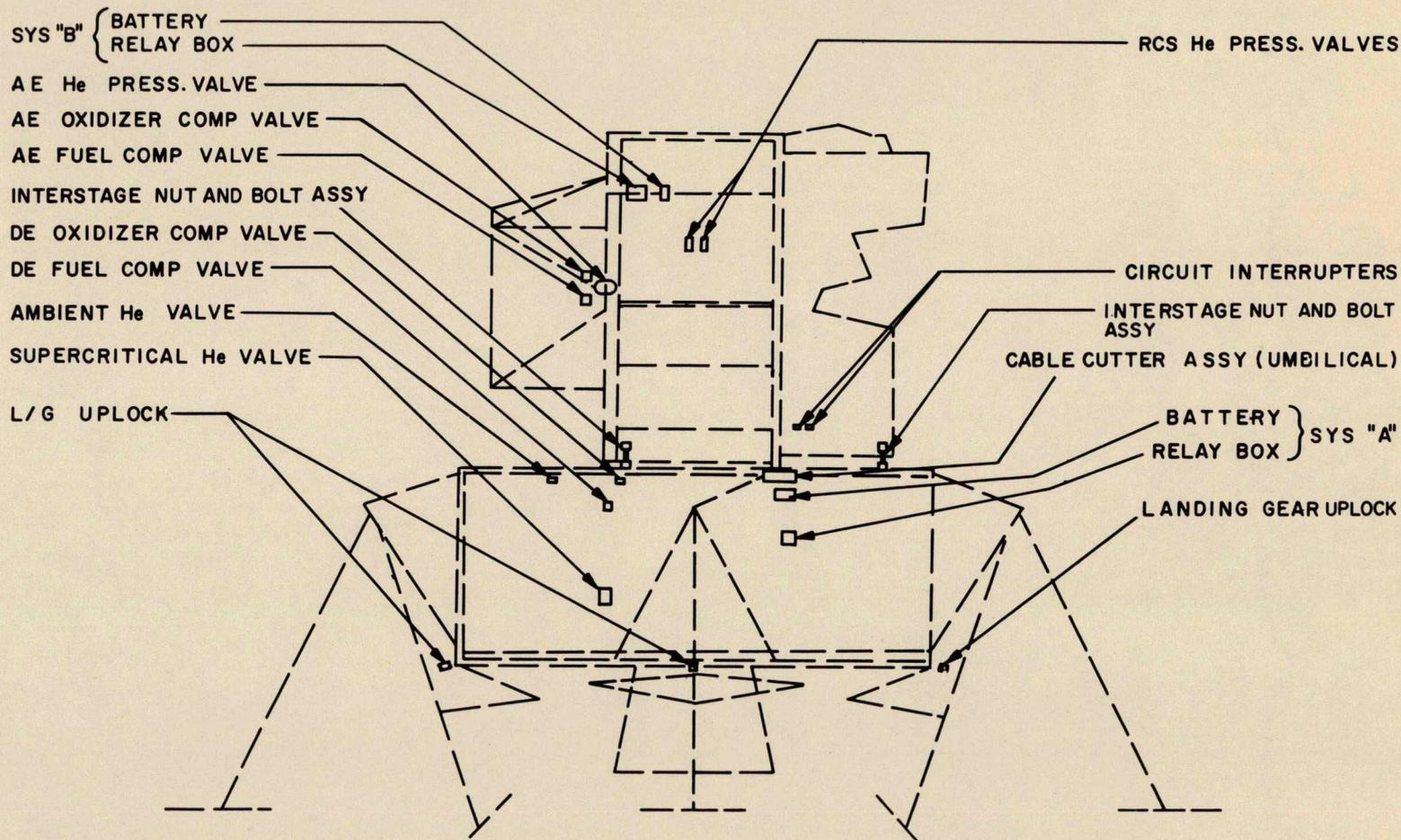
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Figure 39



**EXPLOSIVE DEVICES COMPONENT LOCATIONS**

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MAR 67

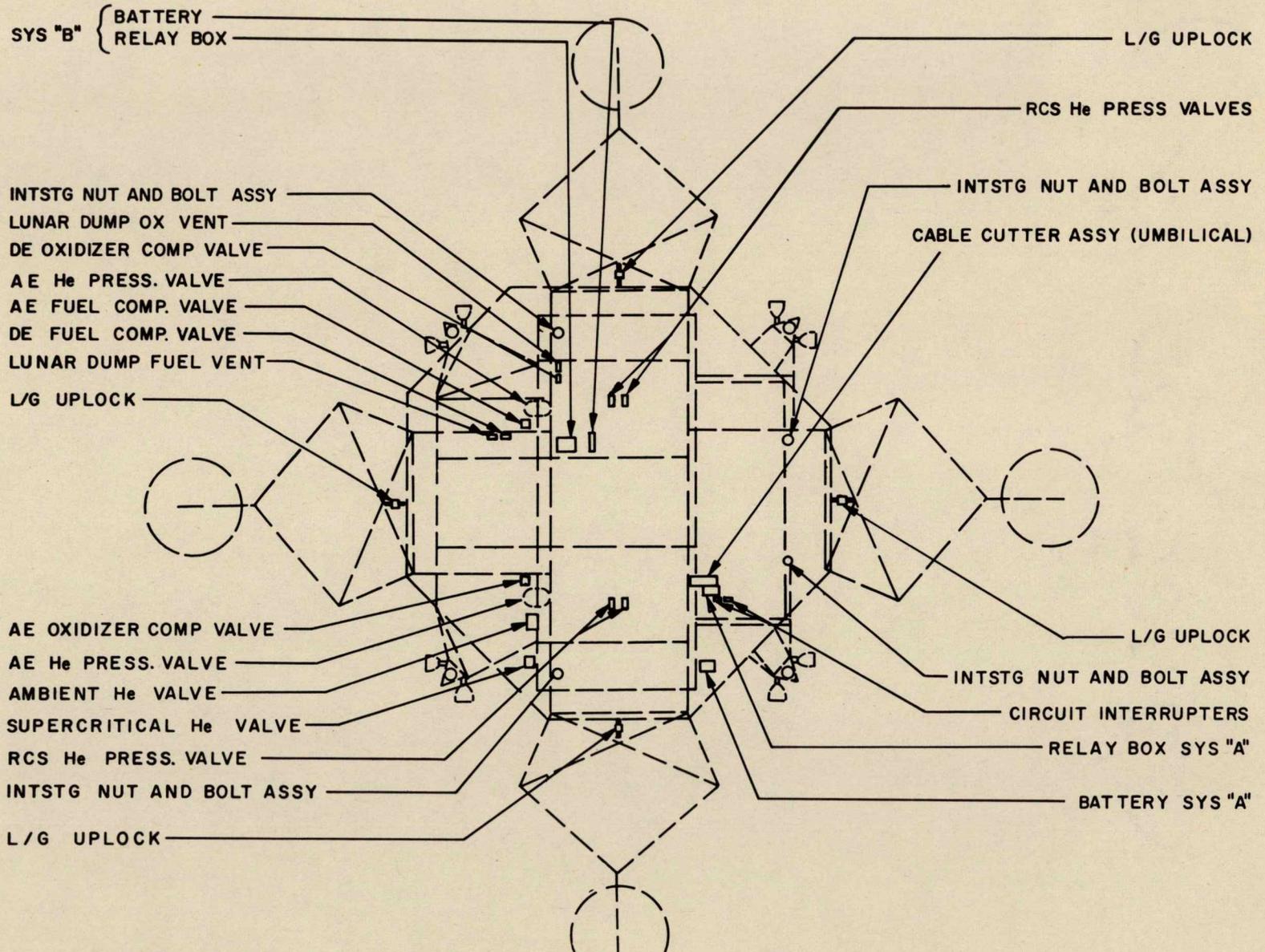


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Figure 41

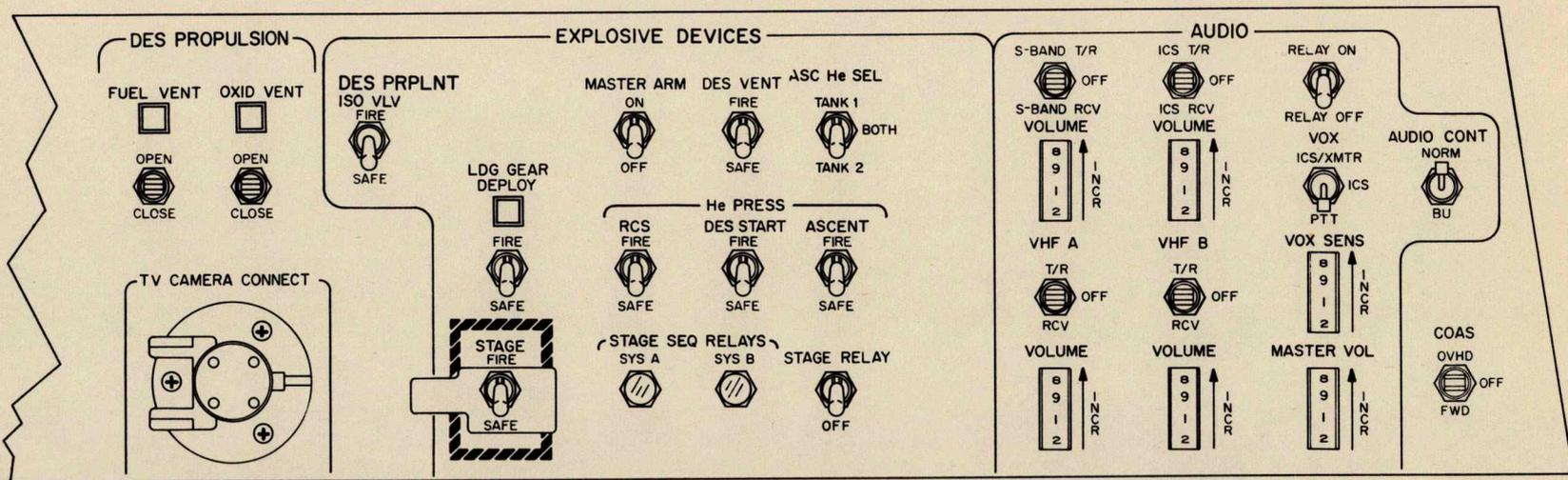
**EXPLOSIVE DEVICES COMPONENT LOCATIONS (SIDE VIEW)**

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EXPLOSIVE DEVICES COMPONENT LOCATIONS(TOP VIEW)

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 FEB 67



PANEL 8  
LM3

T30900-6  
MAY 67

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Figure 43

(such as "RCS PRESS", "DES START", "LDG DEPLOY", etc.) actuates two relays, one in each of the relay boxes. Each relay closes a circuit between its ED bus and the associated explosive device. Each staging relay, when actuated, connects an ED bus to a set of staging function relays (for ascent circuit interrupters, interstage nut and bolts, and cable cutter). Each function is provided with two separate initiators; each initiator uses power for initiation from a separate ED bus. Each initiator having a circuit with a bridgewire enabling it to explode its initiator charge. Each of the initiators is capable of performing its task unaided; the second initiator provides the required redundancy. The duplication of relays, and redundant electrical circuits with initiators, provides an efficient and positive firing ED subsystem.

#### ED SUBSYSTEM EVENTS AND CONTROL

The ED subsystem is designed with redundant circuits and components for safety and reliability. Each circuit and each component is capable of performing the function it was designed for, unaided. The ED events occur in the following sequence:

RCS Pressurization  
 Landing Gear Deploy  
 Descent Propellant Isolation Valve  
 Descent Engine Propellant Pressurization  
 Descent Engine Propellant Vent  
 Ascent Engine Propellant Pressurization  
 Interstage Nuts and Bolts and Ascent Stage  
 Deadfacing Occur Simultaneously  
 Umbilical Severed

#### ED CONTROL

EVENT	ED CONTROL		
	MANUAL OPERATION	AUTOMATIC OPERATION	AUTOMATIC/ MANUAL
1. Master Arm Switch	X	Abort Stage Switch	X
2. RCS He Press.	X		
3. Landing Gear Deploy	X		
4. Des Prop. Iso. Vlv.	X		
5. Des Start (He Press.)*	X		
6. Des. Vent.	X		
7. ASC He Tank Select	X		
8. ASC. He Press	X	Abort Stage Switch	X
9. Stage Separation	X	ASC Eng. On Command	X
10. Interstage Nuts and Bolts		Signal To Staging Relay K5	
11. Circuit Interrupter (2) (Deadface)		Signal To Staging Relay K6	
12. Cable Cutter		Signal To Staging Relay K3 and K4	

- \* Descent engine start will pressurize propellant system with ambient He, after engine has started squid valve on supercritical He will fire automatically from engine command.

## EXPLOSIVE DEVICES

The modular concept is used for the ED and assemblies. The explosive charge assemblies are separate from higher assemblies and from structural elements. All ED's and components are capable of installation at the launch site as late in the LM assembly and prelaunch activity as possible.

The following explosive devices separately or in various combinations accomplish the following specified functions:

Apollo Standard Initiator (ASI). The electrically actuated ASI initiates all explosive functions required during the mission. This is a common usage device. (figure 44)

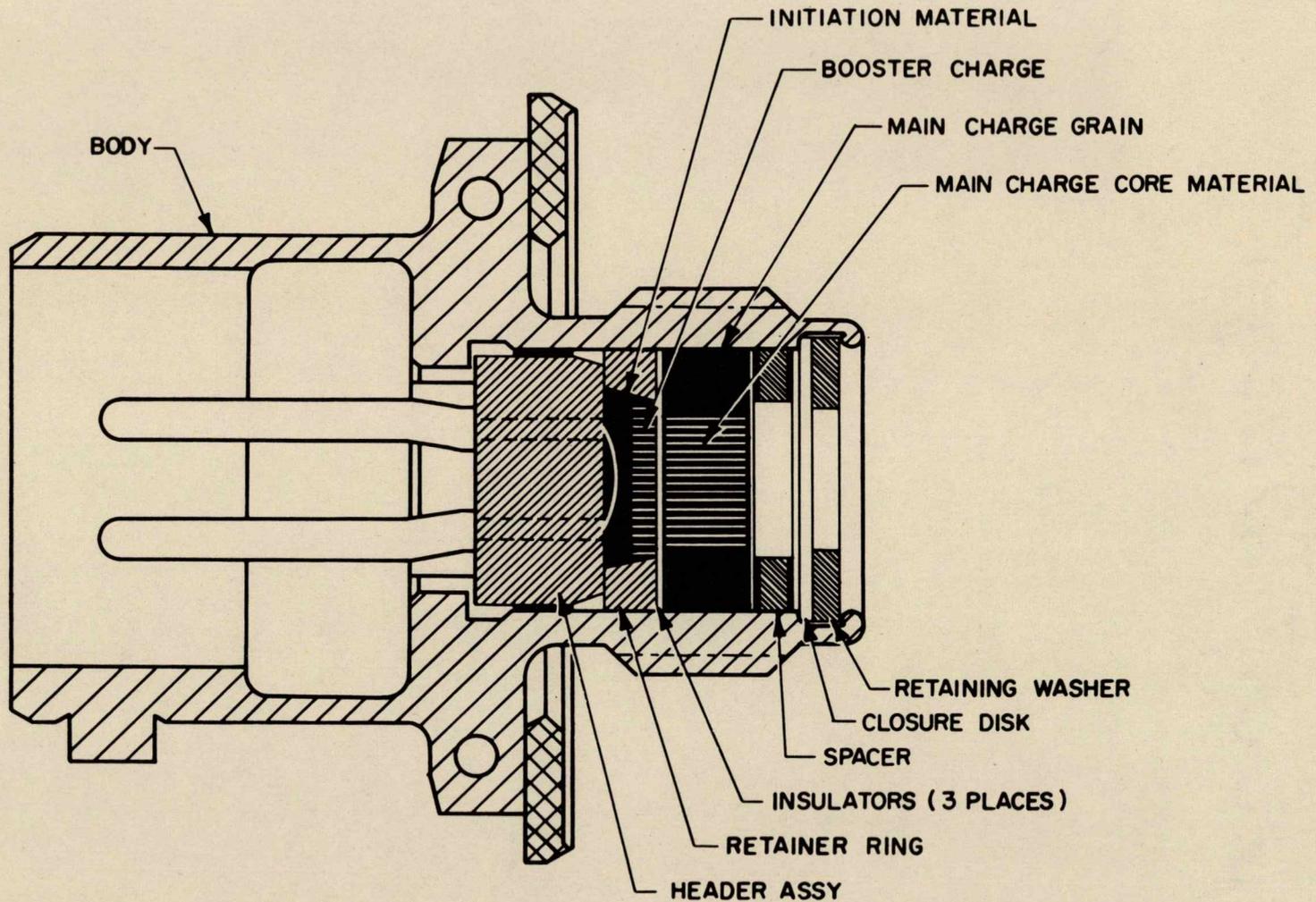
Apollo Standard Detonator (ASD). The ASD is used to detonate all high explosive charges in the LM. This is a common usage device. (figure 45)

Helium Presurization Squid Valves, Compatability Valves and Vent Valves. These valves are all alike and operate in the same manner, they are used either singly or in pairs dependent on their use within the engine systems (RCS, Ascent and Descent Engine Systems). The explosive valves are actuated by one or both of the two ASI's installed on the valve. (figure 46)

Circuit Interrupter. Circuit Interrupters (two each) are provided to terminate all signal and power leads running between the Ascent and Descent Stages which are live at the time of separation or which could subsequently become alive due to activation of a circuit. These devices are initiated explosively 30 milliseconds after stage command is received. They are actuated by either of the two ASI's installed. (figure 47)

Explosive Nut and Bolt. The Ascent and Descent Stages are structurally joined by four explosively actuated nuts and bolts each with a single initiator. Upon receiving the stage separation signal, they actuate within a total elapsed time of 0.1 sec. (Figures 48 and 49)

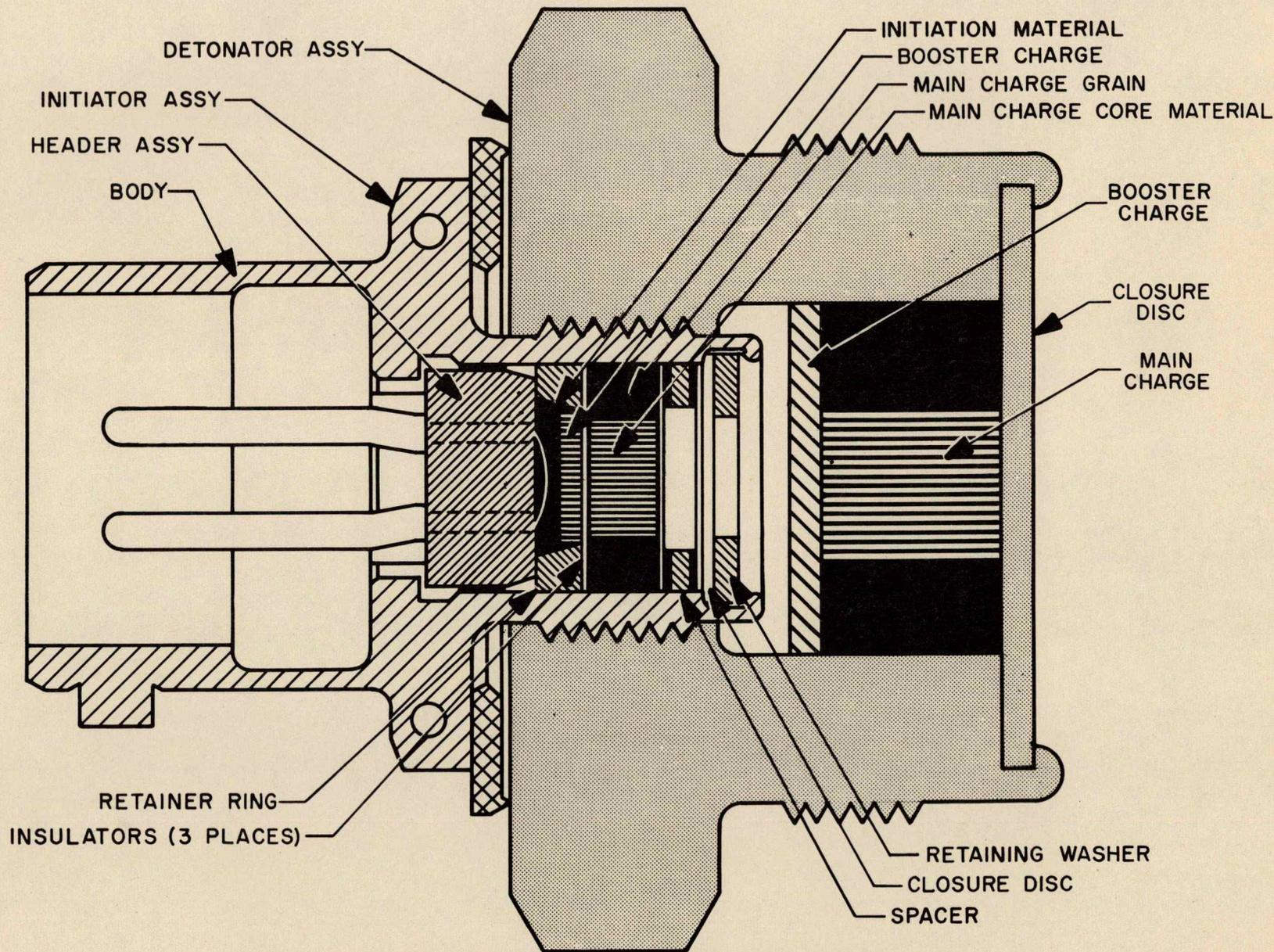
PYROTECHNICS



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Figure 44

STANDARD INITIATOR



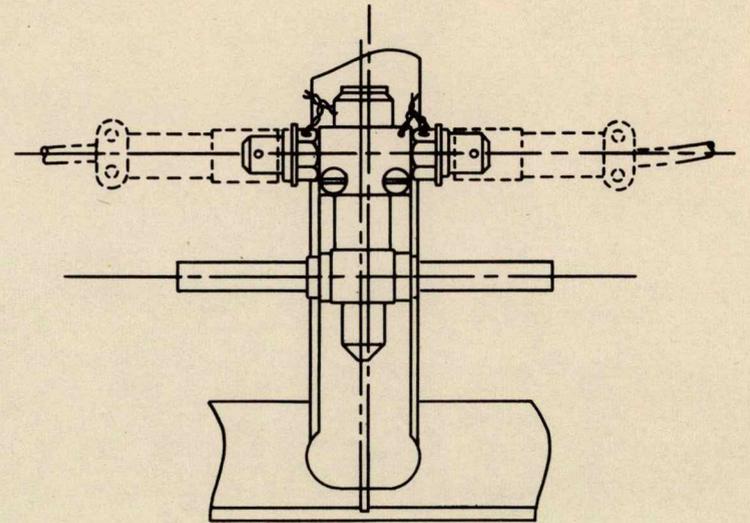
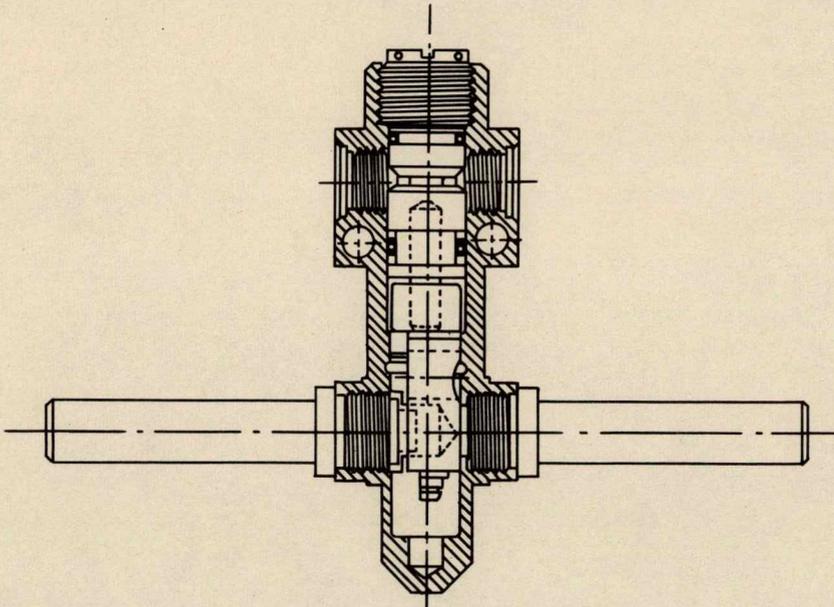
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Figure 4.5

INITIATOR AND DETONATOR ASSEMBLY

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PYROTECHNICS

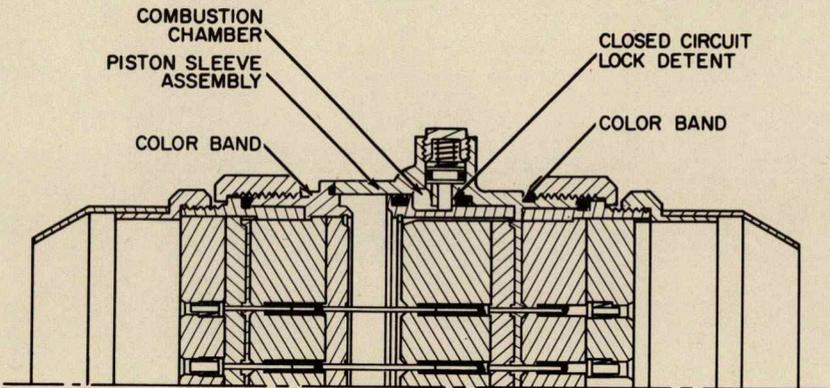


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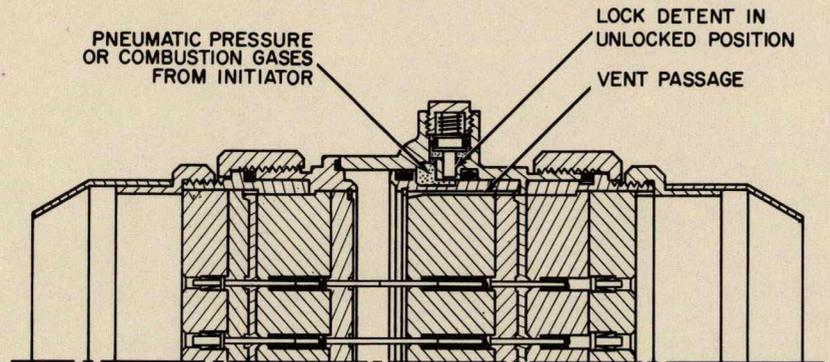
Figure 46

HELIUM PRESSURIZATION SQUID VALVE

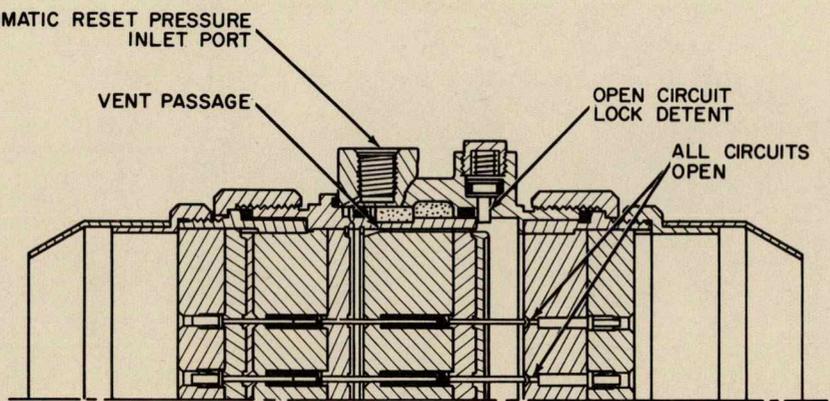
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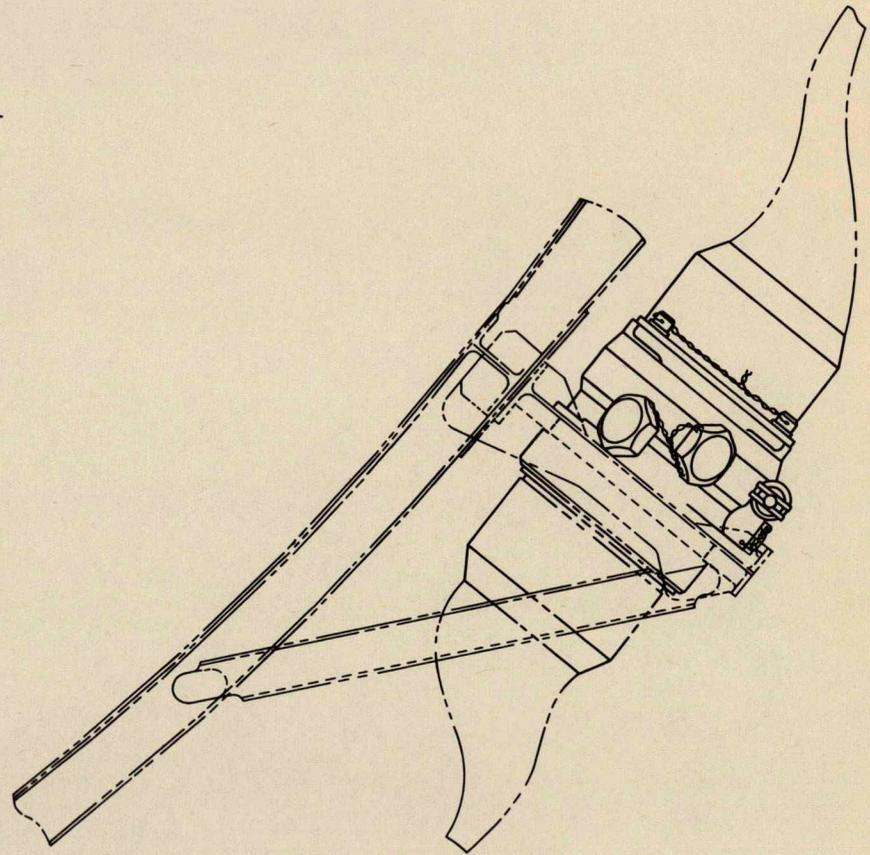
VIEW 1



VIEW 2



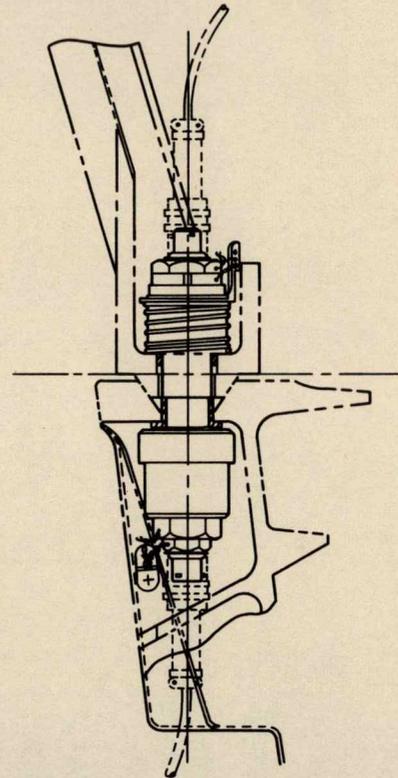
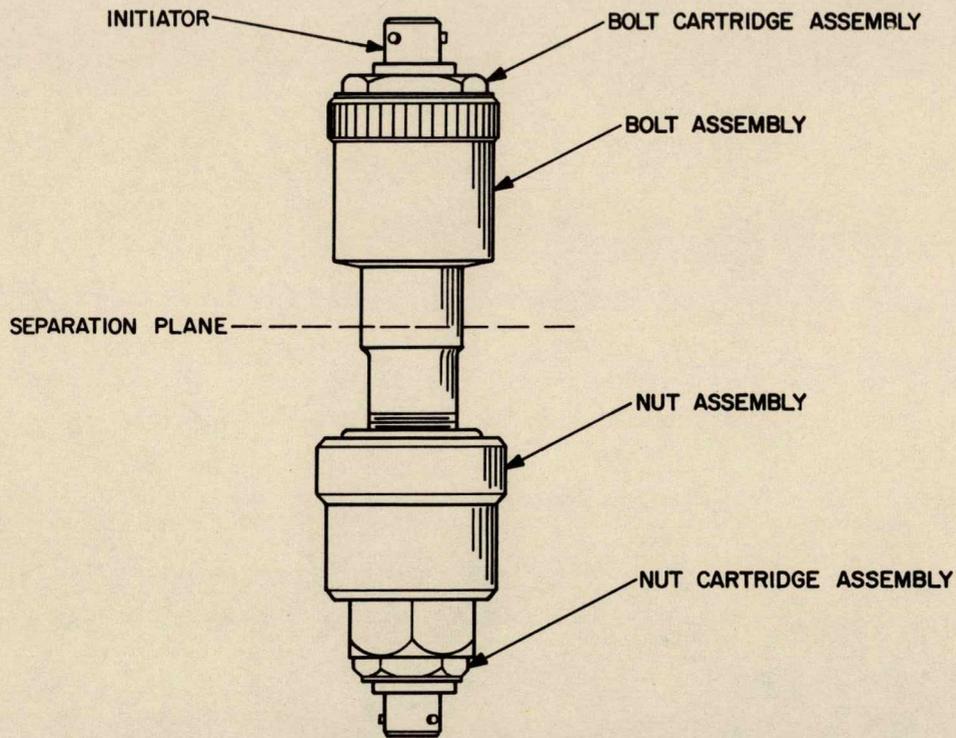
VIEW 3



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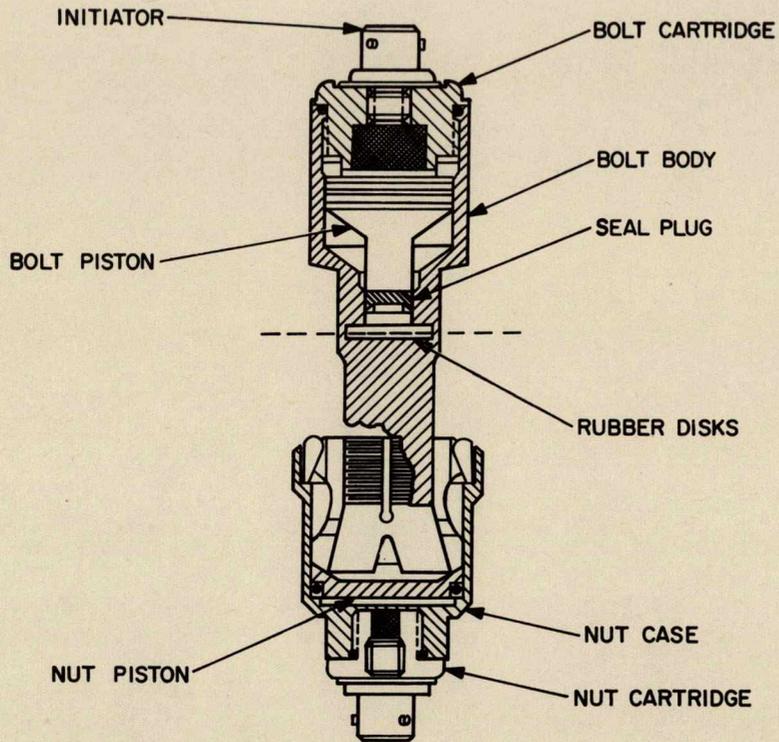
Figure 4.7

**CIRCUIT INTERRUPTER**

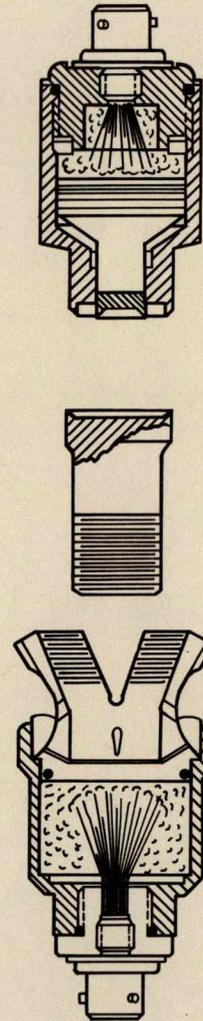


**INTERSTAGE STRUCTURAL CONNECTION  
NUT AND BOLT ASSEMBLY**

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AFTER FIRING



**INTERSTAGE STRUCTURAL CONNECTION  
 NUT AND BOLT ASSEMBLY**

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Cable Cutter. A dual initiation mode mild detonating fuse is used. Each mode can sever an umbilical 35 percent greater than the actual umbilical within 0.5 second after receipt of the fire signal at the cable cutter. A crossover network is provided to fire both modes should a failure occur in the normal initiation mode of one. (figure 50)

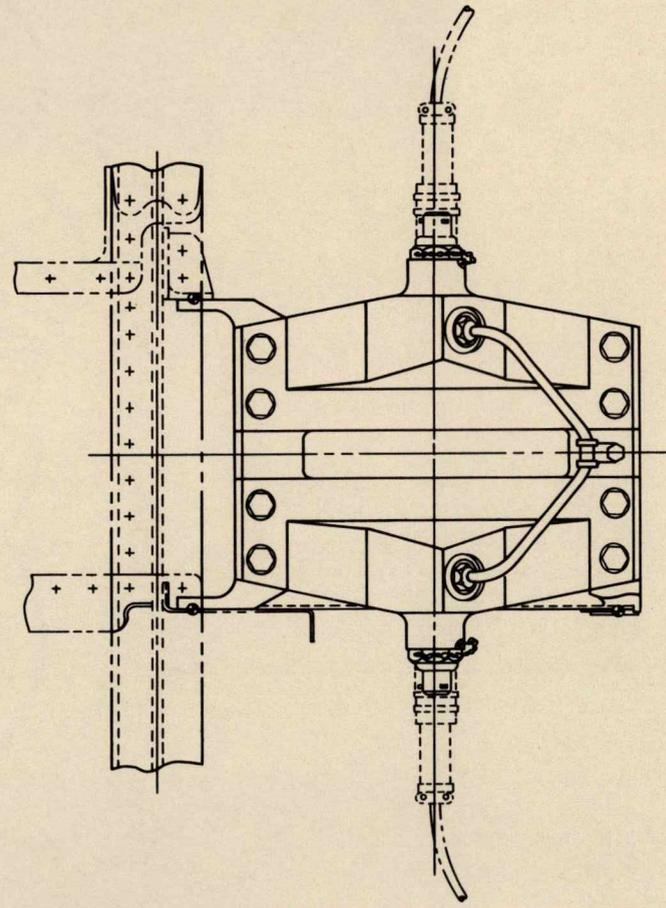
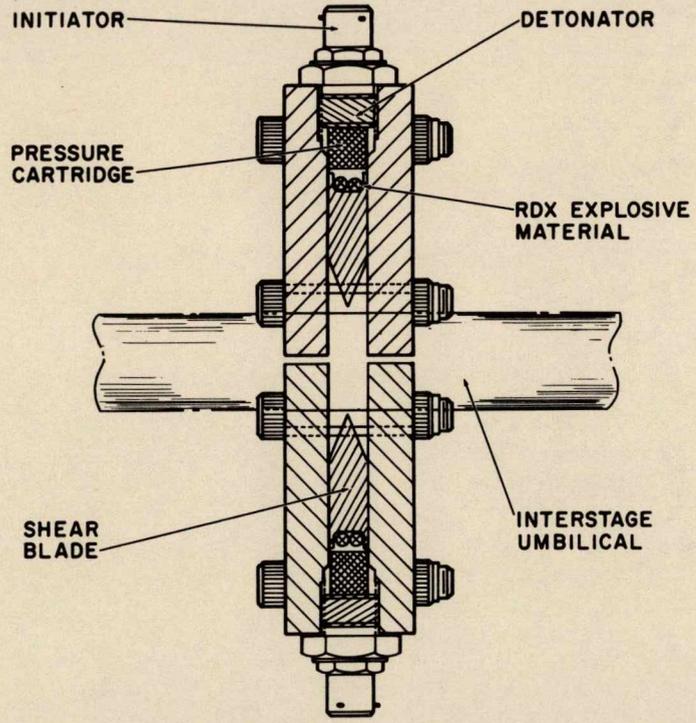
Landing Gear Uplock. Two independent ASD's are used in each of the four uplocks. When fired, tremendous shock waves are generated acting on the but ends of the two uplock cutting blades, the blades are driven toward the connecting strap, in opposite directions, resulting in severing the strap and deploying the gear. (figure 51)

### ED CIRCUITRY

Circuit protection for the EDS is provided by a system of high reliability circuit breakers and current limiting fuses. Circuit breakers are provided as follows: To clear the logic fuses of ground fault in the EDS; To protect the wiring from deterioration (includes smoke or toxic fumes in the ascent stage cabin), caused by faults and overloads; Two circuit breakers are found on the CB panel, one on panel 11 for system "A" logic and one on panel 26 for system "B" logic.

ED circuits are the only electrical load connected to the ED power bus and are not powered from the logic bus. All ED circuits and logic circuits are electrically and physically isolated from one another, and the wiring is routed separately wherever possible. ED circuits are not grounded but logic and instrumentation circuit ground returns are separated and in no way cause the ED circuit to become grounded.

ED design is fail safe in all respects. The EDS has two independent circuits, providing complete redundancy. There are no mechanical or electrical crossovers except for the common mechanical actuation of control switches. A single failure or malfunction does not cause a function failure or mission abort. Redundant wiring is used where the loss of a single lead could cause premature initiation of a major function or loss of control of the function.



**CABLE CUTTER ASSEMBLY**

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Figure 50

All initiators are protected from electromagnetic interference and static electricity by means of a ground loop control circuit. The initiators are grounded via the control relay to the ED negative bus at all times, until the circuit is fired. When fired, the control relay is energized subjecting the initiator to the positive 24V DC ED bus. A fuse-resistor in series with the circuit (between the pyro bus and control relay) protect both the bridgewire and batteries from overloads. The fuse-resistors are rated at 20 Amps for 100 milliseconds with a 1 ohm resistance. (figure 52)

#### MASTER ARM SWITCH AND CIRCUIT

The "MASTER ARM" switch on the "EXPLOSIVE DEVICES" control panel consists of two SPDT switch modules with a common two-position lever-locking toggle mechanism in the OFF and ON position. (figure 43)

Setting the "MASTER ARM" switch to ON, enables 28 volts DC from EPS systems A and B to energize relays K1 putting the ED batteries on the ED buses. The buses are also armed by operating the "ABORT STAGE" switch on the Commander's center panel, which also connects 28 volt DC power to the set coil of the latching control relays K1. This method bypasses the "MASTER ARM" switch. (figure 53)

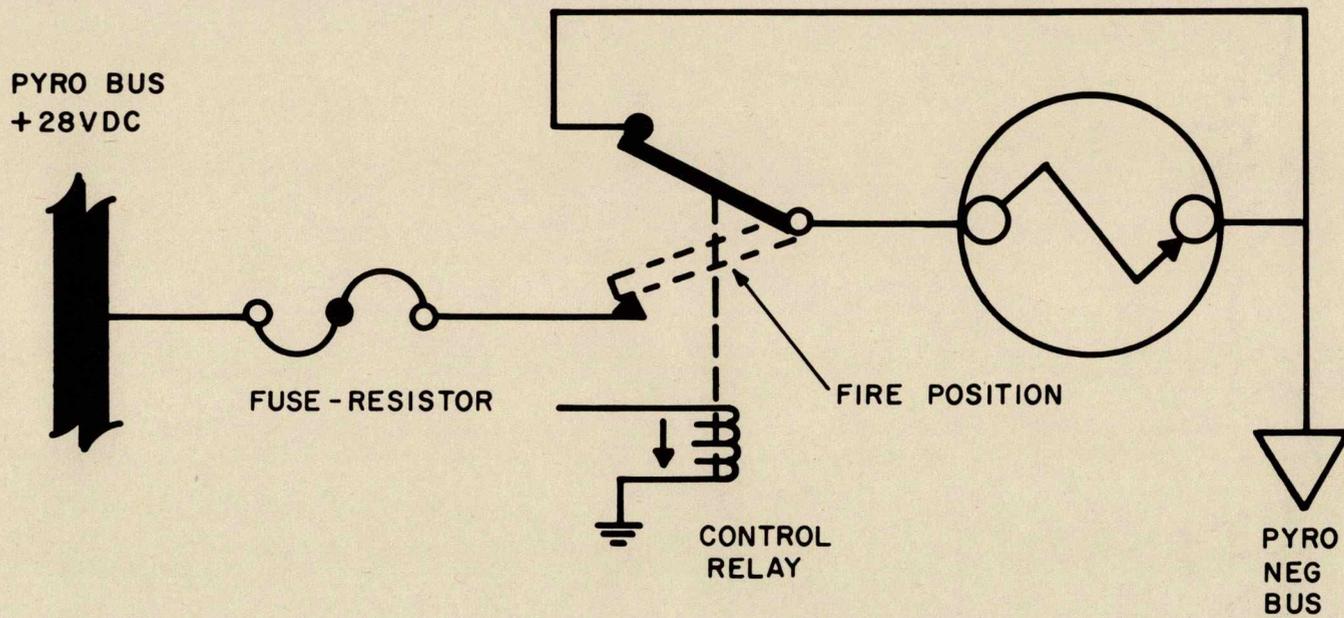
Setting the "MASTER ARM" switch to OFF, deenergizes the ED buses. This enables 28 volts DC to flow from EPS system A and B to the reset coils of the latching control relays K1 and breaks the circuit between the ED batteries and ED buses. (figure 53)

If a malfunction should occur and one or both of the K1 relay do not energize the ED relays light on the System Engineer's annunciator panel will illuminate. By checking the yellow, STAGE SEQ relays light on the ED panel, the one illuminated will indicate in what ED system the malfunction occurred. By resetting the Master Arm switch to OFF then ON the malfunction may be remedied. If not, the ED devices will operate on one system. If remedied the caution lights will go out.

#### ED INITIATORS

The initiators used in the ED subsystem are single bridgewire Apollo standard initiators (figure 44). Apollo standard initiators provide a high power-to-weight ratio, require low energy to initiate, are compact, and have a high degree of reliability.

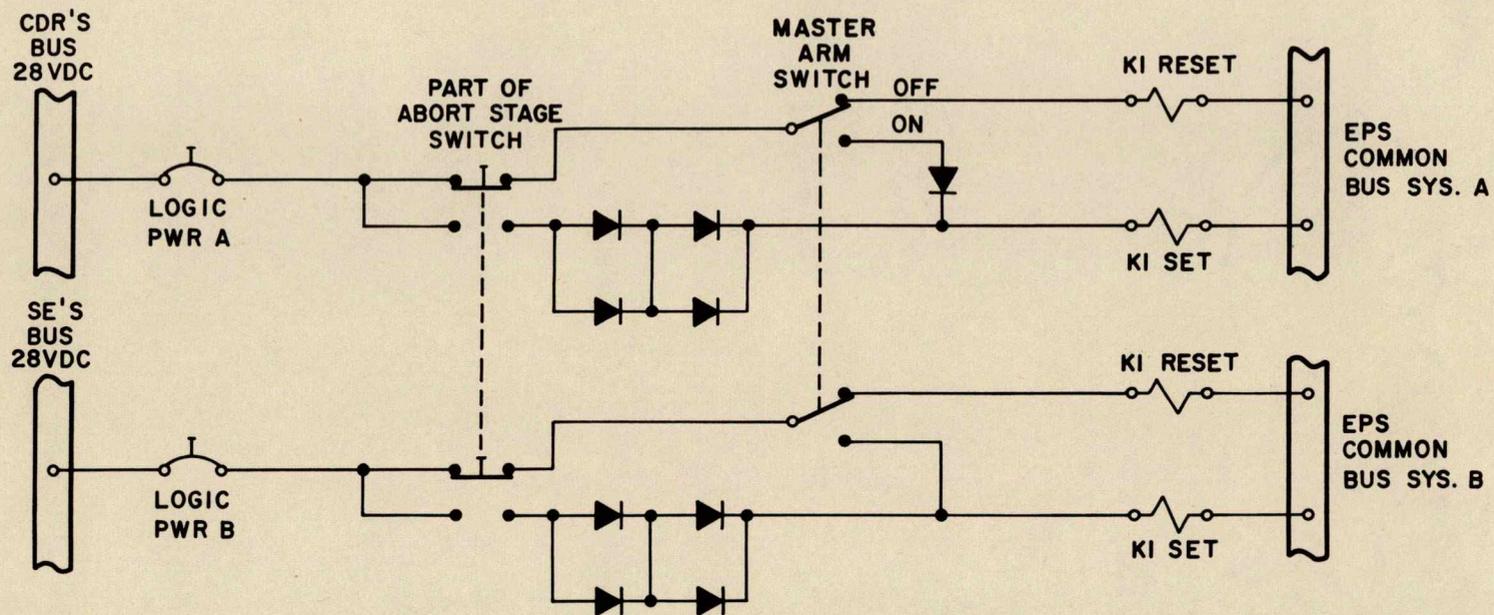
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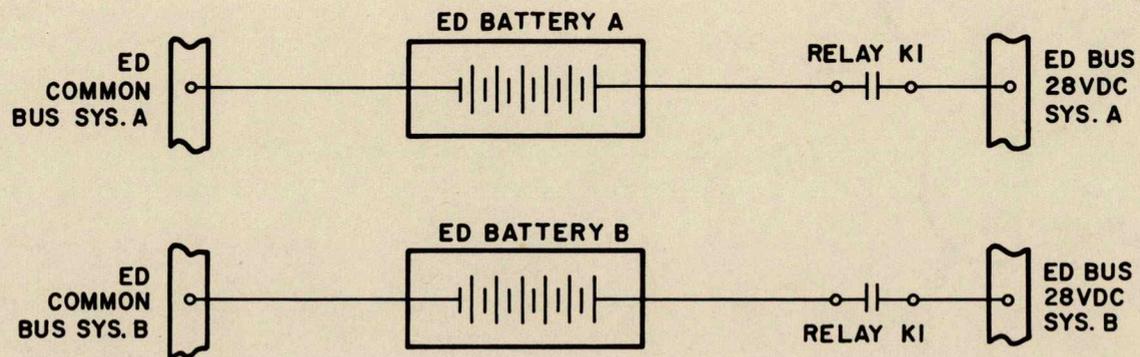
INITIATOR GROUND LOOP CIRCUIT

Figure 52

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**MASTER ARM & ABORT STAGE SWITCH INTERFACE**

Figure 53

Each LM explosive function uses two initiators for redundancy. An electrical current of 5 amperes, applied to the initiator bridge-wire, generates heat that activates the initiator firing. Each initiator is controlled by a separate and independent firing relay contact. Each initiator of a explosive device is fired by a separate ED battery.

The initiators will fire within 5 milliseconds when subjected to 3.5 amperes DC.

They will not fire when subjected to 1 ampere DC for 5 minutes at an ambient temperature of plus 165°F.

Bridgewire resistance is 1 ohm measured at an ambient temperature (lab temp. +70°F) with DC power of .02 volt and .02 ampere applied.

#### RELAY BOXES AND BATTERIES:

The ED relay boxes and batteries are located in both ascent and descent stages. The relay box and associate battery for ED system "A" is located in the quad 4 area of the descent stage. The relay box and battery for system "B" is located in the upper-left side of the ascent stage midsection near the EPS water tank. (Figures 41 and 42)

Relay Boxes: Latching and non-latching relays are used in the ED subsystem control system, these being located within the relay boxes.

Latching relays consist of two coils (set and reset) with associated contacts; they are used in the ED subsystem to control the stage and master arm sequences. The set coil when energized, initiates circuit action, and the reset coil when energized, stops circuit action. Once the set coil has been pulsed, it opens the normally closed pair of contacts that are in series with the set coil and closes the normally open pair of set contacts that are in series with the reset coil. The reset coil is pulsed; this opens the contacts in series with the reset coil and closes the contacts in series with the set coil. This arrangement deenergizes the relay coil immediately after it is energized, and leaves the contacts latched in the set or reset mode, depending on the coil pulsed.

Non-latching relays, used in control and fire circuits, consist of one coil with associated non-latching contacts. Contacts are maintained in the open or closed position, only when the coil is energized.

## BATTERIES:

The ED subsystem utilizes two silver oxide-zinc batteries to fire the explosive devices initiators and power stage sequencing control relays. The batteries are approximately 2.75 inches wide, 3.03 inches high, 6.78 inches long and weight 3.5 pounds each when filled with a potassium hydroxide, 1/2 saturated electrolyte solution.

The battery case is constructed of plastic which is coated with a thin layer of stainless steel. Each of the twenty (20) internal cells is separated from each other by a sheet of non-corrosive material. Pressure relief valves are provided in each of the twenty cell area, and a relief valve in the battery case vents excessive pressures in the event of a battery pressure condition. Relief pressure of each cell is approximately 35 psig. Each cell is vented into the battery case as well. The case relief valve vents directly into the descent stage enclosure at  $30 \pm 5$  psig. The battery case relief valve reseats at 20 psig.

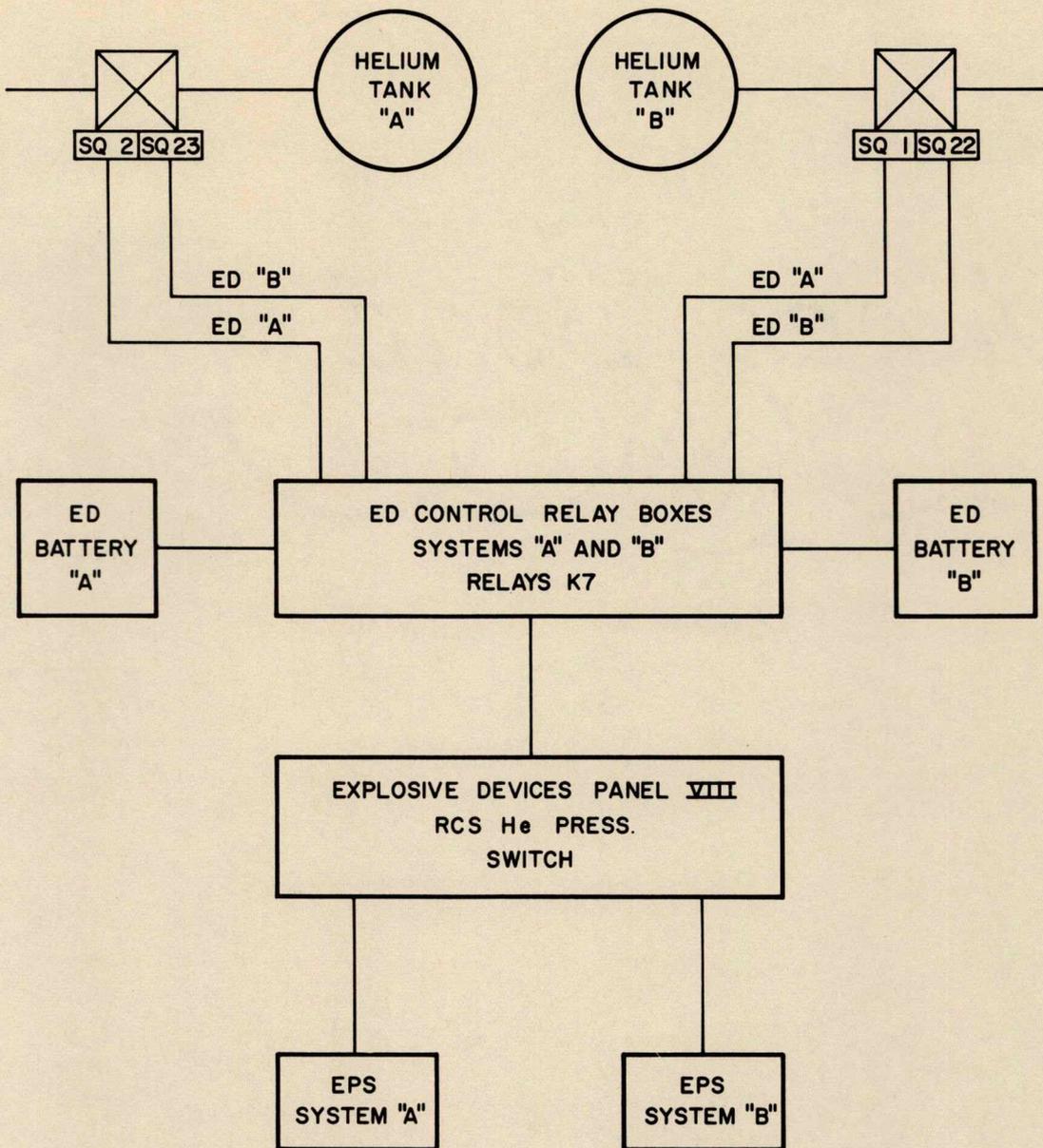
Each ED battery is rated at 24 volts DC, 0.75 ampere-hour. The battery can produce 75 amperes for 36 seconds. They are considered to be discharged at 75 ampere and 20 volts DC for the purpose of the LM mission.

Each ED battery is used to power one of the ED systems (system "A" or "B"). They are completely and independently isolated from their ED bus and relay box. Normal operation of either ED battery will provide adequate electrical power for all events actuated within its individual system.

## RCS PROPELLANT TANK HELIUM PRESSURIZATION:

Helium is used to pressurize the RCS propellant tank. Two helium, two fuel and two oxidizer tanks are used in the system. One helium tank is used to pressurize a fuel and oxidizer tank. (Figures 40, 41 and 42 show locations of valves) Two ED valves are used in conjunction with each helium tank, and are located in parallel in the pressurization plumbing. Each valve is fired by one of the ED systems.

The valves are normally in the closed position; their firing circuits are controlled by relays actuated by the "RCS PRESS" control switch on the ED control panel (Figure 43). The switch consists of two SPDT switch modules actuated by a common two-position switch with a lever-locking toggle mechanism that maintains the switch in the SAFE and momentary in the FIRE position. (See Figure 54 for a functional block diagram of the RCS propellant tank pressurization).



**RCS PROPELLANT PRESSURIZATION  
FUNCTIONAL BLOCK DIAGRAM**

T30915-47  
FEB 67

Setting the switch to FIRE enables 28 volts DC power from EPS systems A and B to energize coils of relays K7. Energizing either of these two relays completes the circuit between initiators and the ED-buses; the initiators in the RCS helium isolation valves are fired. Firing the initiators causes the expanded gases to act on a piston (Figure 46), driving the piston downward and shearing the closed helium pressure line. This opens the valve(s) to permit pressurized helium from the RCS helium tanks to flow to the propellant tanks and pressurize the propellant. The valves are maintained in this position mechanically and cannot be closed.

Operation and Function:

"MASTER ARM" switch ON.

"RCS PRESS" switch FIRE.

28V DC (EPS buses) energizes relays K7.

Relays K7 energized supplies 24V DC

(ED buses) to fire He squid valves

SQ 22, SQ 23, SQ 1, and SQ 2.

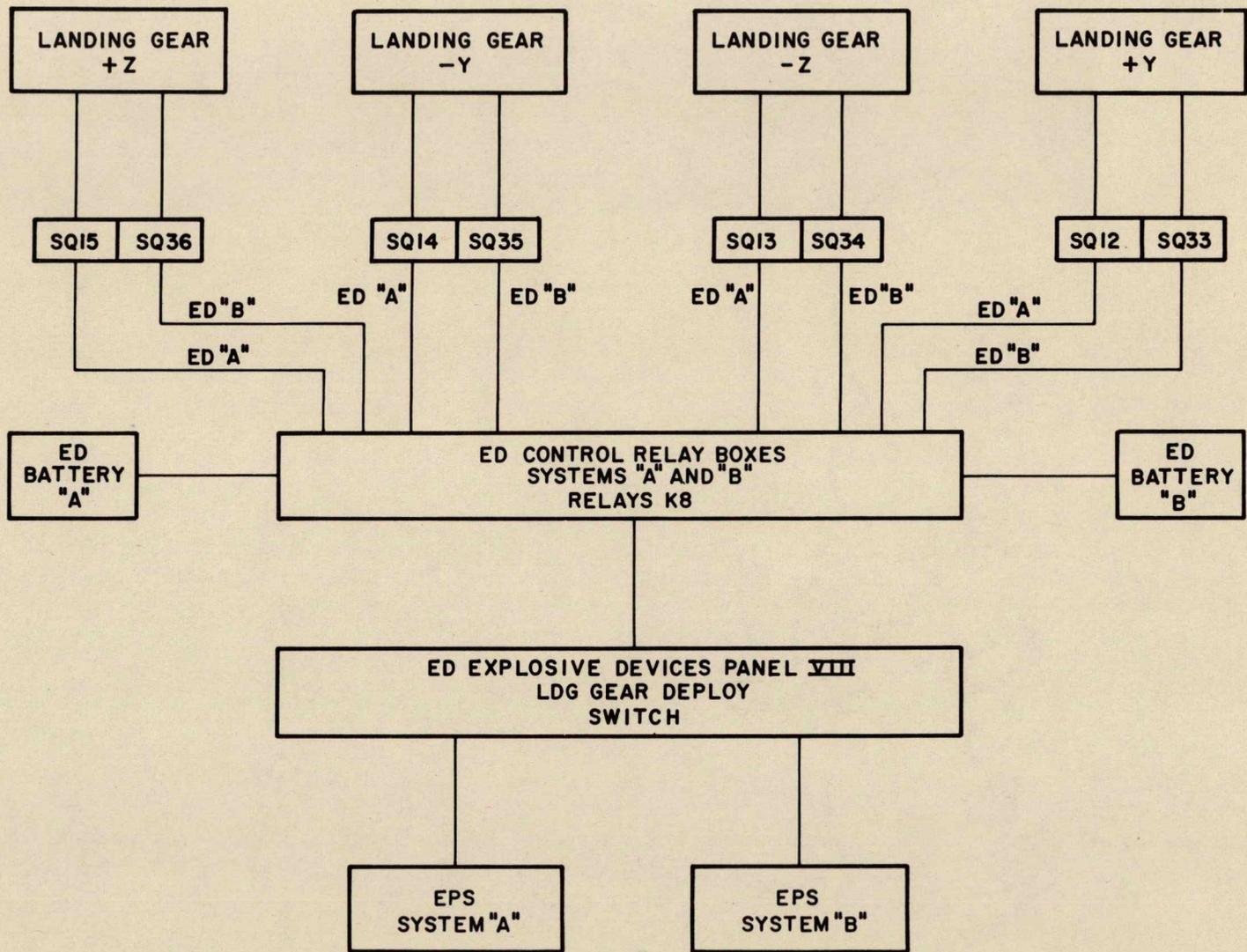
"MASTER ARM" switch OFF.

LANDING GEAR DEPLOYMENT UPLOCK DEVICES:

The LM landing gear is stowed in the retracted position at earth launch and remains retracted until deployed by the Commander at a specified time during the mission profile. The "LDG GEAR DEPLOY" switch on the ED control panel (Figure 43) is used to deploy the landing gear. The switch is a two-position switch with a lever-locking mechanism for the SAFE position.

Four uplock devices (Figures 40, 41 and 42), each with two Apollo standard initiators, restrain the landing gear. Each initiator is controlled and fired by two separate fire and control circuits in parallel. (See Figure 55 for a functional block diagram.) Firing of one initiator in each of the four landing gear uplocks results in landing gear deployment and lighting of the "LDG GEAR DEPLOY" indicator on the ED control panel. Setting the "LDG GEAR DEPLOY" switch to FIRE, permits power from the EPS bus systems A and B to pass through the closed switch contacts to the coils of the parallel-connected relays K8. Energizing these relays, closes the relay contacts and permits ED battery power to flow to the eight landing gear uplock initiators.

Firing an initiator generates shock waves that act on the butt ends of the two uplock cutting blades. The blades sever a strap that connects the landing gear primary strut with the LM descent stage lower structure, permitting landing gear deployment. The operation response time of the uplock is approximately 20 milliseconds after a 5 ampere DC current is applied to the initiator bridgewire.



LANDING GEAR DEPLOYMENT FUNCTIONAL BLOCK DIAGRAM

T30915-48  
FEB 67

Operation and Function:

"MASTER ARM" switch ON.

"LDG GEAR DEPLOY" switch FIRE.

28 Volts DC (EPS Buses) energize relays K8.

Relays K8 energized supplies 24 volts

DC (ED Buses) to fire uplock initiators

SQ 12, SQ 13, SQ 14, SQ 15, SQ 33, SQ 34,

SQ 35, and SQ 36.

Landing gear deploy indication.

"MASTER ARM" switch "OFF".

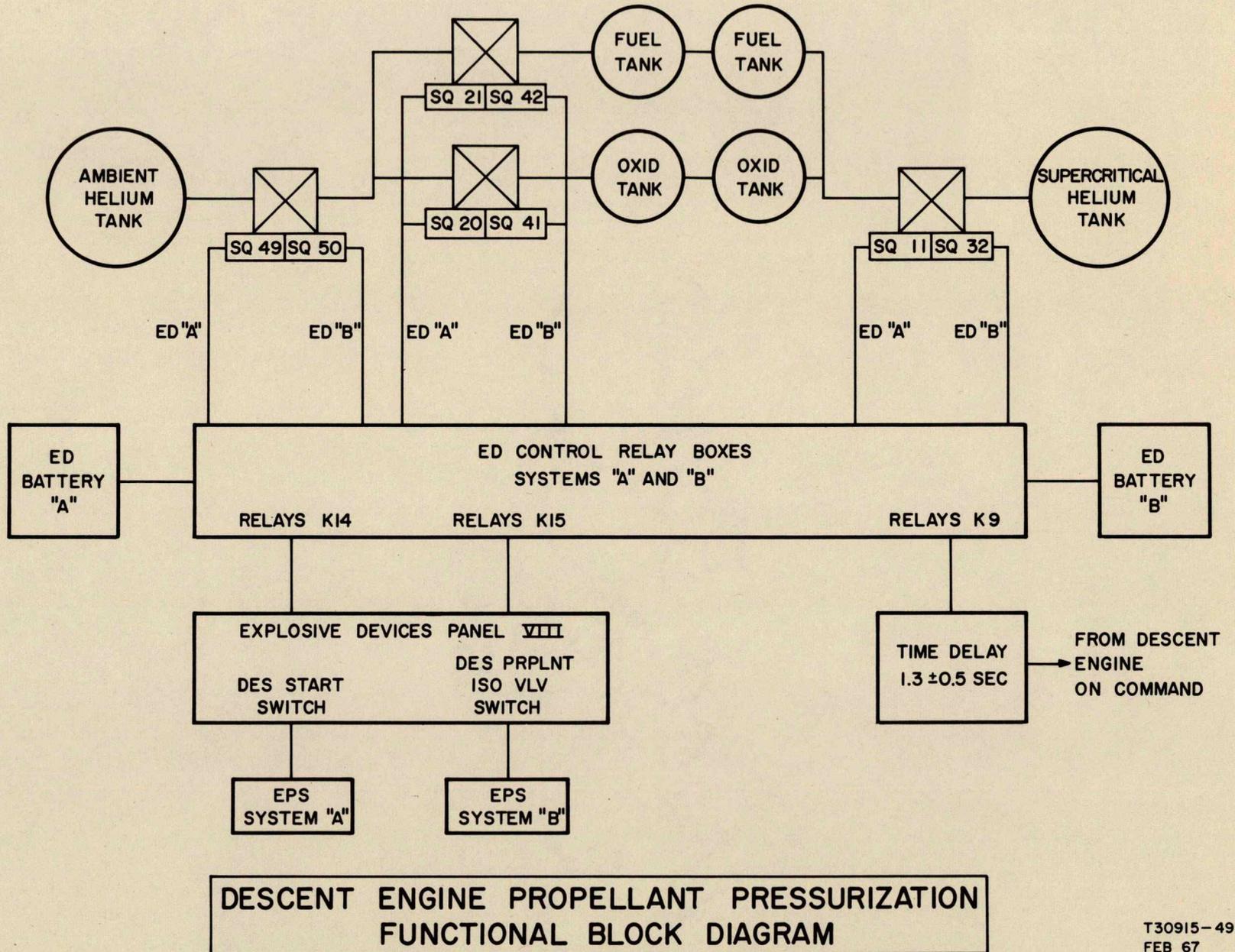
DESCENT ENGINE PROPELLANT TANK HELIUM PRESSURIZATION  
AND COMPATABILITY VALVES:

Helium is used to pressurize the descent engine propellant tanks. Two helium supply tanks are used in conjunction with the pressurization of the fuel and oxidizer tanks; one ambient helium tank and one supercritical helium tank. Prior to engine start the ambient helium is utilized to pressurize the fuel and oxidizer tanks. After the engine has started the supercritical helium is automatically released to continue tank pressurization.

Four electroexplosive squid valves are used in the helium pressurization system. One squid valve is used to release the ambient helium and one to release the supercritical helium. Two compatibility isolation squid valves are incorporated in the system downstream of the quadcheck valves at the fuel and oxidizer tanks. One valve is used for the fuel tanks and one for the oxidizer tanks. (Figures 40, 41 and 42)

The valves are normally in the closed position; their firing circuits are controlled by relays K9, K14 and K15. The compatibility isolation valves are fired first by placing the "DES PRPLNT ISO VLV" switch in the FIRE position (Explosive Devices Panel Figure 43). In the FIRE position 28 volts DC from the EPS bus systems A and B is passed through the closed contact of the switch to the coils of relays K15. Energizing relays K15 closes the contacts permitting ED battery power to fire the initiators on the fuel and oxidizer compatibility squid valves. (Figure 56)

The "DES START" helium pressure switch (Explosive Devices Panel) is then placed in the FIRE position. This will allow 28 volts DC from the EPS buses to energize the coils of relays K14. Relays K14 being energized 24V DC from the ED batteries, system A and B, will fire the ambient helium squid valve allowing the helium to pressurize the fuel and oxidizer tanks. Firing either initiator in the valves opens the valves in the same manner as described in the operation of the RCS helium valves.



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Figure 56

With ambient helium pressurizing the four propellant tanks the descent engine is then started. As the descent engine starts an electrical signal is sent to Relays K9 through a time delay of  $1.3 \pm 0.5$  seconds. After the time delay power from the EPS buses will energize the coils of Relays K9. With Relay K9 energized and the contacts closed, power from the ED battery power systems A and B will fire the initiators of the squid valve on the supercritical helium tank. With the valve in the open position, supercritical helium will continue to pressurize the fuel and oxidizer tanks.

Operation and Function:

"MASTER ARM" switch ON

"DES PRPLNT ISO VLV" switch FIRE

28 volts DC (EPS Buses) energizes Relays K15

Relays K15 energized supplies 24 volts DC

(ED) Buses to fire compatibility squid valves

SQ41, SQ42, SQ20 and SQ21

"DES START" helium press. switch FIRE.

28 volts DC (EPS Buses) energizes Relays K14

Relays K14 energized supplies 24 volts DC

(ED Buses) to fire helium squid valve SQ 49

and SQ50

Fuel and Oxidizer tanks pressurized.

DESCENT ENGINE - ON

Descent Engine ON Command energizes Relays K9

through a  $1.3 \pm 0.5$  second time delay

(28 volts DC from EPS Buses energizes relays)

Relays K9 energized supplies 24 volts DC (ED Buses)

to fire squid valve on supercritical tank SQ 11

and SQ32

Supercritical helium now pressurizing fuel and

oxidizer tanks

"MASTER ARM" switch OFF.

DESCENT ENGINE PROPELLANT TANKS HELIUM VENT

On lunar landing the descent engine will be shut down leaving the propellant tanks still pressurized. It is possible the LM Descent Structure will absorb a high amount of heat soak back from the lunar surface. With the increase of temperature the propellant tanks may become over pressurized into the critical stage, therefore, the helium side of the tanks are vented after engine shut down to prevent an over pressurized condition. This is accomplished by firing explosive squid valves in the helium pressure side of the tanks. (Figures 41 and 42)

To vent the helium pressurization the "DES VENT" switch, on the Explosive Devices Panel (Figure 43), is placed in the FIRE position. This will enable 28 volts DC from the EPS buses (Systems A and B) to energize the coils of Relays K13. With Relays K13 energized and the contacts closed 24 volts DC will flow from the ED batteries firing the squid valves for the propellant tanks; one valve for the fuel tanks and one for the oxidizer tanks. (Figure 57) With the valves fired open to accomplish the venting of the tanks the solenoid vent valve must be opened. Utilizing the switches, "FUEL VENT" and "OXID VENT" DES Propulsion on Panel VIII, the tanks can be vented by moving the switches to OPEN. When the valves are fully open the indicating lights above the switches will show gray. After the tanks are completely vented the valves are shut off by moving the switches to the CLOSE position. The indicating lights will show barberpole when the valves are fully closed.

Operation and Function:

"MASTER ARM" switch ON

"DES VENT" switch FIRE

28 volts DC (EPS Buses) energizes Relays 13  
Relays 13 energized supplied 24 volts DC  
(ED Buses) to fire squid valves SQ 43 and 45  
fuel vent valve and SQ 44 and 46, oxidizer  
vent valve.

"FUEL VENT" - "OXID VENT" switches OPEN

28 volts DC (EPS Buses) energizes solenoid valves  
for fuel and oxidizer.

Indicating lights show GRAY

"MASTER ARM" switch OFF when system is depressurized

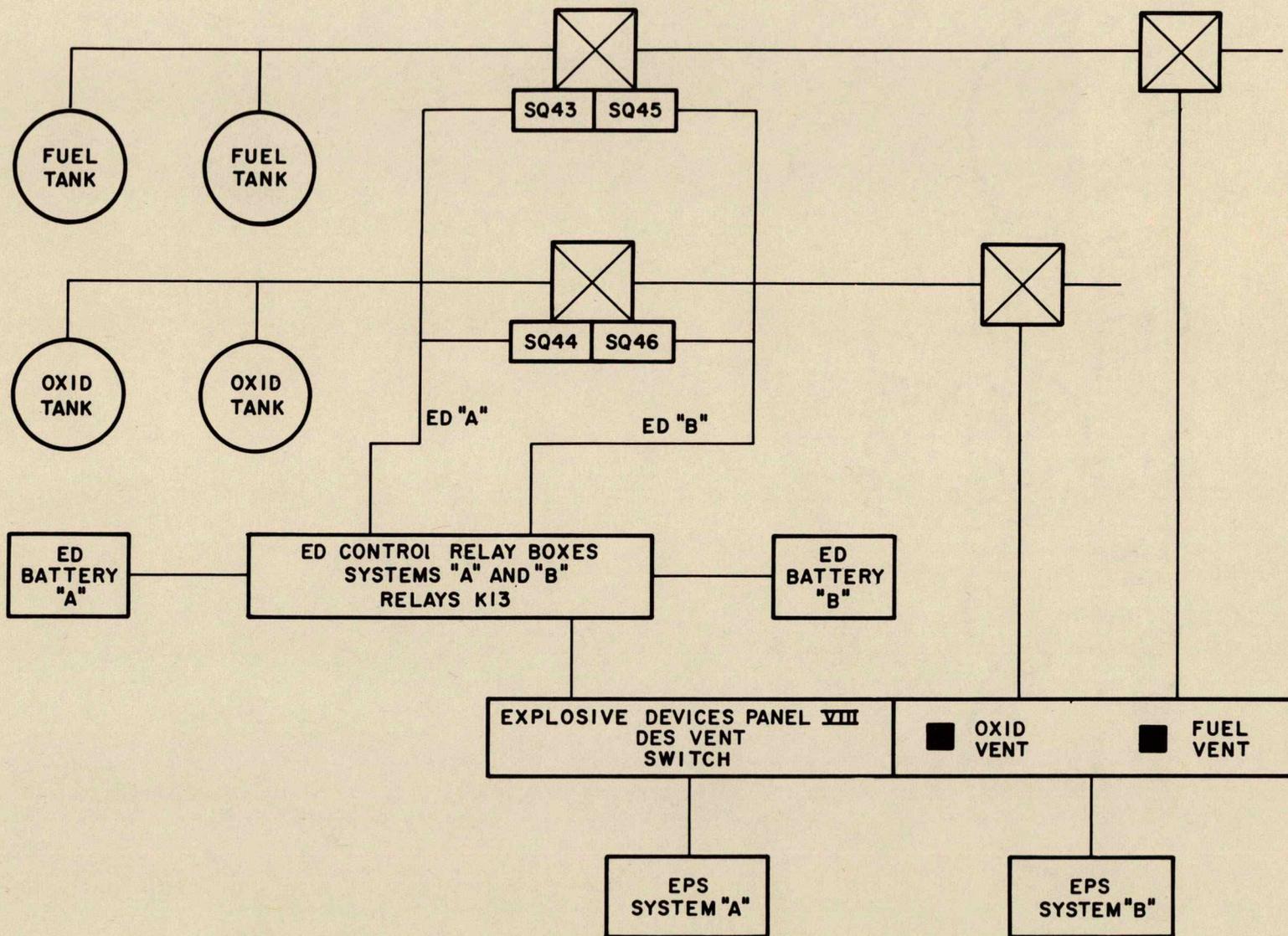
"FUEL VENT" - "OXID VENT" switches CLOSE

Solenoid valves will close indicating lights  
show BARBERPOLE

ASCENT ENGINE PROPELLANT TANK HELIUM PRESSURIZATION AND COMPATABILITY VALVES

Helium is used to pressurize the ascent engine propellant tanks. Two helium tank squid valves, each with two initiators, and two sets of parallel redundant compatibility valves two with two initiators each and two with one initiator each, are used for this purpose. The valves are all located within the Ascent Stage, Figures 40, 41 and 42 will indicate the locations. The crew will have the capability of pressurizing the propellant tanks with either or both of the helium tanks.

The valves are normally in the closed position; they are controlled by initiator control and fire circuits, depending upon the setting of the "ASCENT" helium pressure switch on the Explosive Devices Control



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Figure 57

**DESCENT ENGINE HELIUM PRESSURIZATION VENT  
FUNCTIONAL BLOCK DIAGRAM**

Panel VIII (Figure 43)(See Figure 58 for a functional block diagram of the Ascent engine propellant pressurization.) In addition, the control relays for the helium tank squid valves and the compatibility valves can be energized from a direct signal from the "ABORT STAGE" switch. The "ASCENT" He Press. switch consists of two SPDT switch modules actuated by a common two-position lever-locking toggle mechanism that has a maintain in the SAFE and momentary in the FIRE position. Setting the "ASCENT" He Press. switch to FIRE enables 28 volts DC power to flow from EPS Systems A and B to the coils of control relays K10 and K11, depending upon the "ASC He SEL" switch setting, and Relay K12. Energizing the coils of these relays closes the relay contacts and enables 24 volts DC power to flow from the ED Battery Bus to the helium tank squid valve initiators and the compatibility valve initiators. Firing the initiators in the valves (one is sufficient to accomplish the task) will open the valve in the same manner as previously described under RCS engine propellant helium pressurization.

#### ASCENT ENGINE HELIUM TANK SELECT CONTROL

The "ASC He SEL" switch, on the Explosive Devices Panel VIII (Figure 43), is a three-position switch with lever-locking mechanisms in all positions. Setting the Tank Select Switch to "TANK 1" enables 28 volts DC power from the switch to close the contacts of Control Relay K10. The contacts are in series with the initiators used for Helium Tank No. 1 squid valve. Setting the switch to BOTH enables 28 volts DC power from the switch to close the contacts of Control Relays K10 and K11. This completes the circuits to fire the initiators of both tanks. Setting the switch to TANK 2 enables 28 volts DC power from the switch to close contacts of Control Relay K11. The contacts are in series with the initiators used for Helium Tank No. 2 squid valve. After firing, the helium tank squid valve remains OPEN and cannot be closed. (Figure 58)

#### Operation and Function

"MASTER ARM" switch ON

"ASCENT" He Press switch FIRE.

28 volts DC (EPS Buses) energizes either or both Relays K10 and 11 also K12. (Relays K10 and K11 are energized depending upon the position of the tank selector switch "ASC He SEL")

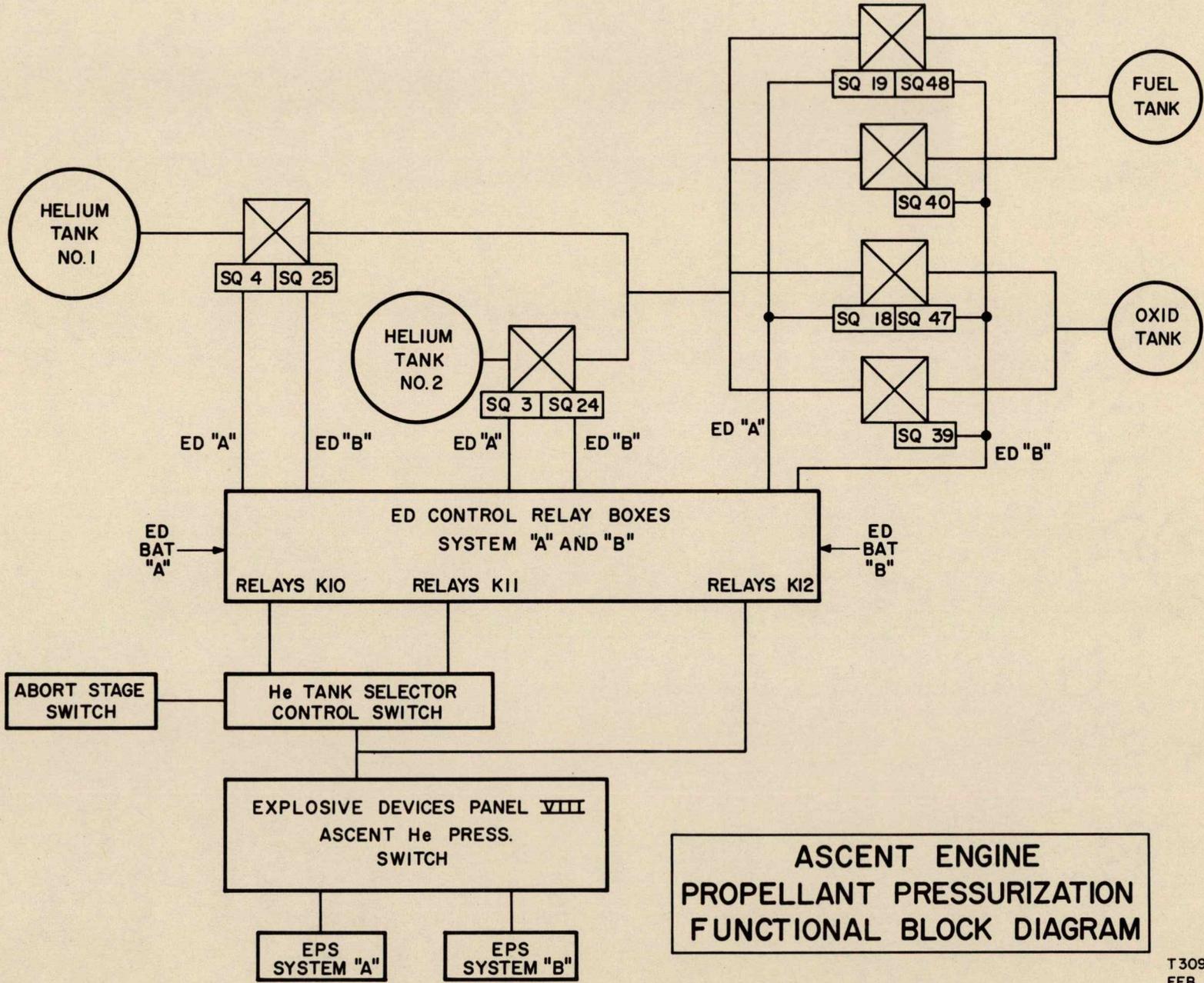
Relays K10 and K11 energized supply 24 volts DC (ED buses) to fire helium tank squid valves.

Relay K10 fires SQ4 and SQ25

Relay K11 fires SQ3 and SQ24.

Relay K12 energized supplies 24 volts DC (ED Buses) to fire all compatibility valves, SQ 19 and 48, SQ40, SQ18 and 47, and SQ39.

"MASTER ARM" switch OFF.



**ASCENT ENGINE  
PROPELLANT PRESSURIZATION  
FUNCTIONAL BLOCK DIAGRAM**

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Figure 58

NOTE: All Relays and Valve Initiators can be energized and fired from a signal from the "ABORT STAGE". This will bypass the normal "MASTER ARM" switch and "ASCENT" He Press. switch.

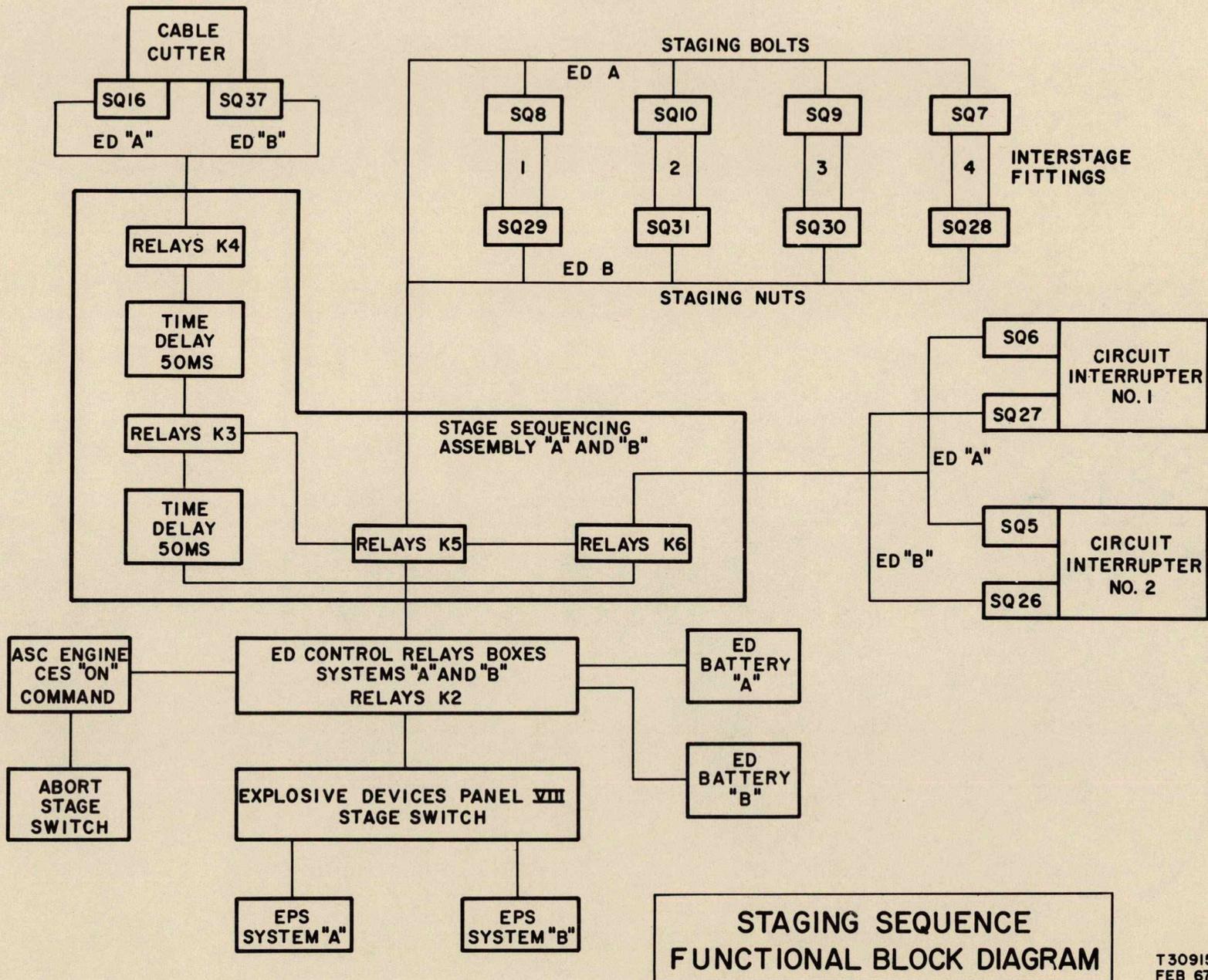
#### STAGE SEPARATION AND COMPONENTS

Stage separation necessitates disconnecting the interstage structural nuts and bolts, interrupting all the live circuits between the Ascent and Descent Stages, and severing the interstage umbilical cable. This is accomplished by initiators fired by operation of the STAGE switch on the ED Control Panel (Figure 43) or the ABORT STAGE switch on the Commander's Center Panel. Operating either of these switches will fire the initiators on the four interstage nuts and bolts, the two circuit interrupters, and the cable cutter assembly, in their proper sequence. (Figures 40, 41 and 42 show locations.)

Setting the STAGE switch to FIRE enables 28 volts DC power from the EPS Systems A and B to the set coils of latching relays K2. (See Figure 59 for a functional block diagram of stage separation.) Staging Relay K2 contacts close, connecting the ED stage sequencing circuits to the buses passing 24 volts DC through a normally closed contact of Relays K3, energizing relays K5, for the interstage nuts and bolts, and relays K6, for the circuit interrupters. Staging Relays K3 and K4 do not operate immediately due to the time-delay circuitry. A time delay is necessary to ensure removal of all ED power from the interstage umbilical before cutting the umbilical. After a 50 millisecond time delay, transistors Q1 and Q2 conduct and permit 24 volts DC battery power to energize Relays K3; the contacts of K3 close and open its normally closed contact de-energizing Relays K5 and K6. With all the contacts of K3 closed, but one, places them in series with another 50 millisecond time delay circuit. Control Transistors Q3 and Q4 will then permit 24 volts DC battery power to energize Relays K4; closing K4 contacts will fire the initiators of the umbilical cable cutter. (See Wiring Diagram Figure 60.)

Staging operations are sequenced as follows: Stage Delay Circuit System A - Ascent Circuit Interrupter Relay K6 and Relay K5 for the interstage BOLT, Relay K3 and cable cutter Relay K4; stage delay circuit of System B - Ascent Circuit Interrupter Relay K6 and Interstage NUTS Relay K5, Relay K3 and cable cutter Relay K4.

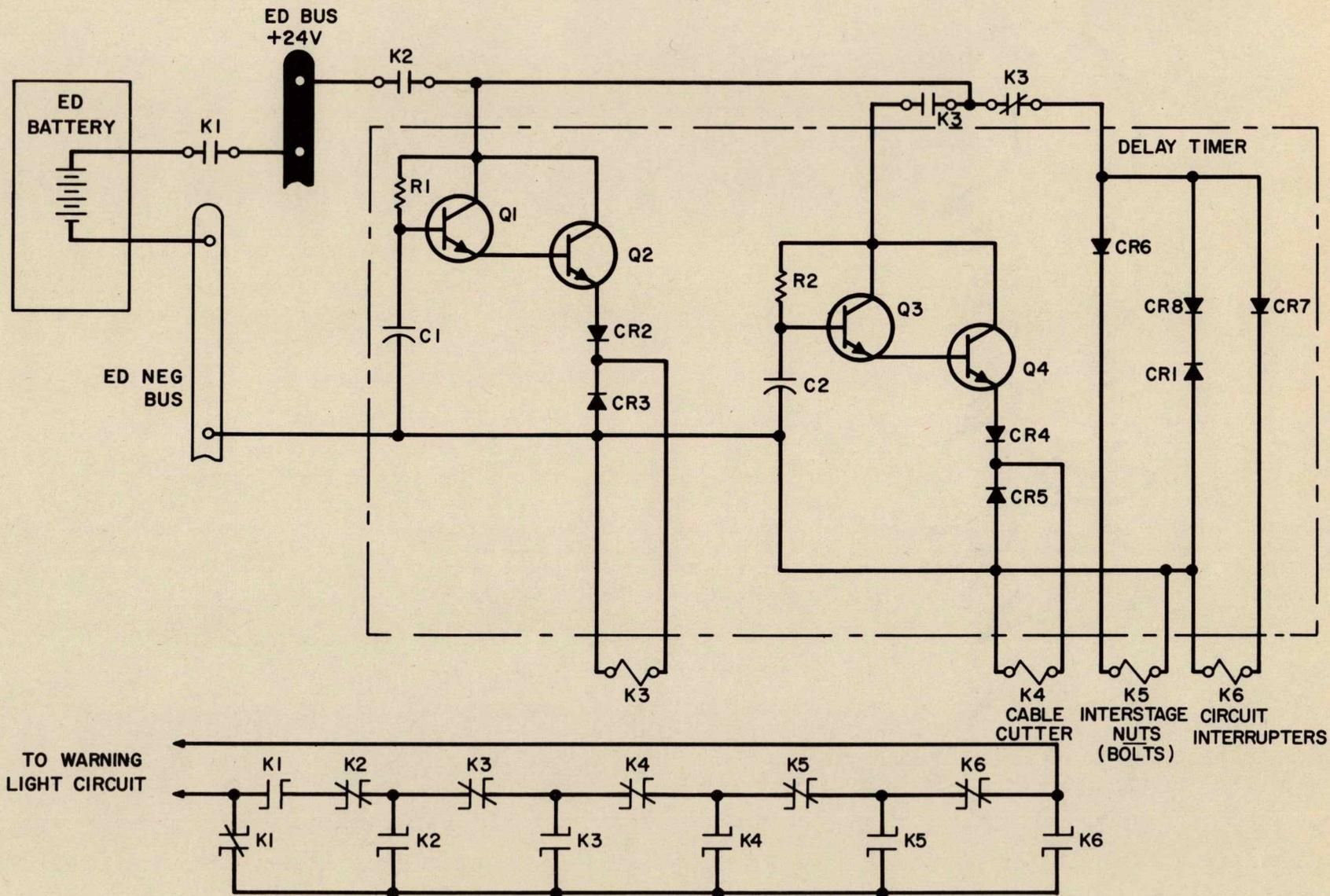
Staging operation may also be initiated by operation of the ABORT STAGE switch. Pressing the ABORT STAGE switch sets up the following sequences:



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Figure 59

**STAGING SEQUENCE  
FUNCTIONAL BLOCK DIAGRAM**



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Figure 60

**STAGE SEQUENCE DELAY CIRCUIT AND WARNING LIGHT CIRCUIT**

Start abort stage program in LGC and AGS

Switches to ascent electrical power

Inhibits descent engine ARM

Arms ascent engine

Sets logic to accept engine fire command

The ED batteries are placed on the ED Bus by energizing Relays K1 by passing the MASTER ARM switch. On ascent engine ON command a signal (28 volt DC) is sent energizing Relays K2 (staging relays) starting staging sequency by bypassing the STAGE switch.

Operation and Function:

"MASTER ARM" switch ON

"STAGE" switch FIRE

28 volts DC (EPS buses) energizes Relays K2  
Relays K2 energized close contacts allowing  
24 volts DC (ED Buses) to energize Relays K5 and  
K6; Relays K3 are energized after a 50 millisecond  
delay.

Relays K5 energized supply 24 volts DC (ED Buses)  
to fire the interstage nuts and bolts initiators.  
(Fire in 15 milliseconds) Nuts SQ28, SQ29, SQ30  
and SQ31. Bolts SQ7, SQ8, SQ9 and SQ10

Relays K6 energized supply 24 volts DC (ED Buses) to  
fire circuit interrupters. (Fire in 20 milliseconds)  
SQ5, SQ6, SQ26 and SQ27.

After 50 milliseconds Relay K3 is energized allowing  
24 volts DC (ED buses) to energize Relay K4 through  
an additional 50 millisecond time delay.

Relay K3 energized opens contacts to Relays K5 and K6  
deenergizing them.

After 50 milliseconds Relays K4 energize allowing 24  
volts DC (ED Buses) to fire the umbilical cable cutter.  
(Fire in 25 milliseconds) SQ16 and SQ37.

"MASTER ARM" switch OFF

Abort Stage Sequence:

"ABORT STAGE" switch PRESS

28 volts DC (EPS Buses) starts the following sequence.  
Start Abort Stage Program in LGC and AGS switches  
to Ascent Electrical Power inhibits Descent Engine Arm

Arms Ascent Engine.

Sets Logic to accept engine fire command.

Ascent engine ON command signal energizes Relays K2 starting staging sequence as above.

#### WARNING LIGHTS:

A series of warning lights are incorporated within the circuitry of the relays of the Stage Sequencing Assembly. Relays K1, K2, K3, K4, K5 and K6 will effect the operation of the lights (Figure 60). The lights are located as follows: one light, "ED RELAYS", is on the Annunciator Panel of the System Engineer's Center Panel II; there are two yellow warning lights on the ED Panel VIII one for System "A" and one for System "B".

In the event of a malfunction of one of the relays, during stage sequencing, the "ED RELAYS" warning light will illuminate and the yellow warning light will illuminate indicating the system the malfunction has occurred.

Should a warning light come ON during stage sequencing; set the STAGE switch to OFF, set the "STAGE RELAY" switch to RESET then OFF. This will reset Relays K2 to its original position. By putting the "STAGE" switch to the FIRE position again, the stage sequencing will start up again. This will afford the malfunctioning relay the possibility of freeing itself.

It should be noted though, that if only one light on the ED Panel (either System A or B) illuminates, the staging will be complete as all components will be fired by the other system. All the components have the capability of complete operation by the firing of only one initiator.

#### INTERSTAGE STRUCTURAL CONNECTIONS (NUTS AND BOLTS)

The LM uses four nuts and bolts (Figures 47, 48 and 49) for interstage structural connections. These nuts and bolts are explosively actuated for ascent and descent stage separation. When one or both initiators are fired, expanding gasses force a piston to compress within the nut or bolt. This results in fracture and separation of the bolt; the force will split and separate the thread end of the nut. Reaction time for complete nut and bolt separation is approximately 15 milliseconds.

Power for the firing control circuit is controlled by the stage sequencing circuitry which energizes relays K5, firing the initiators of the nuts and bolts. ED System "A" will fire the initiator of the bolt, while System "B" will fire the initiators of the nuts. Firing of either the nut or bolt will allow proper stage separation.

#### CIRCUIT INTERRUPTERS

Two circuit interrupters (Figure 46) are used, these are in the Ascent Stage. They are located in front of the Ascent Stage tank thermal shielding; immediately above Quadrant IV of the Descent Stage. Each circuit interrupter uses two ASI's installed in their mounting ports in an aluminum housing. Two dual initiators are used in each circuit interrupter for redundancy.

To activate a function, the initiators are energized during staging operation, when Relays K6 are energized. When energized, it causes a pressure buildup in the circuit interrupter combustion chamber. As pressure builds up in the chamber, two closed circuit lockdetents move to their unlocked position. This frees a piston sleeve assembly that permits the sleeve to move when its actuation pressure is reached.

When the pressure in the combustion chamber provides sufficient force to overcome circuit interrupter separation resistance and O-ring friction, a piston ring assembly is forced to the open-circuit position, disconnecting the electrical pins of the electrical connectors. Spring-loaded open circuit lock detent pins automatically retain the piston sleeve in the open-circuit (circuit interrupted) position.

Circuit interruption removes all electrical power from the inter-stage umbilical and provides positive deenergization before the umbilical is cut.

The stage-sequencing circuit controls circuit interrupter operation. If one initiator on the control circuit malfunctions, the other initiator or redundant circuit interrupts the circuit. Normally, both initiators fire. Approximately 260 electrical conductors are routed through each circuit interrupter. The hot circuits and critical circuits are interrupted. Maximum contact (pin to socket) resistance of a mated interrupter is approximately 0.2 ohm with a 30 millivolt open-circuit voltage and a maximum 10 microampere short-circuit current. The interrupter pin connections are normally in the closed position; they are moved to the open position after firing the initiator. Operation response time of circuit interrupters is approximately 20 milliseconds after a 5 ampere DC current is applied to the initiator bridgewire.

#### UMBILICAL CABLE CUTTER:

The cutter assembly (Figure 50) is used to sever the interstage electrical umbilical. The cutter assembly consists of two explosive trains, two cutter blades, a housing, two initiators, and detonator cartridges. One initiator, detonator, and explosive train operates each blade. Operating either blade cuts the interstage umbilical.

The umbilical cutter is used during stage separation operation. The cutter assembly blades are held safe with shear pins that ensure the interstage umbilical will not be cut without a positive fire signal to the control circuit. Firing the initiator generates pressure that forces the cutting blades towards the interstage umbilical. The blade severs the umbilical. Reaction time for cutter assembly operation is approximately 25 milliseconds after a 5 ampere DC current is applied to the initiator bridgewire.

LSG 770-430-29 - LTA-8

**STRUCTURES SUBSYSTEM**

**STUDY GUIDE**

**LUNAR MODULE**

**LTA-8**

**CONTRACT NAS 9-1100**

**EXHIBIT E; PARAGRAPH 3.7.4**

**TYPE III DOCUMENT**

**FOR TRAINING PURPOSES ONLY; IN  
SUPPORT OF LTA-8 SUBSYSTEM BRIEFINGS**

**REFERENCE CF22/T21-67-T471**

**LM TRAINING SECTION  
PRODUCT SUPPORT DEPARTMENT  
GRUMMAN AIRCRAFT ENGINEERING CORPORATION  
BETHPAGE, NEW YORK**

**AUGUST 1967**

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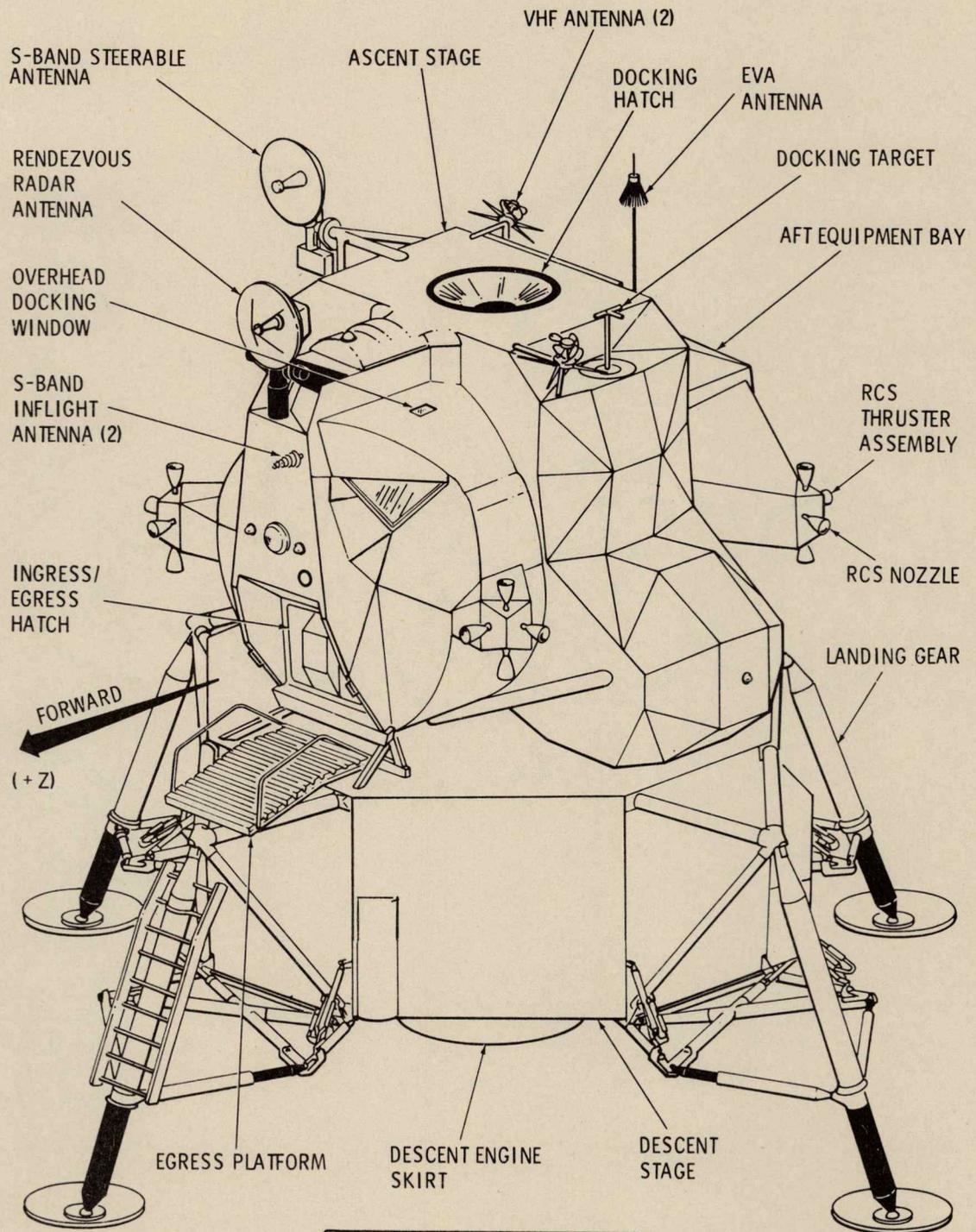
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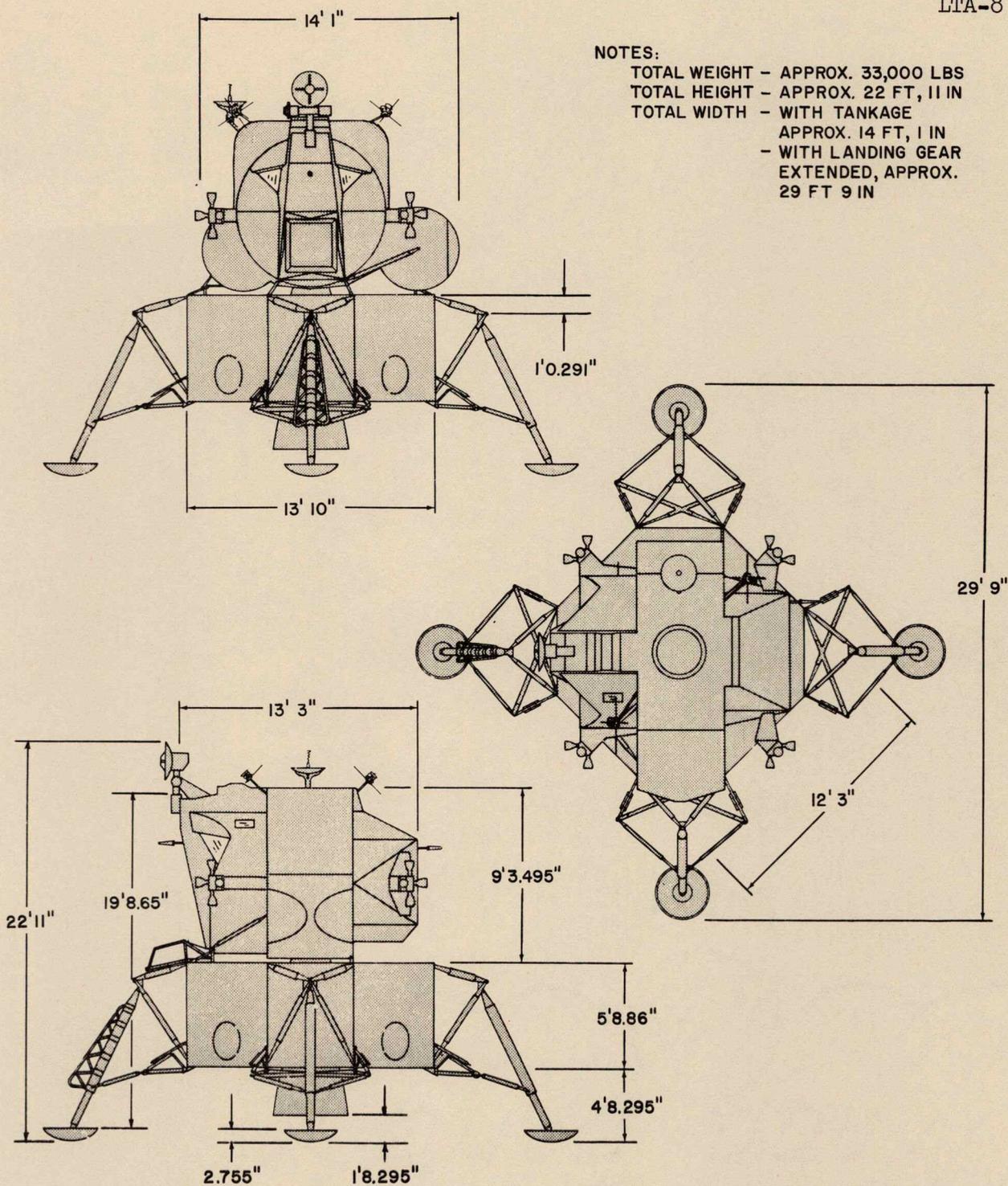


**LM VEHICLE**

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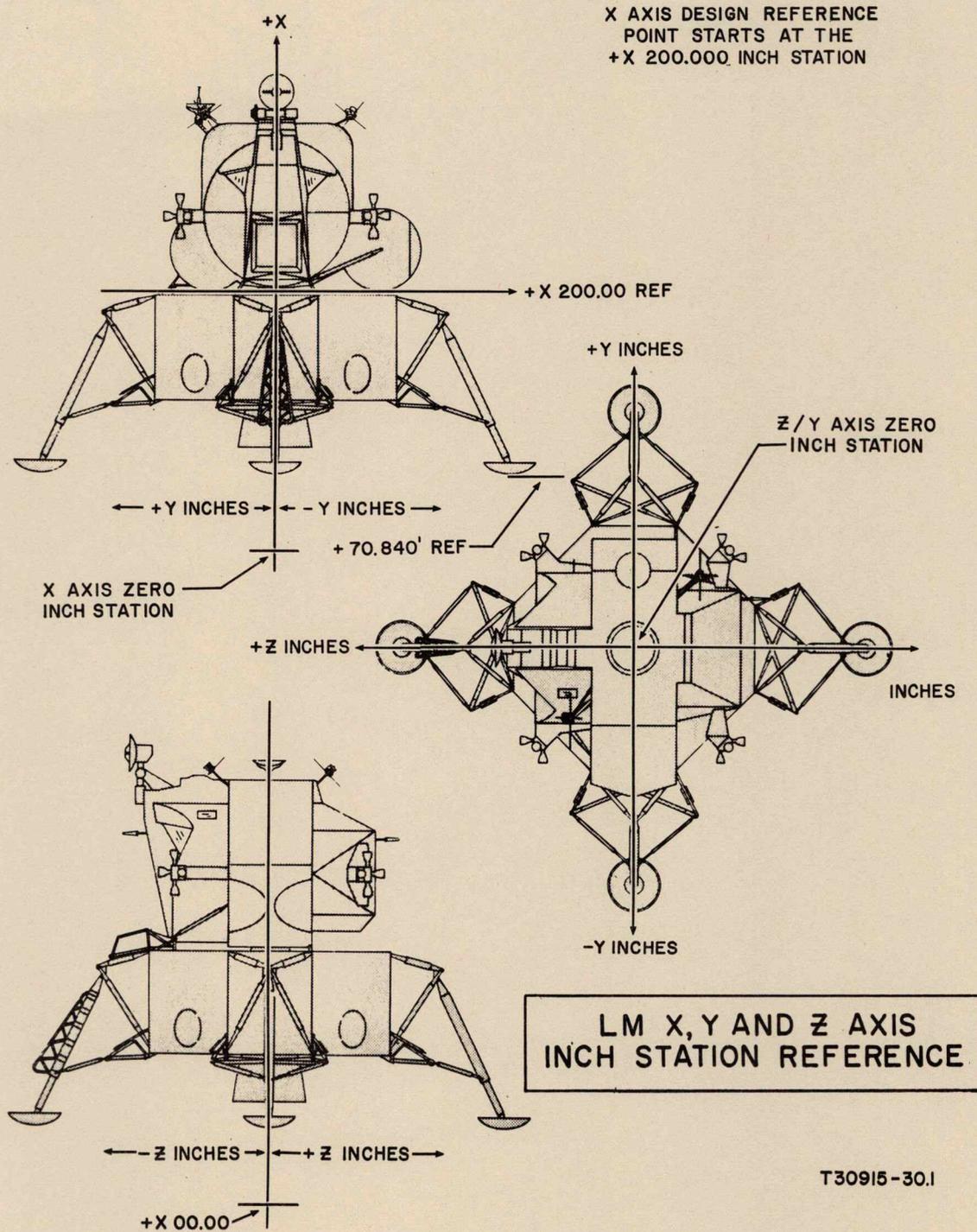
NOTES:

- TOTAL WEIGHT - APPROX. 33,000 LBS
- TOTAL HEIGHT - APPROX. 22 FT, 11 IN
- TOTAL WIDTH - WITH TANKAGE APPROX. 14 FT, 1 IN
- WITH LANDING GEAR EXTENDED, APPROX. 29 FT 9 IN



LM DIMENSIONS

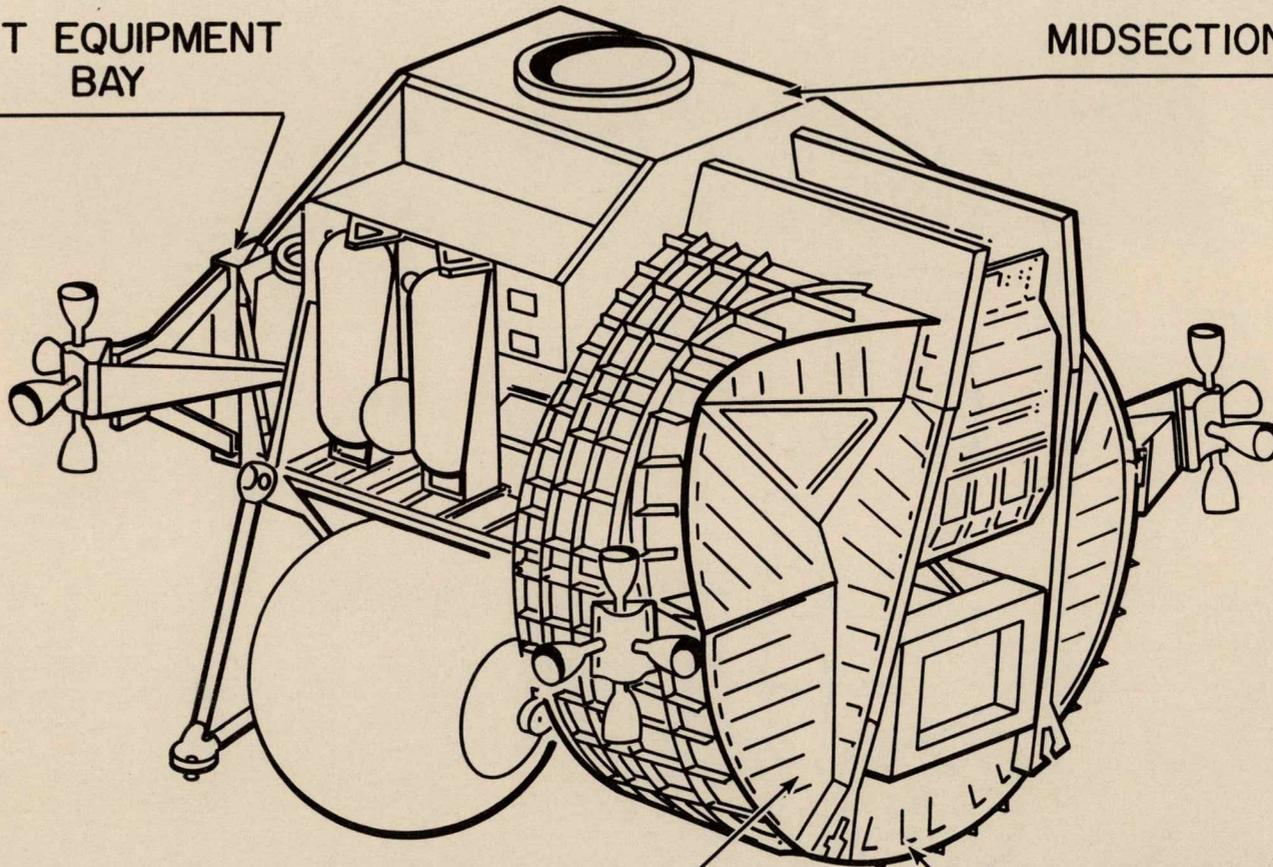
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AFT EQUIPMENT  
BAY

MIDSECTION

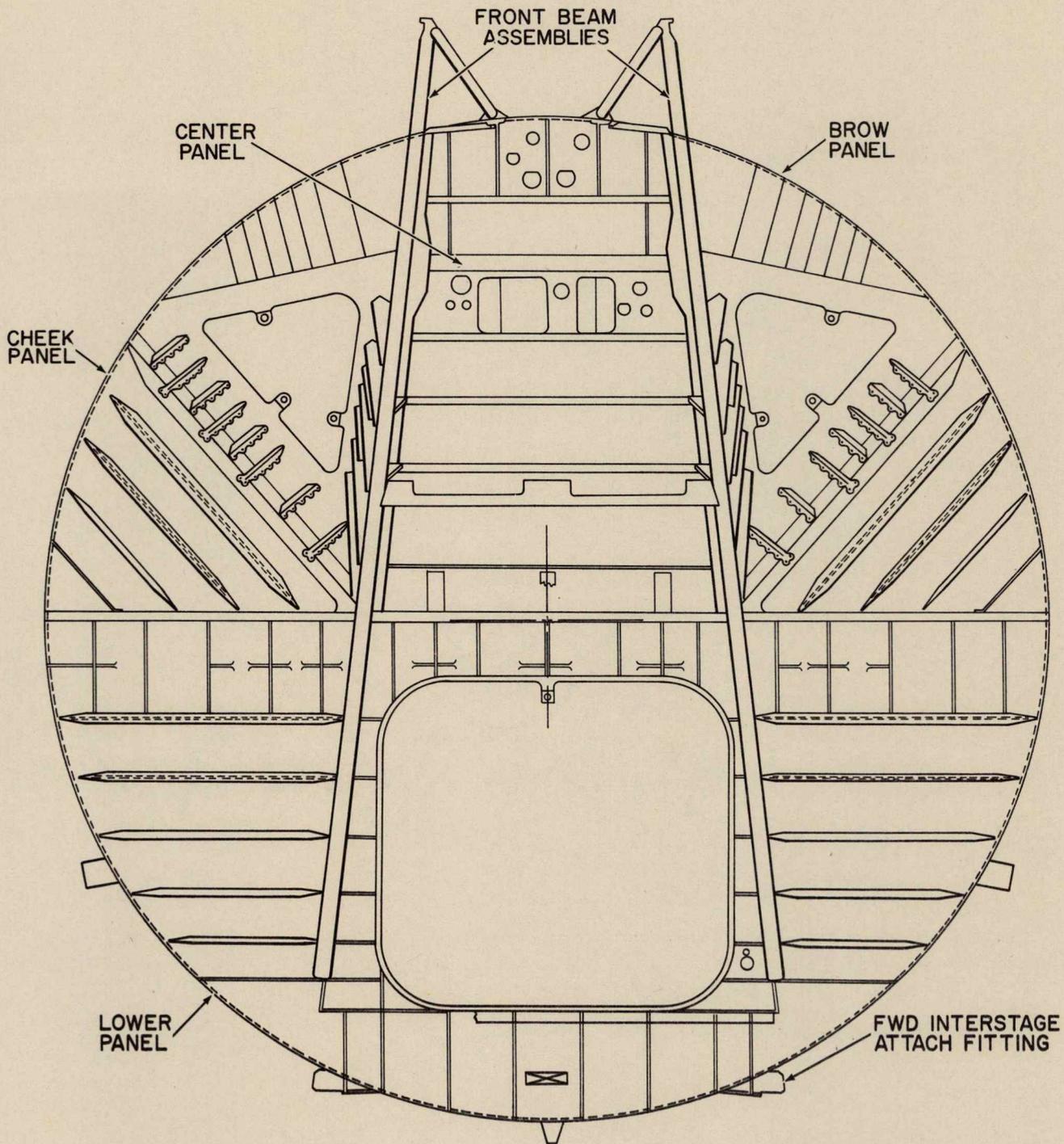


FRONT FACE ASSY

CREW  
COMPARTMENT

LM STRUCTURE

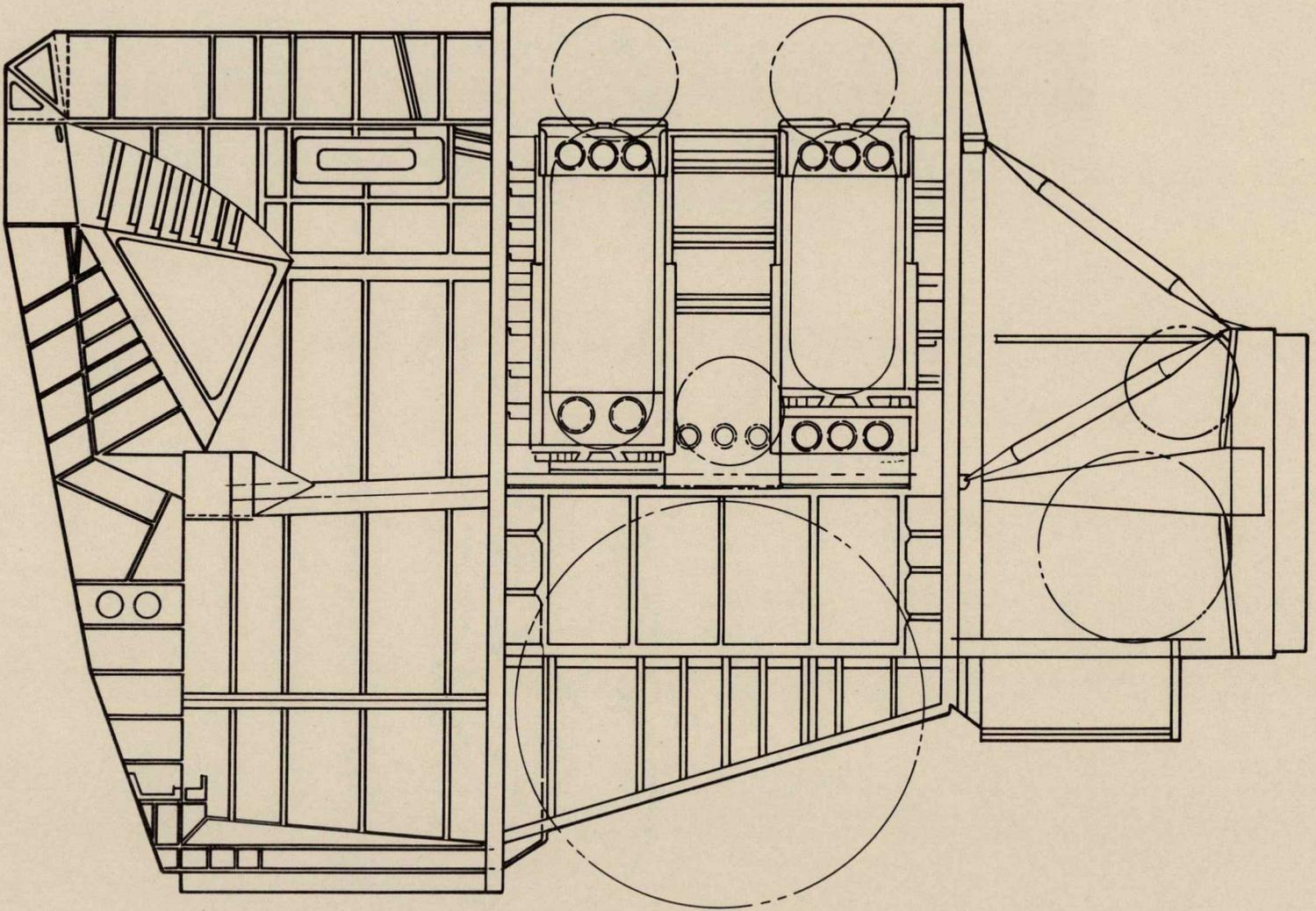
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**FRONT FACE ASSEMBLY**

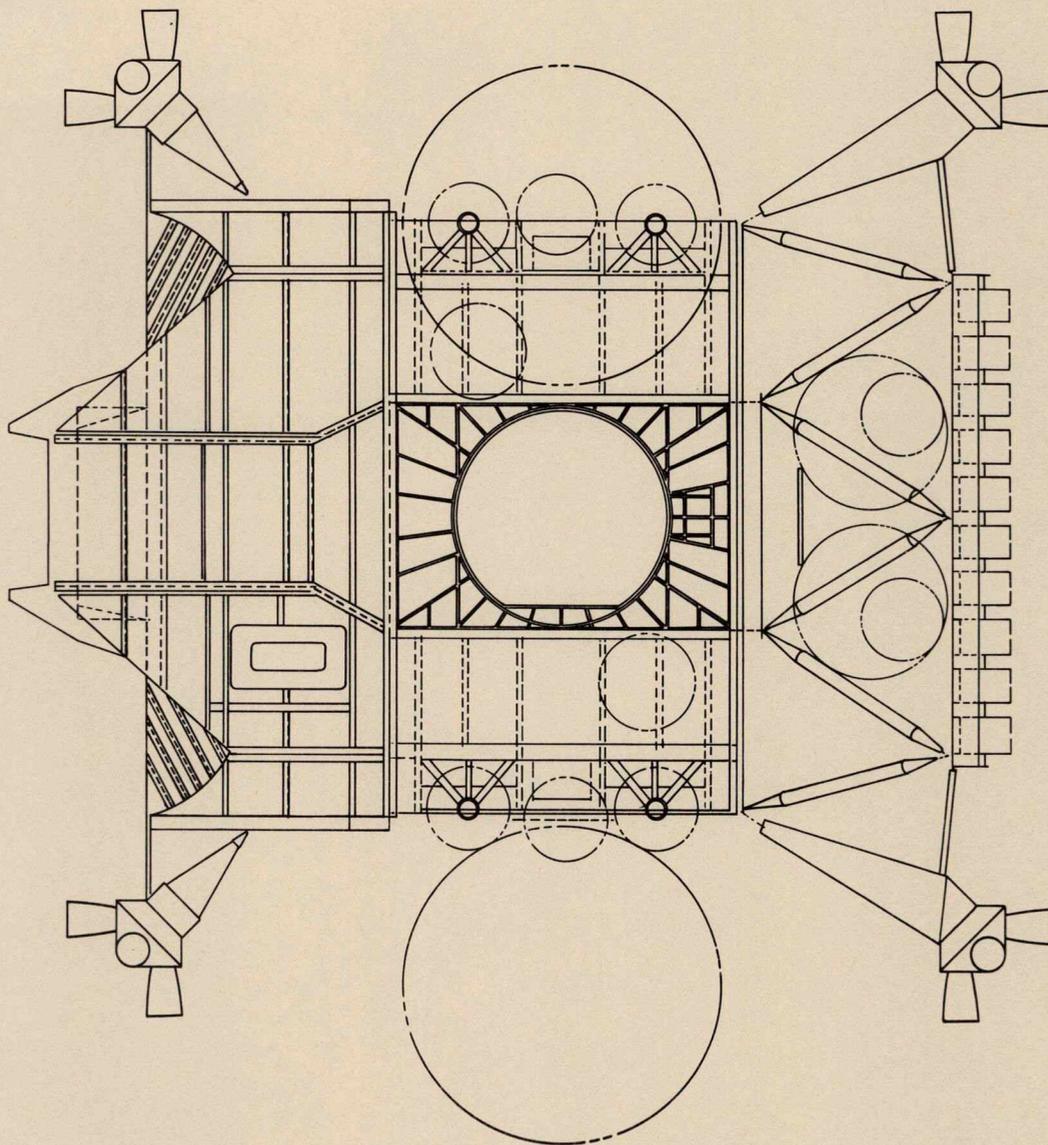
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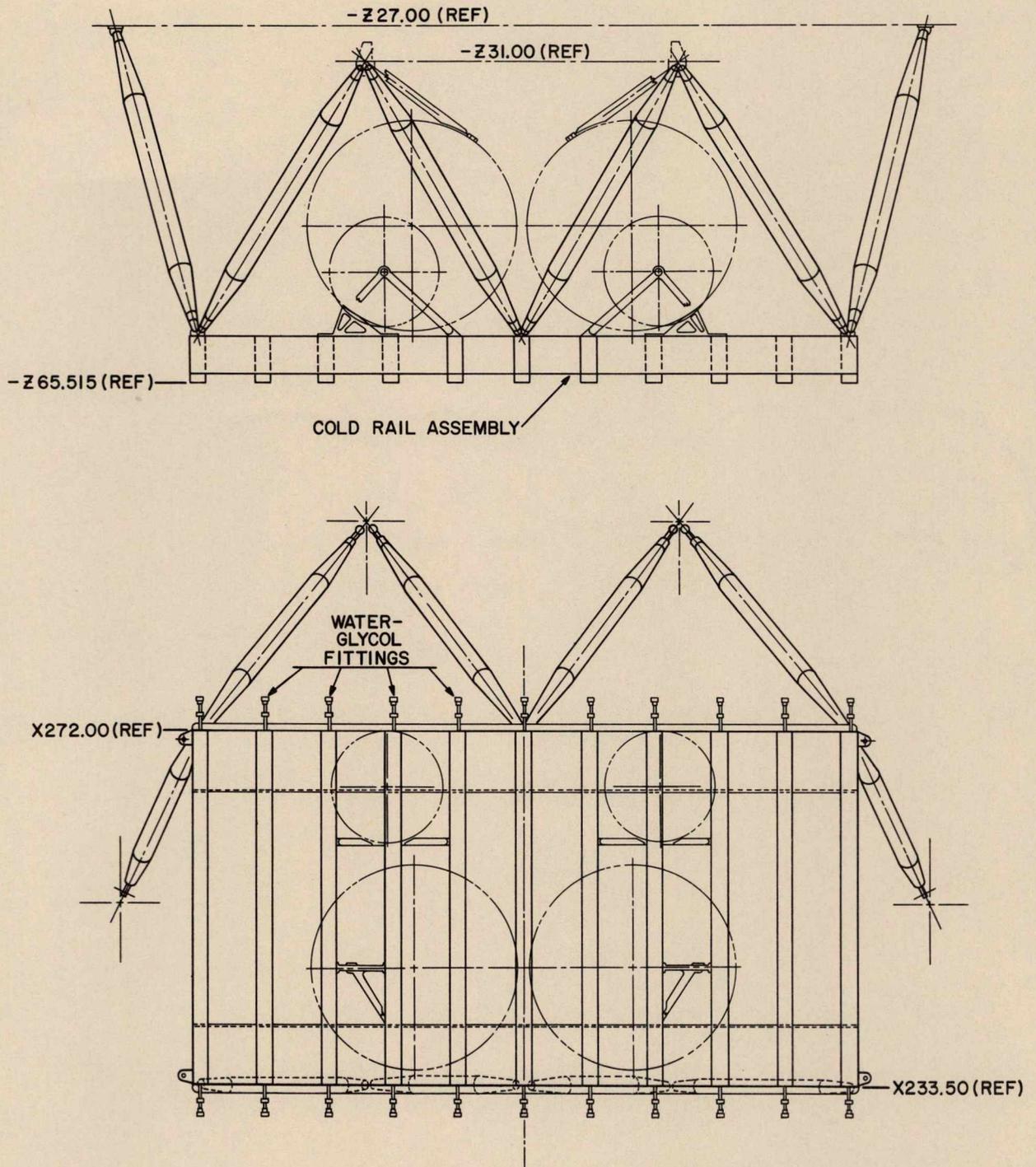
LM STRUCTURE (LEFT SIDE VIEW)

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LM STRUCTURE (TOP VIEW)

T 30915-25.1

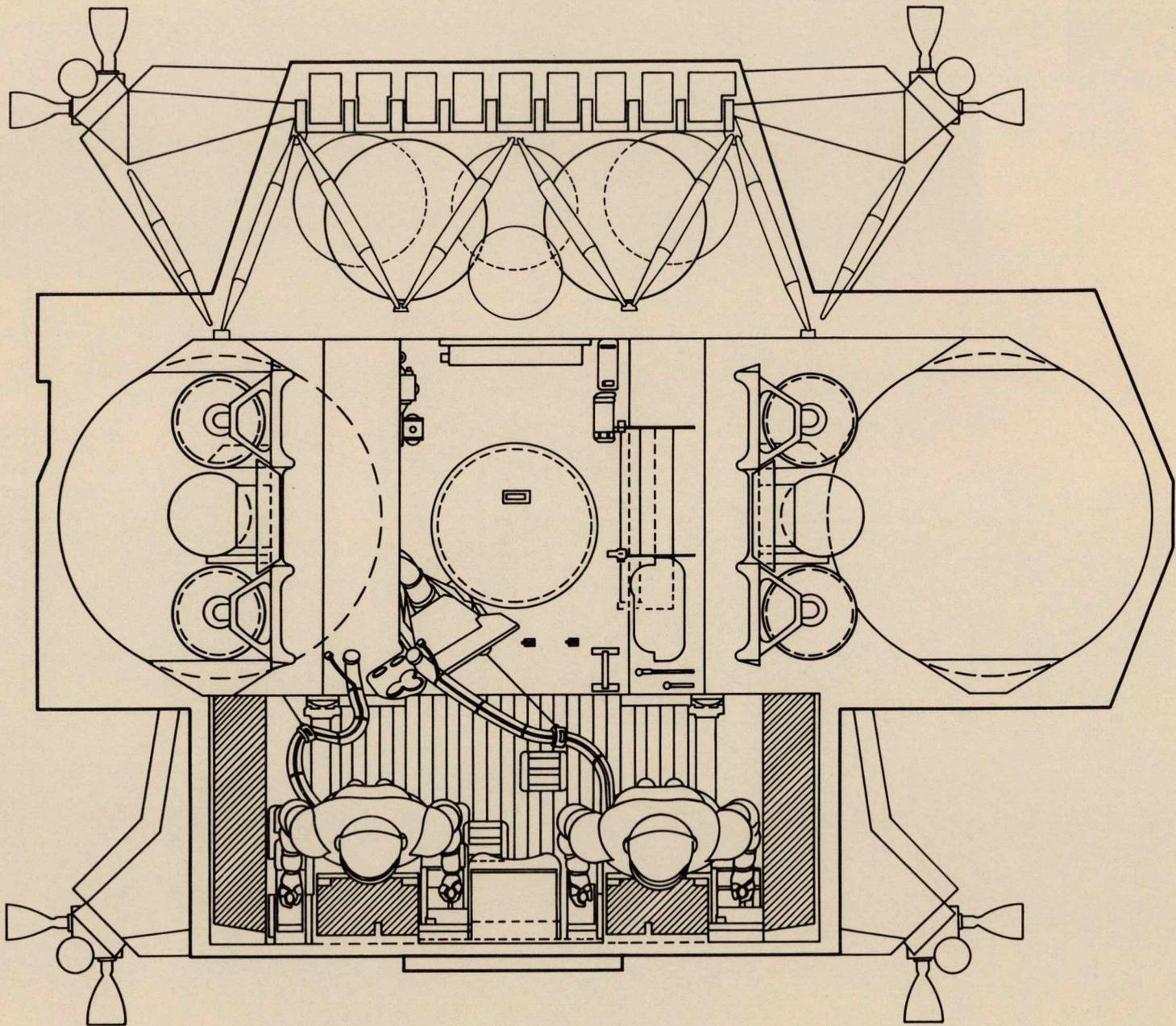


**AFT EQUIPMENT BAY STRUCTURE**

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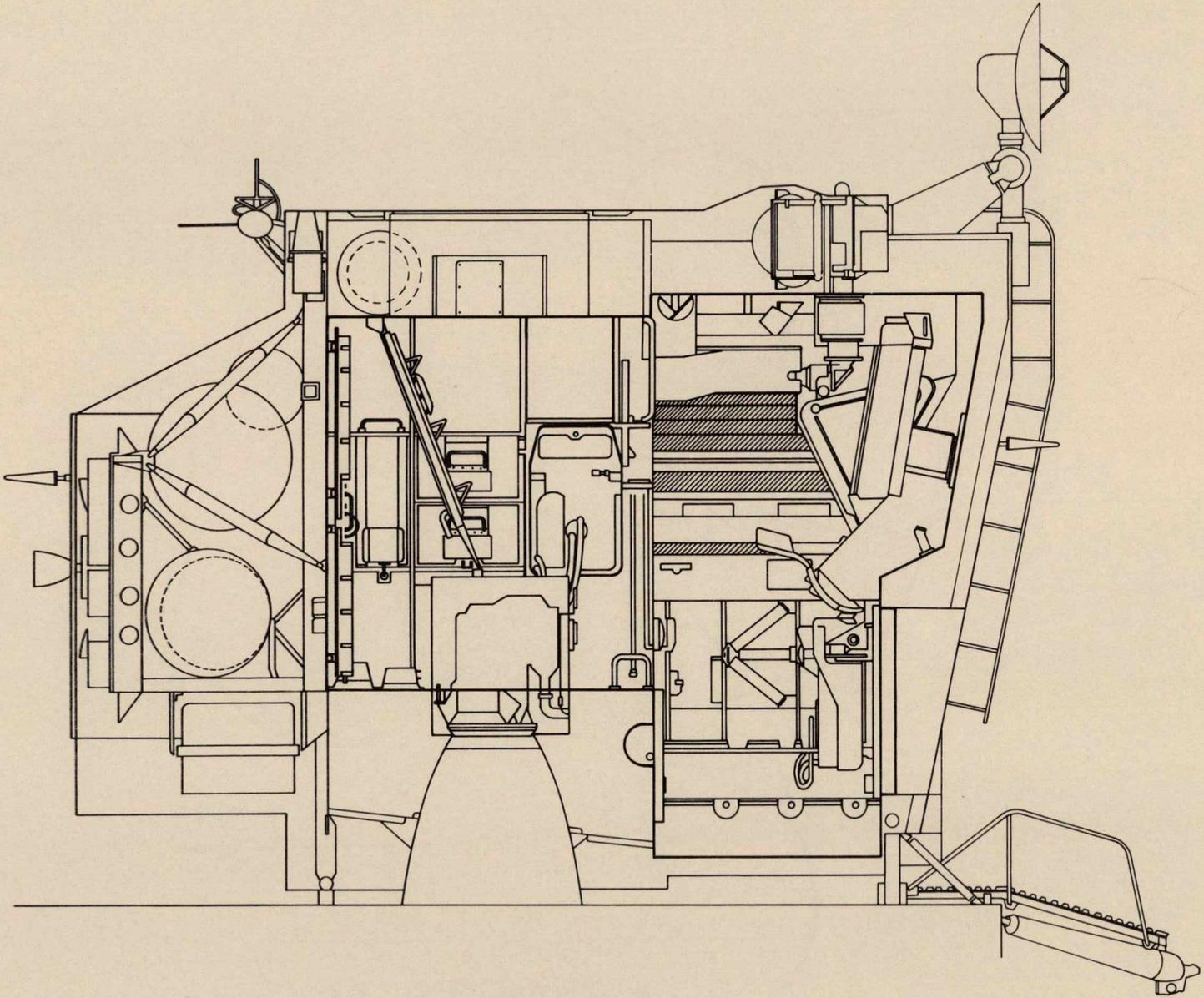
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ASCENT STAGE PLAN VIEW

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LTA-8

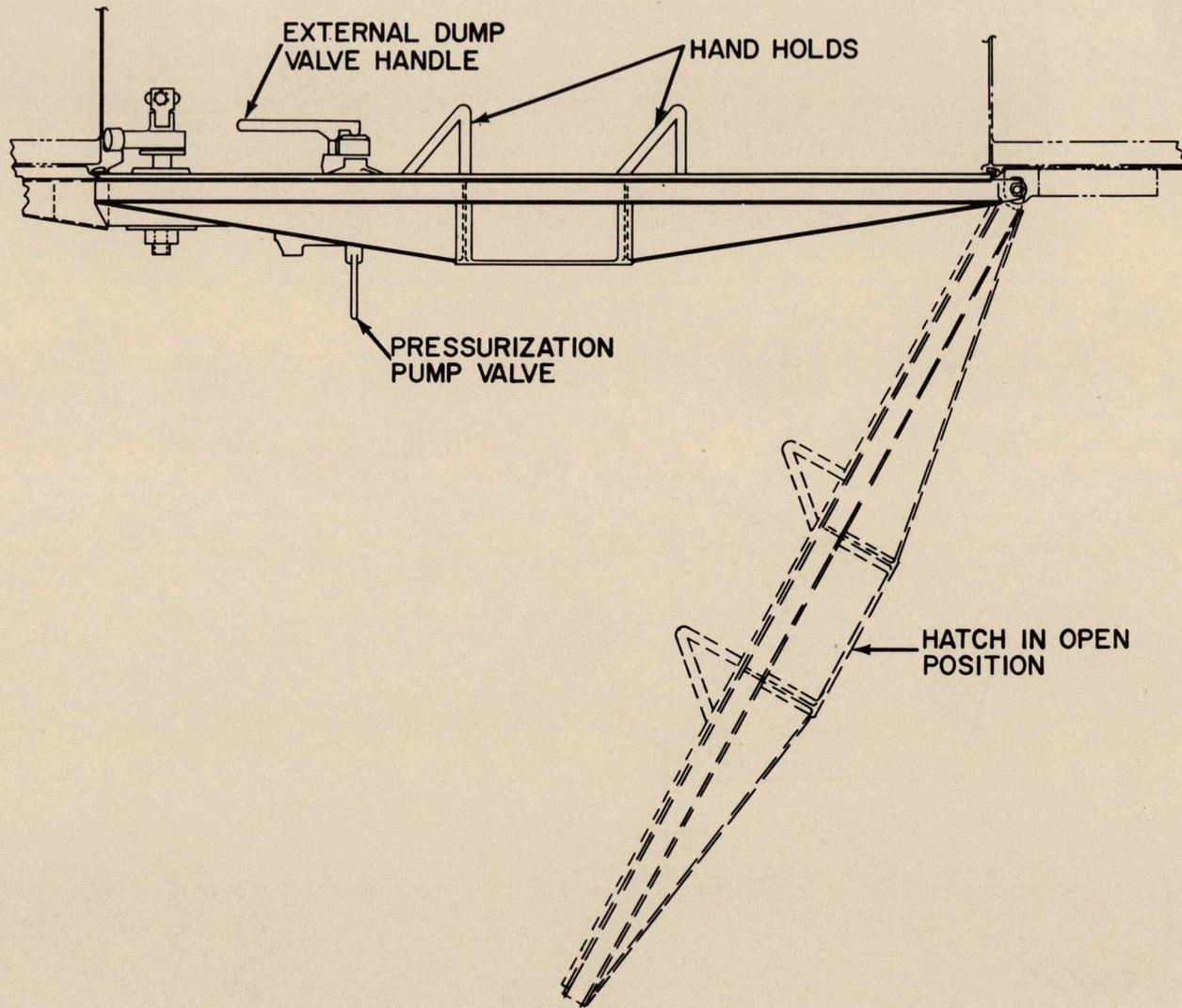


ASCENT STAGE  
CUTAWAY-LEFT SIDE

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Date: August 1967



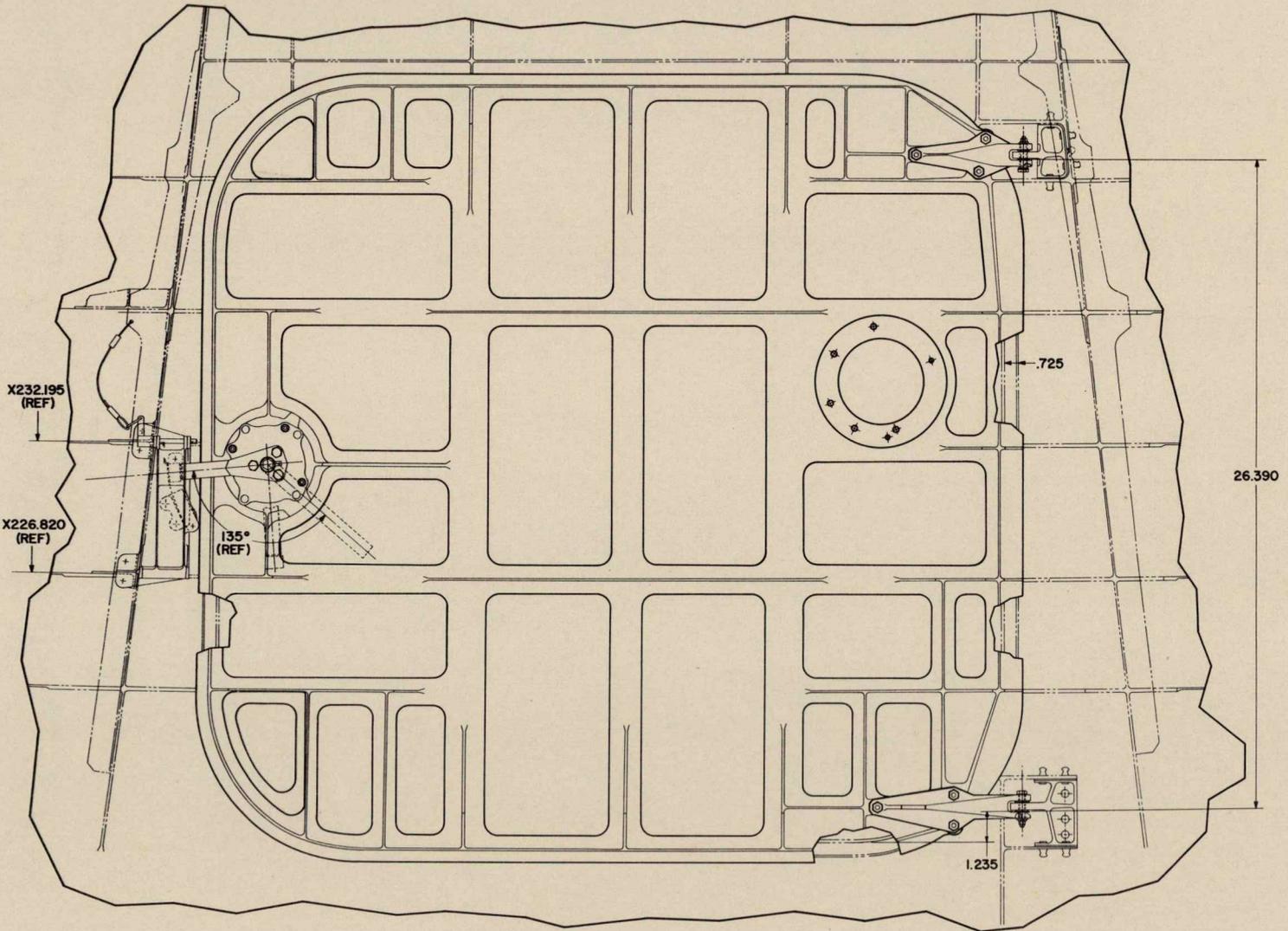
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**DOCKING HATCH**

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LFA-8

Date: August 1967

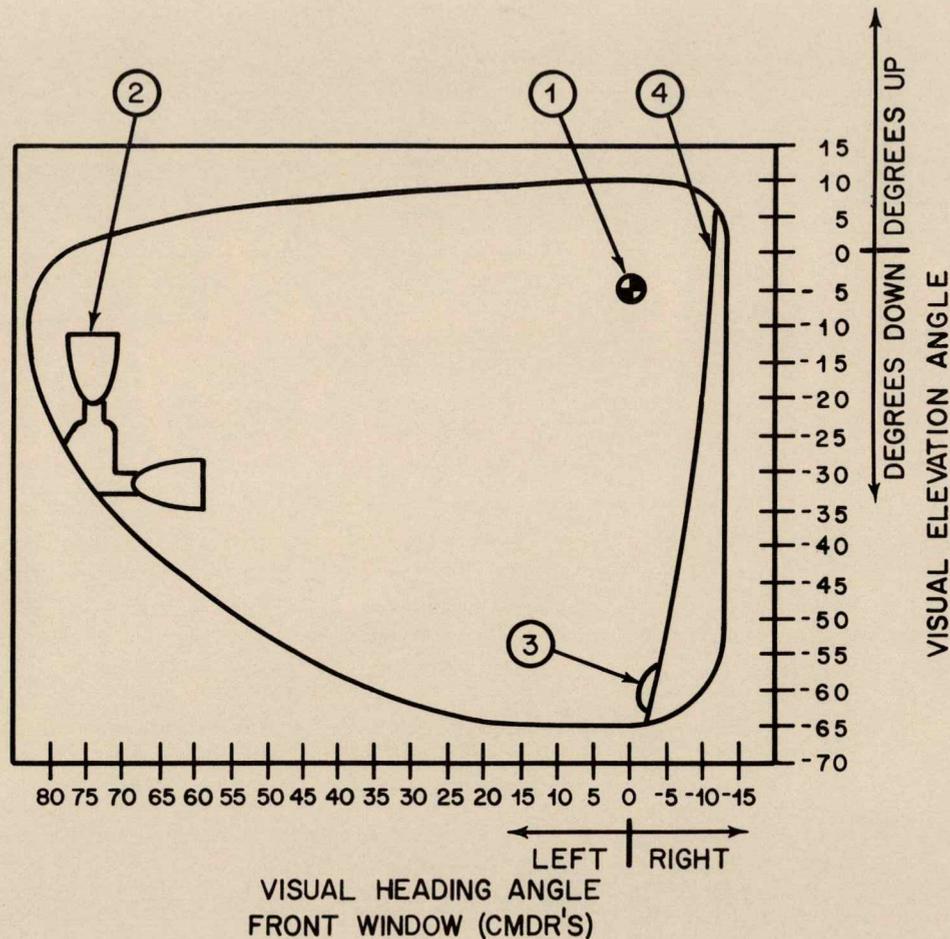


INGRESS/EGRESS HATCH

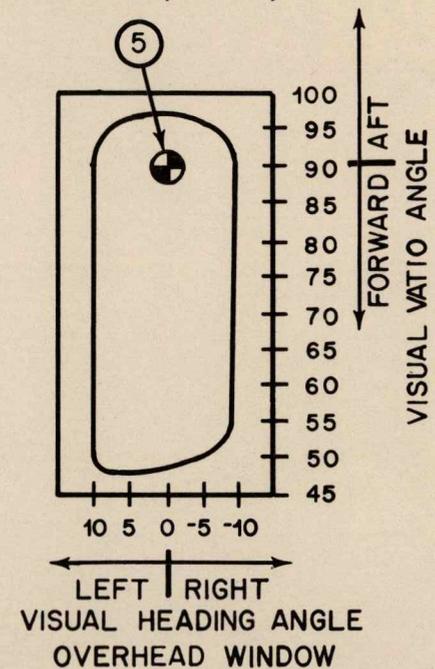
T30915-13.1

LTA-8

Date: August 1967



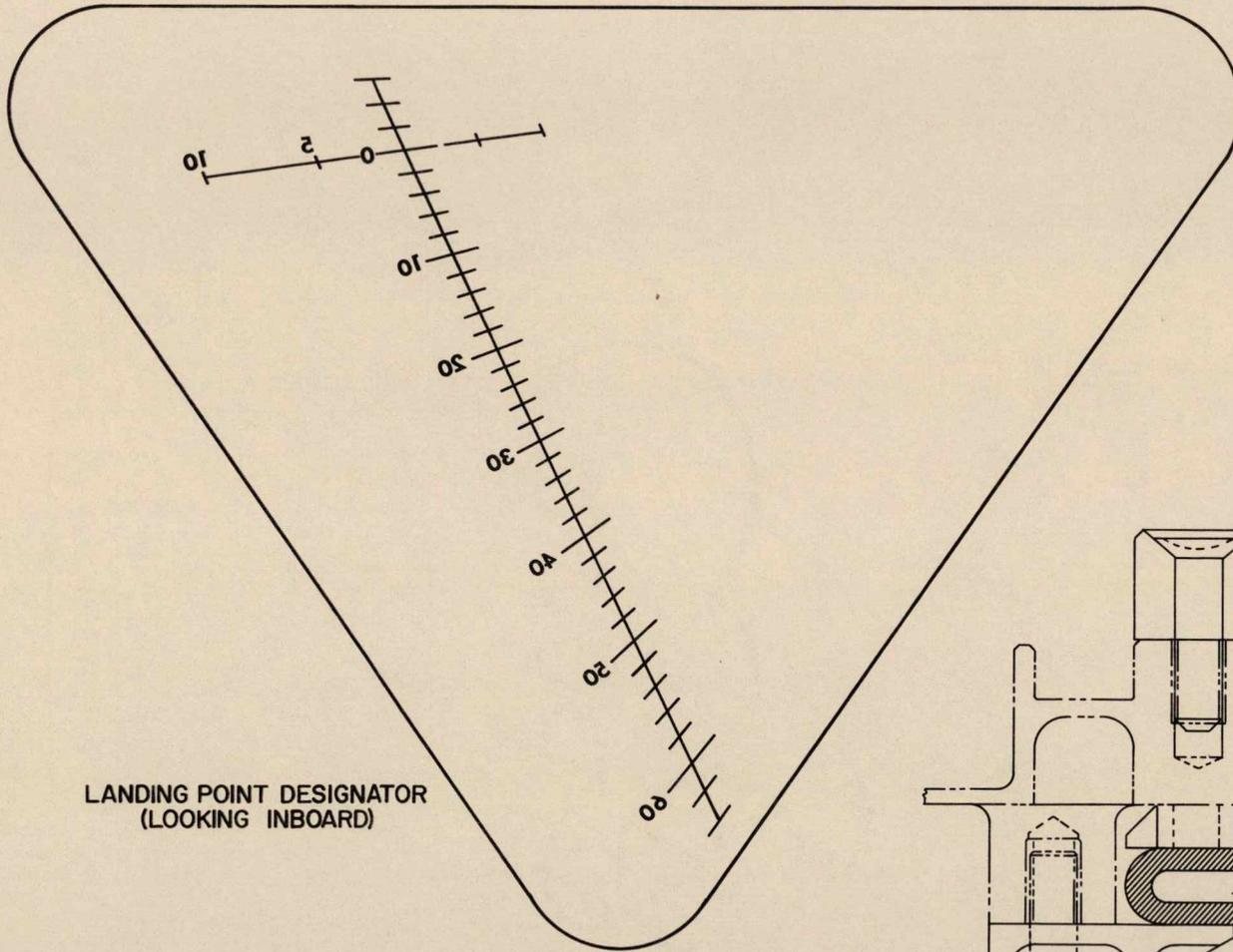
1. CMDR'S DESIGN EYE  
 $\bar{X}=279.25, \bar{Y}=22, \bar{Z}=54$
2. RCS CLUSTER
3. FRONT LANDING GEAR PAD
4. FRONT BEAM
5. CMDR'S DOCKING EYE  
 $\bar{X}=280.375, \bar{Y}=22, \bar{Z}=37.75$



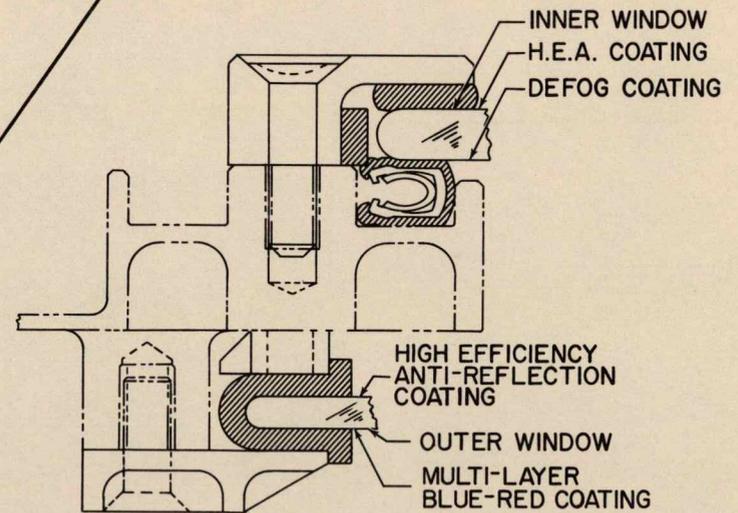
**VISIBILITY DIAGRAM  
FROM COMMANDER'S EYE**

T30915-39.1

Date: August 1967

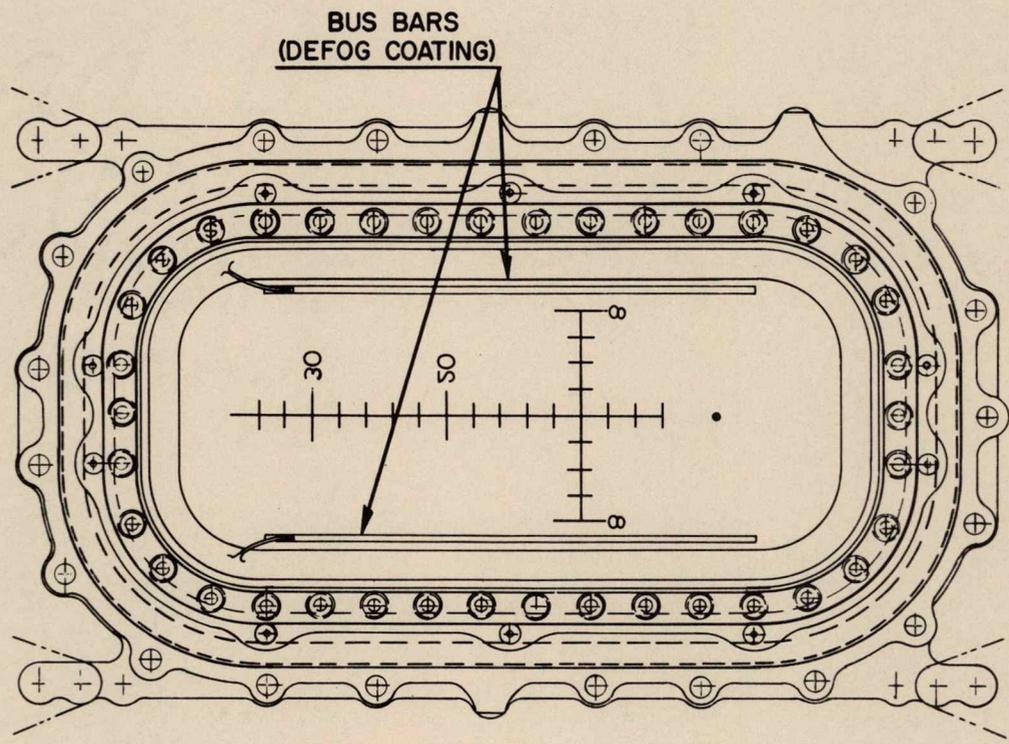
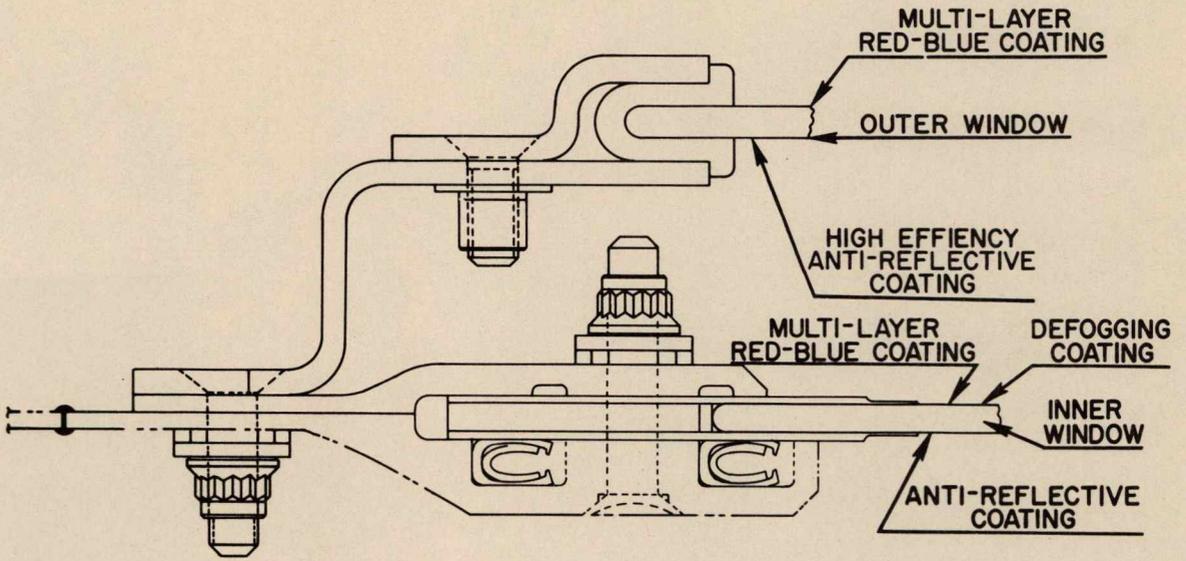


LANDING POINT DESIGNATOR  
(LOOKING INBOARD)



FRONT FACE WINDOW

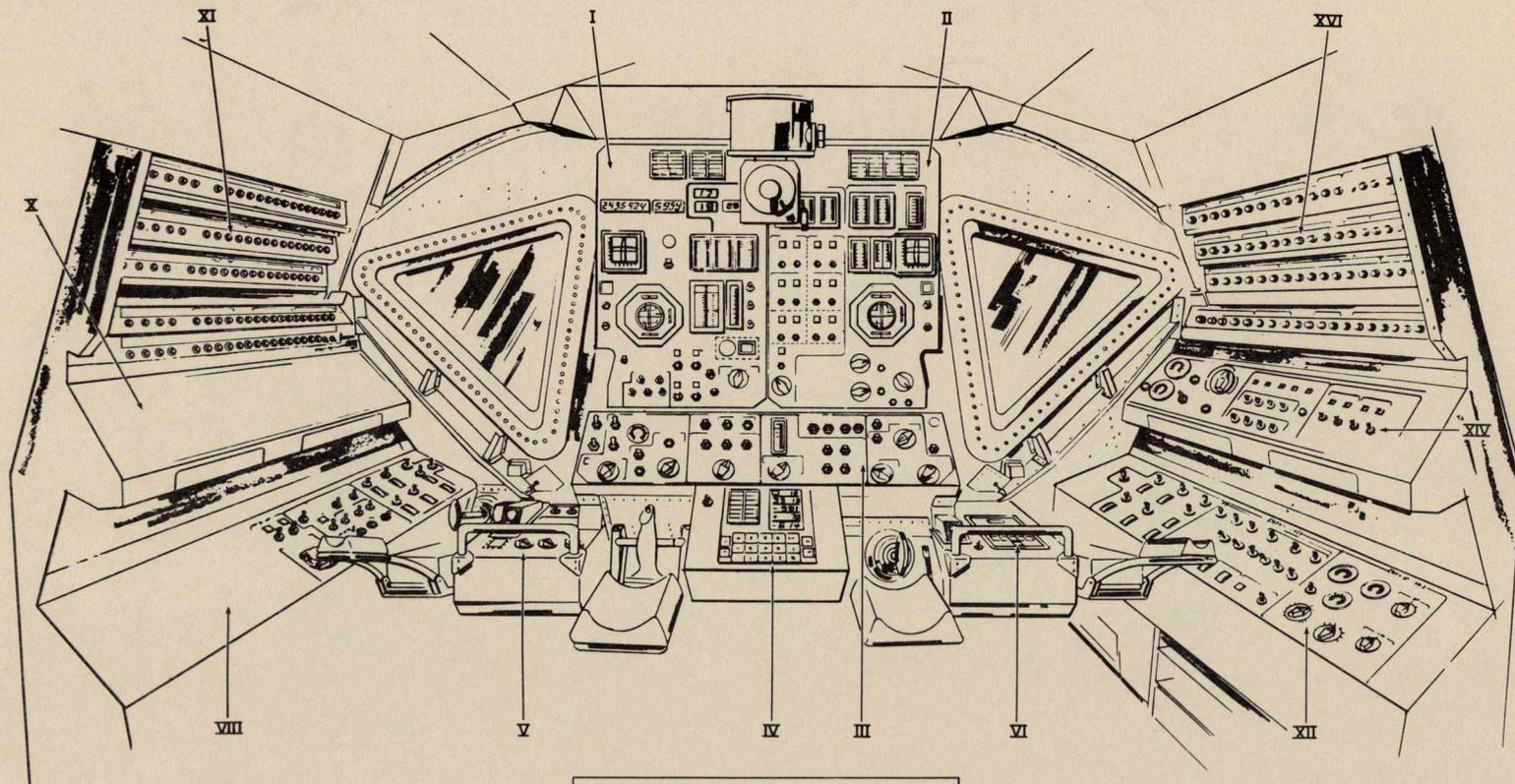
T30915-38.1  
JAN 67



**DOCKING WINDOW**

T 30915-40.1

Date: August 1967

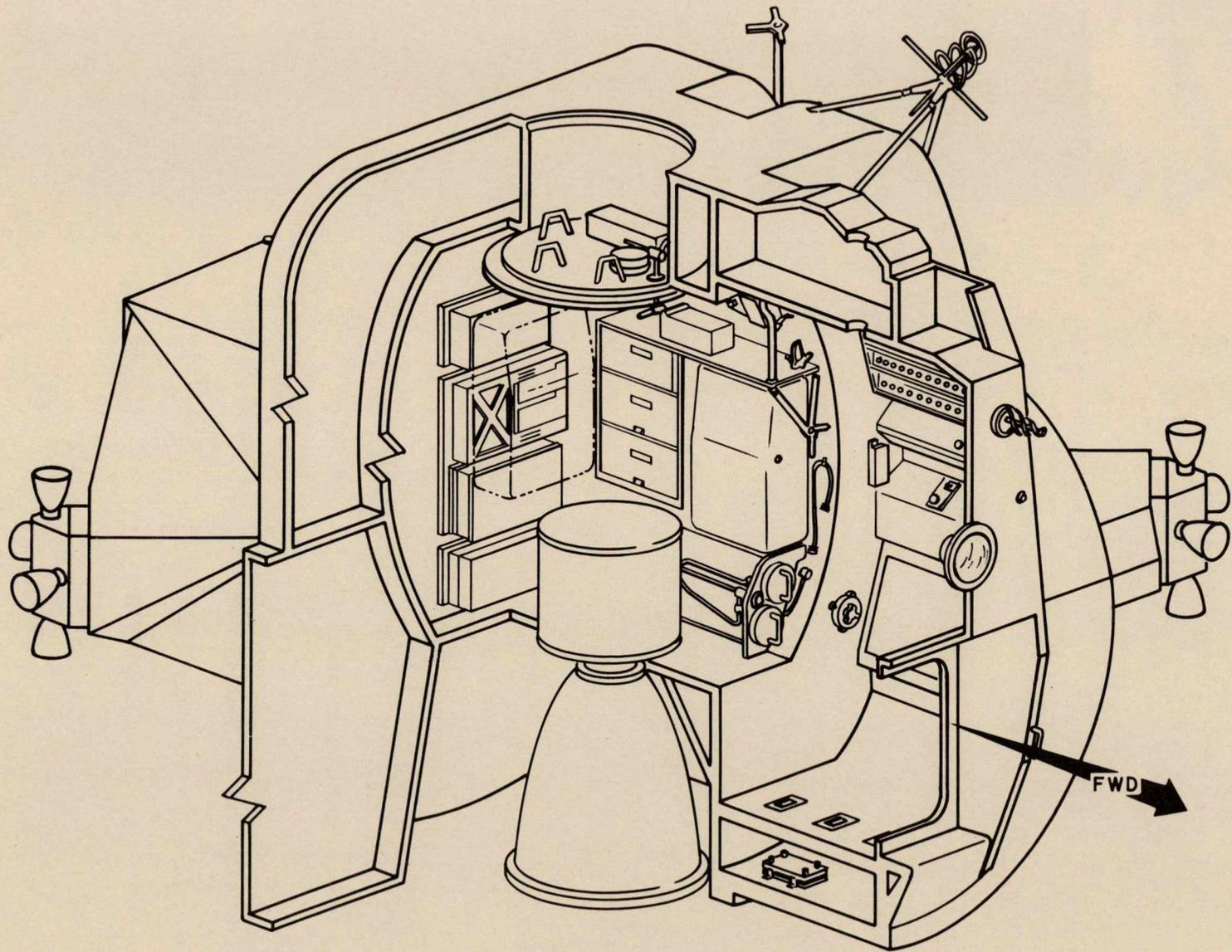


LM DISPLAYS AND CONTROLS

T30005-28.1

LTA-8

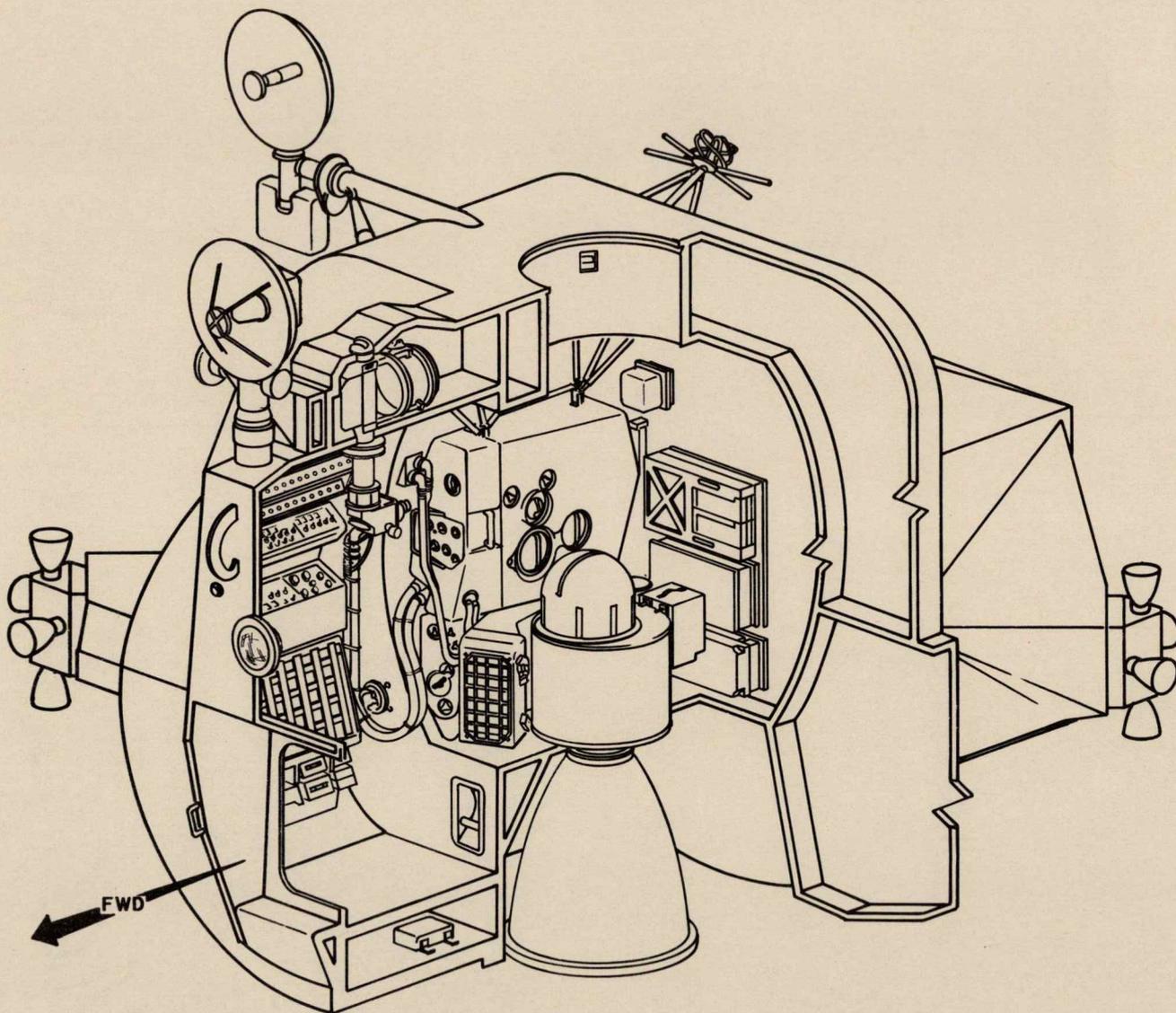
Date: August 1967



ASCENT STAGE-LEFT SIDE

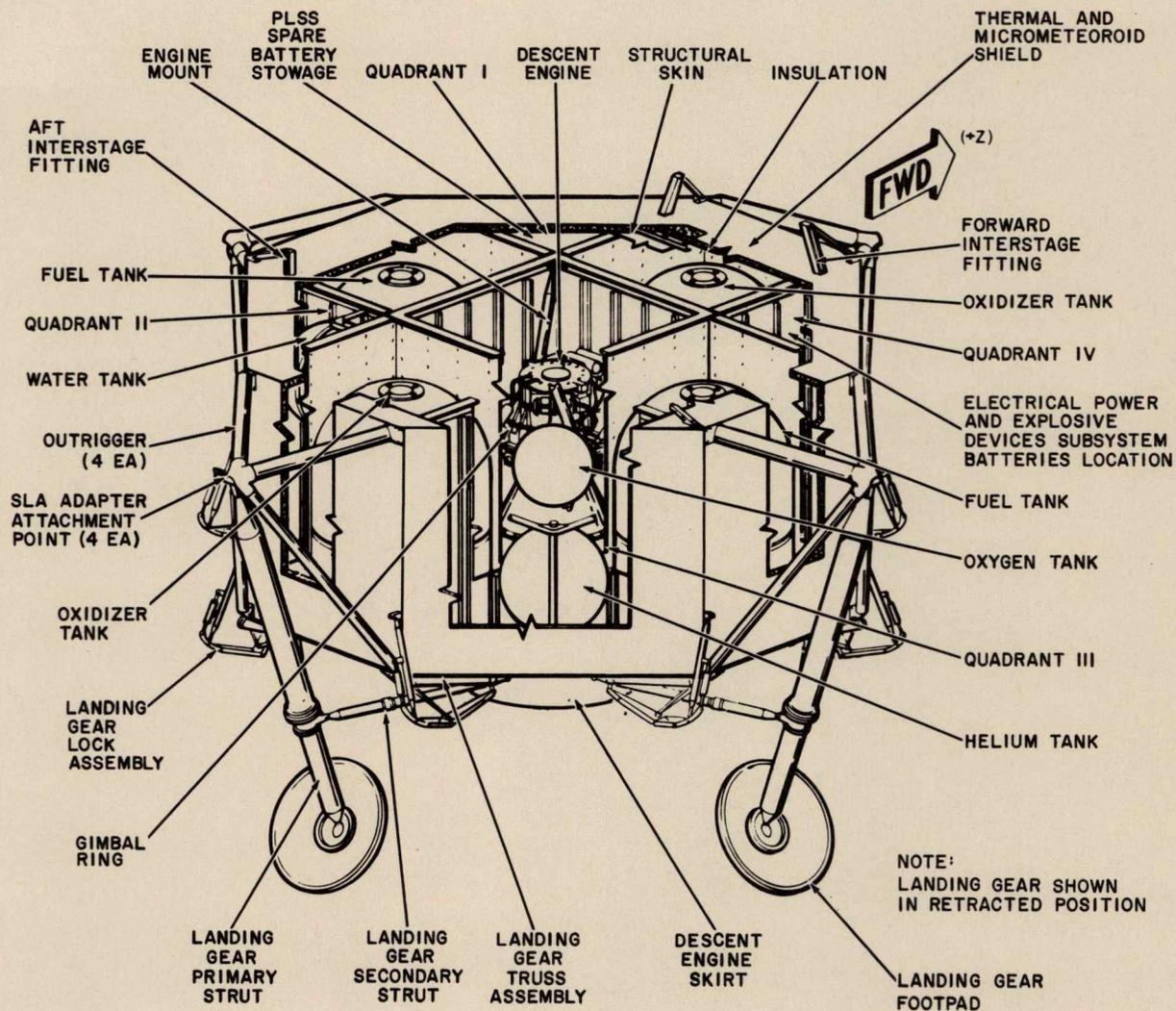
T30915-36.1

Date: August 1967



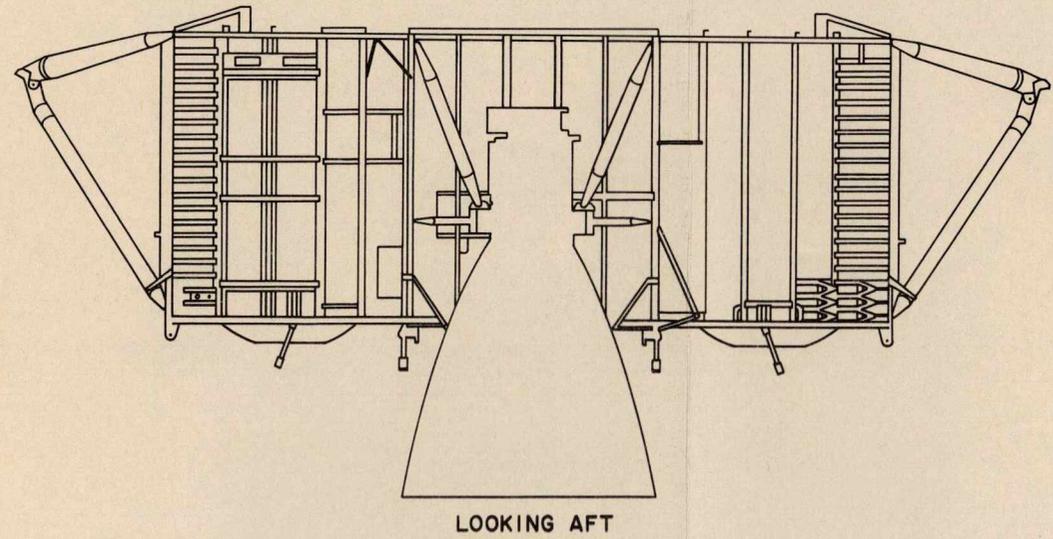
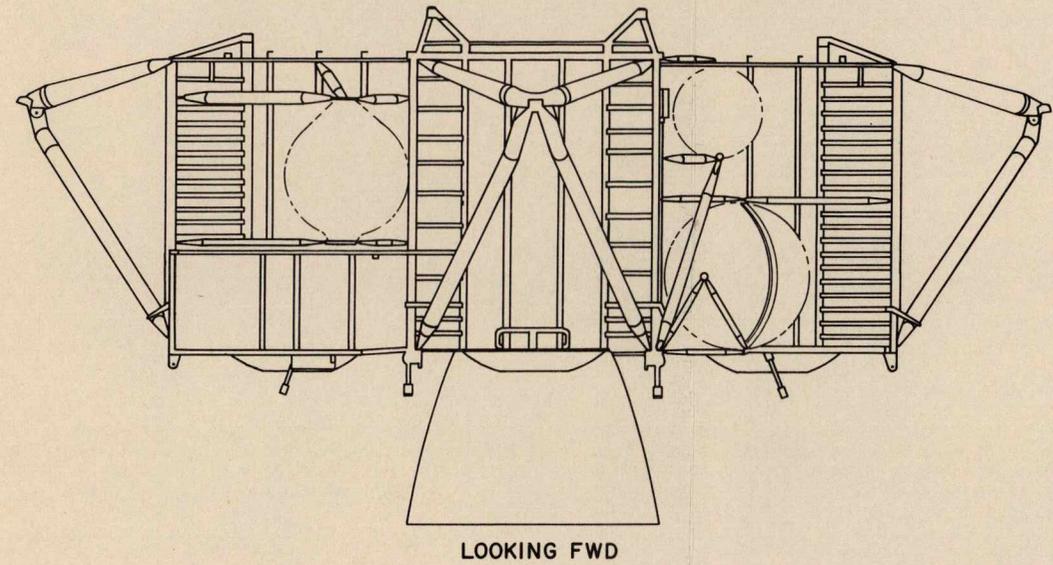
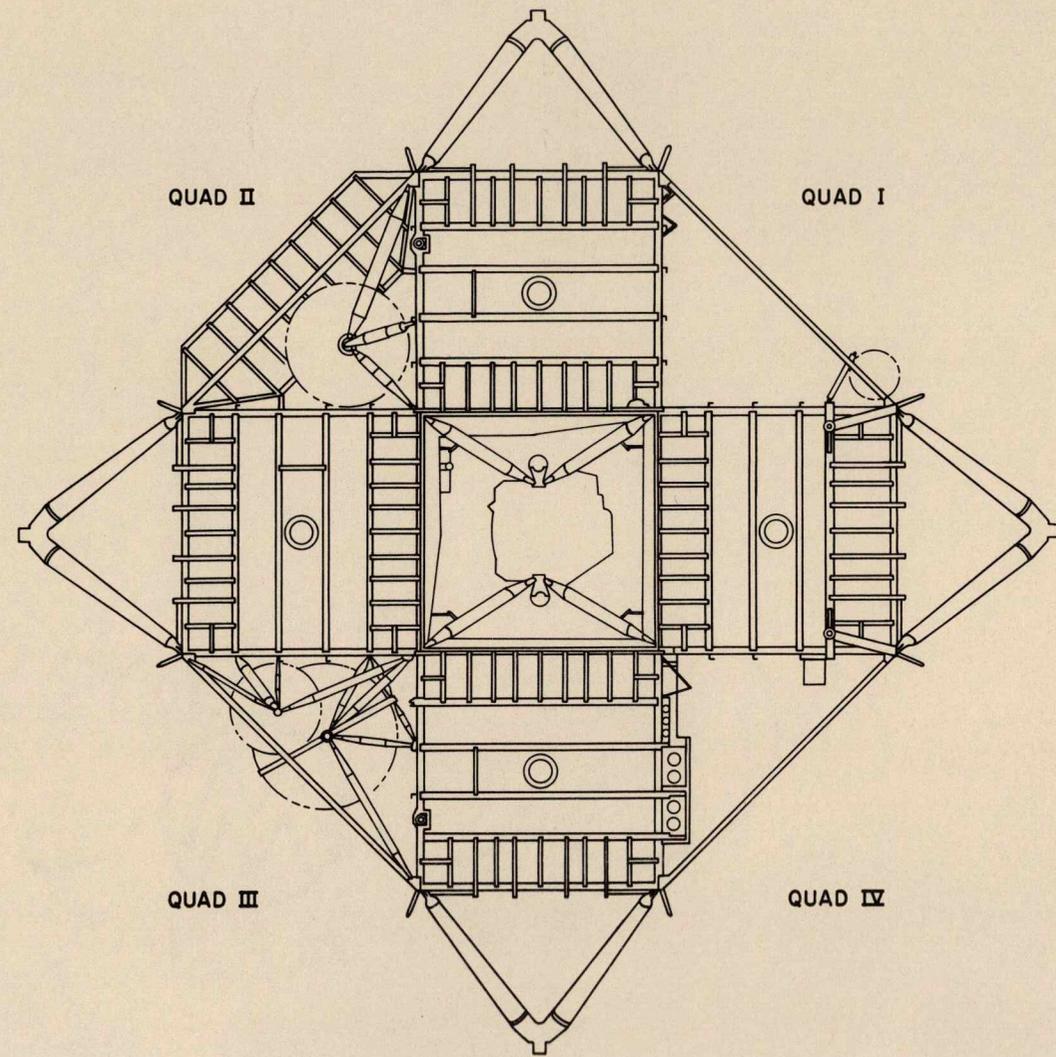
ASCENT STAGE-RIGHT SIDE

T 30915-35.1



### LM DESCENT STAGE

T30915-42.1



**DESCENT STAGE STRUCTURE**

T30915-59.1

Heater Numeric Designators

Every heater is assigned a numeric designator. These will indicate the basic classification of each of the heaters.

LDW 938-10XXX

└─ Equipment Heater  
 └─ Soakback Heater  
 └─ Stabilization Heater

LDW 938-11XXX

└─ Solar Simulation

Heater Locations: LDW 938-10XXX Series

10202-10270	Landing Gear
10301-10310 10901,10902	Tanks
10312-10317	Battery Simulators
10324-10339	RCS Engine - Soakback Heaters
10341,10344	Windows
10366-10379	A/S Engine
10381	D/S Engine
10494	Guard Heaters
10500-10520	CSM Simulator
10509-10512	Interstage Fitting Heaters
10700-10776	D/S Base Heat Shield Soakback
10784-10799	D/S Engine Bay Walls and Struts
10801-10832	RCS Engine Solar Simulation Heaters
10901-10902	A/S Water Tanks

T100-25

Heater Locations: LDW 938-11XXX Series

Docking Tunnel, Droque & Hatch	11092, 11196, 11197, 11566-11568
A/S, Mid-Section, Top	11088-11091, 11309, 11401-11410
A/S, Mid-Section, Upper, +Y	{ 11093, 11094, 11096-11098 11100-11107, 11411-11413
A/S, Mid-Section, Upper, -Y	{ 11071-11081, 11084, 11086 11414-11416
A/S, Mid-Section, Tank, +Y	{ 11110-11113, 11116-11120 11122-11126, 11427-11429
A/S, Mid-Section, Tank, -Y	11055-11070
A/S, Mid-Section, Bottom	{ 11483-11490, 11509, 11510, 11518 11519, 11551
A/S, Mid-Section, Z = +27 Face	11430-11432, 11477-11482
A/S, Strut	11311
A/S, Mid-Section, Z = -27 Face	11433-11435, 11468-11475
A/S, Aft Equipment Bay	{ 11003-11005, 11007-11010, 11015 11016, 11419, 11422-11426, 11554 11569-11577
A/S, Fwd. Cabin	{ 11132-11145, 11148, 11149, 11154- 11164, 11166-11169, 11529-11541 11543-11546, 11549, 11550, 11555
A/S, IMU Area	{ 11039, 11040, 11308, 11312, 11313 11417
D/S, Top	{ 11231, 11459-11467, 11494-11505 11507, 11508
D/S, Bottom	{ 11251, 11253, 11255, 11257, 11558- 11565, 11589, 11600-11603
D/S, Side Walls	{ 11202, 11203, 11208, 11209, 11213 11214, 11219, 11220, 11436-11458 11476, 11491-11493, 11506, 11517 11528
D/S, Base Heat Shield	{ 11268, 11270, 11272-11289, 11521 11523, 11525, 11527
D/S, Base Heat Shield Sidewalls	11258, 11260, 11262, 11264, 11604- 11611
Interstage Fitting Covers	11511-11516
RCS Skins +Y, +Z	{ 11170, 11172, 11174, 11176, 11184 11186, 11188, 11552, 11553
RCS Skins -Y, +Z	{ 11171, 11173, 11175, 11185, 11187 11189, 11547, 11548, 11177
RCS Skins +Y, -Z	11587, 11588, 11591-11596, 11598
RCS Skins, -Y, -Z	11578-11585, 11597
Antennae Solar Sim.	11950-11953, 11960-11963

T100-26

Date: August 1967

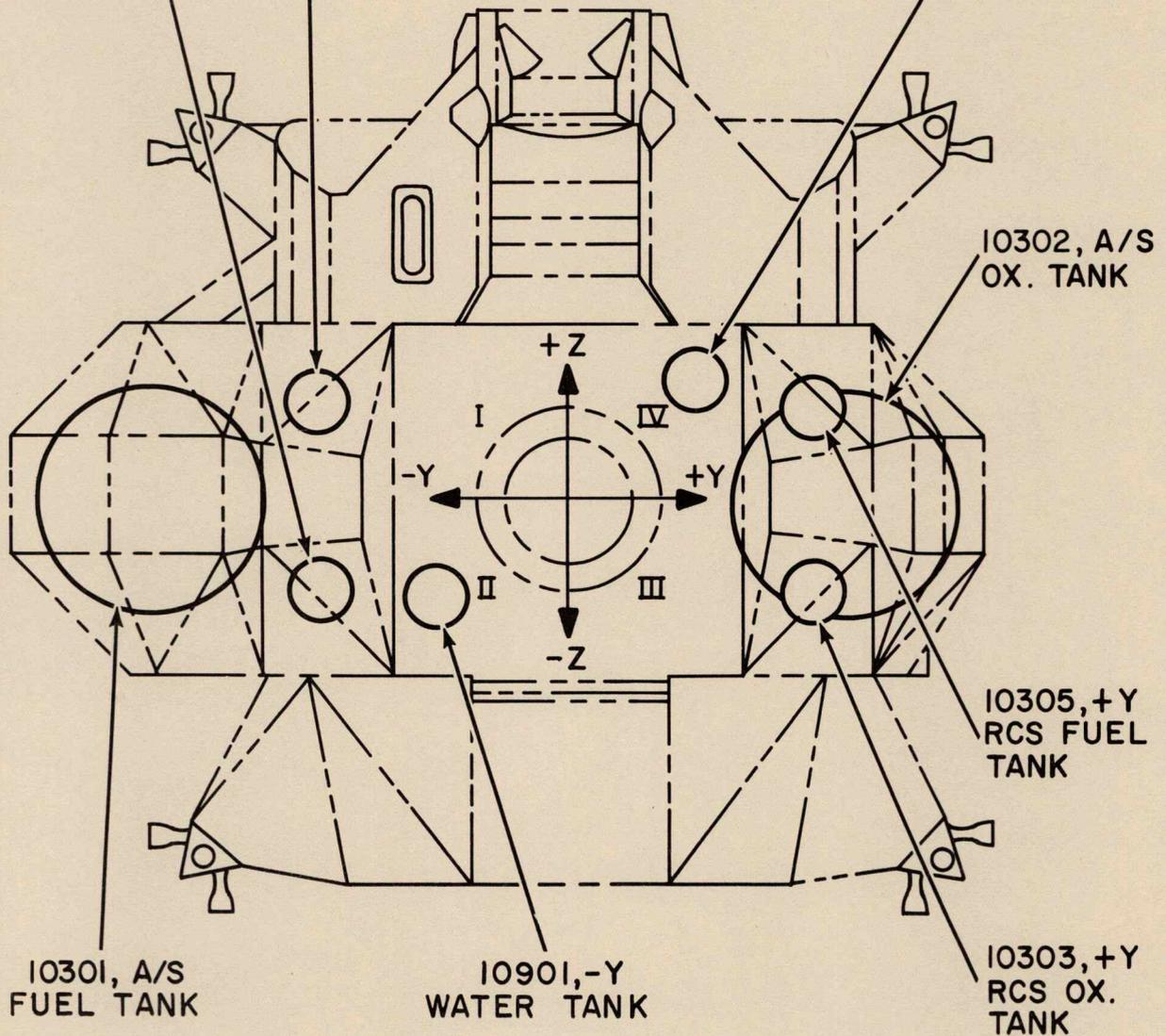
Page 24

10306, -Y RCS  
FUEL TANK

10304, -Y RCS  
OX. TANK

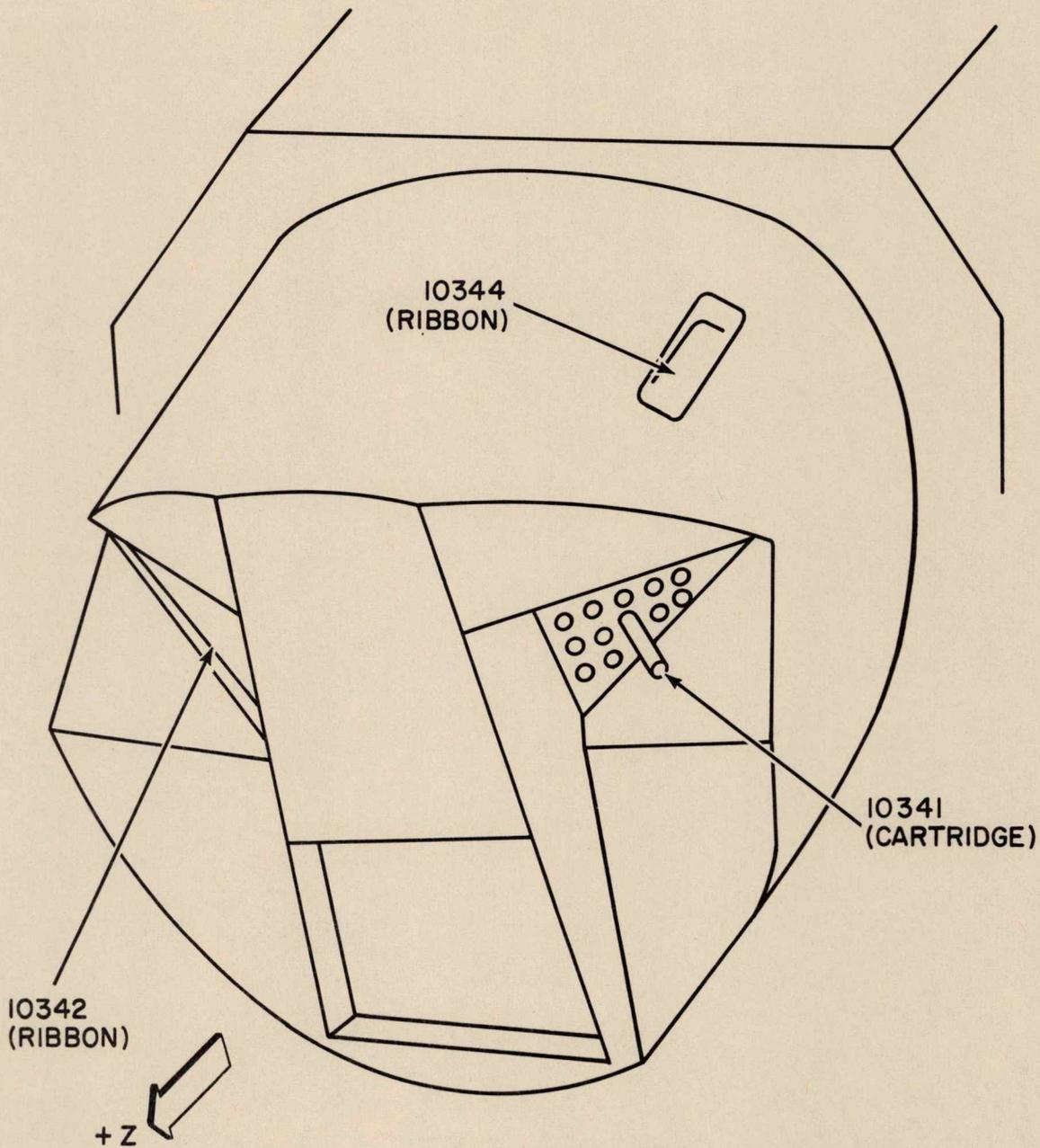
10902, +Y  
WATER TANK

VIEW LOOKING DOWN



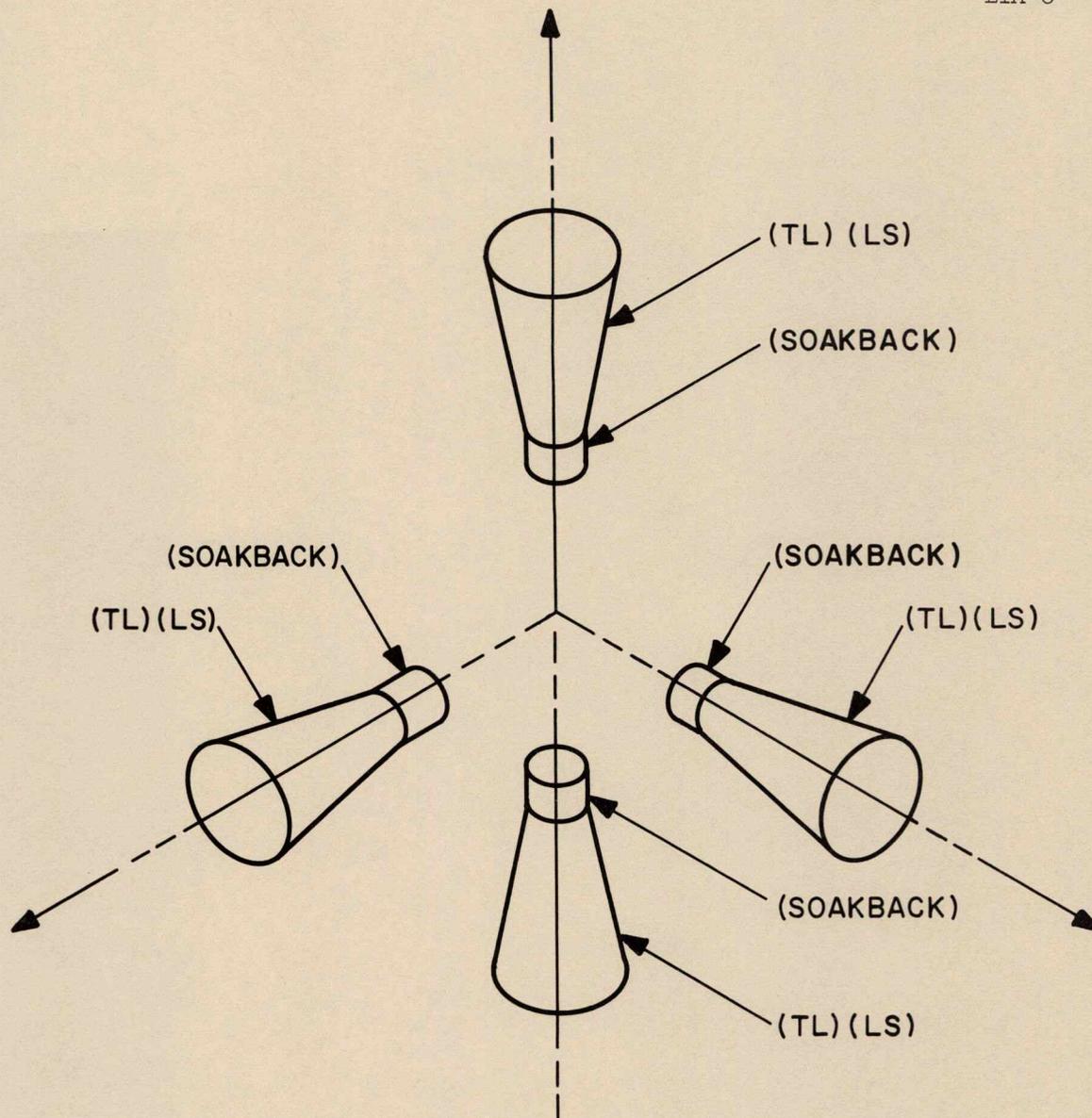
LTA-8 ASCENT STAGE TANK HEATERS

T30900-119.1



**LTA-8 WINDOW HEATERS**

T30900 - 121.1

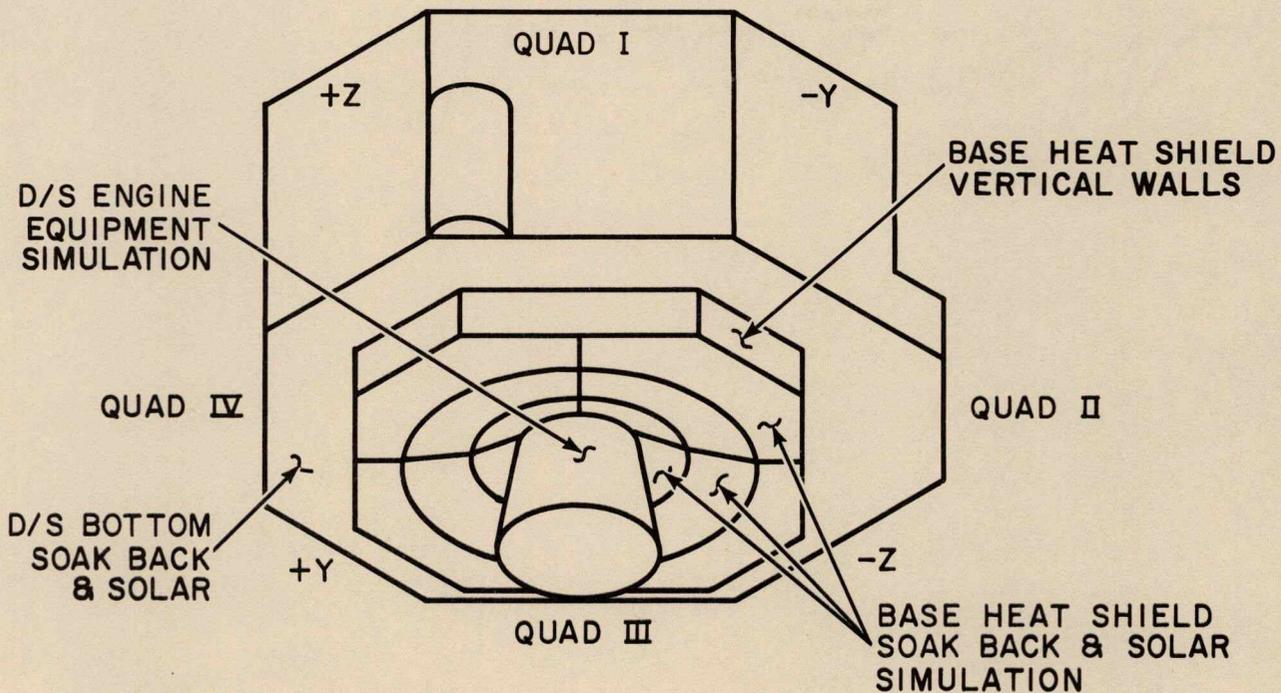
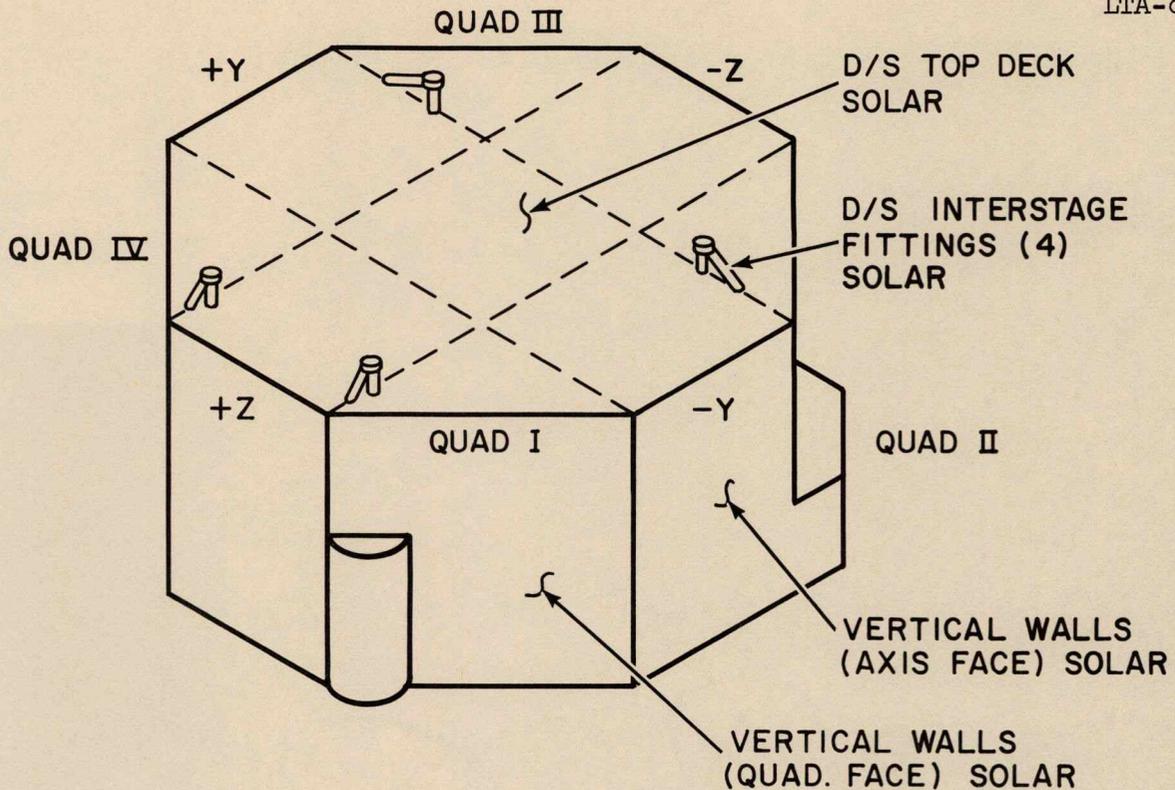


TL = SOLAR SIMULATION HEATER FOR  
TRANSLUNAR FLIGHT CONDITIONS

LS = SOLAR SIMULATION HEATER FOR  
LUNAR STAY CONDITION

LTA-8 RCS QUAD HEATERS

T30900-116.1



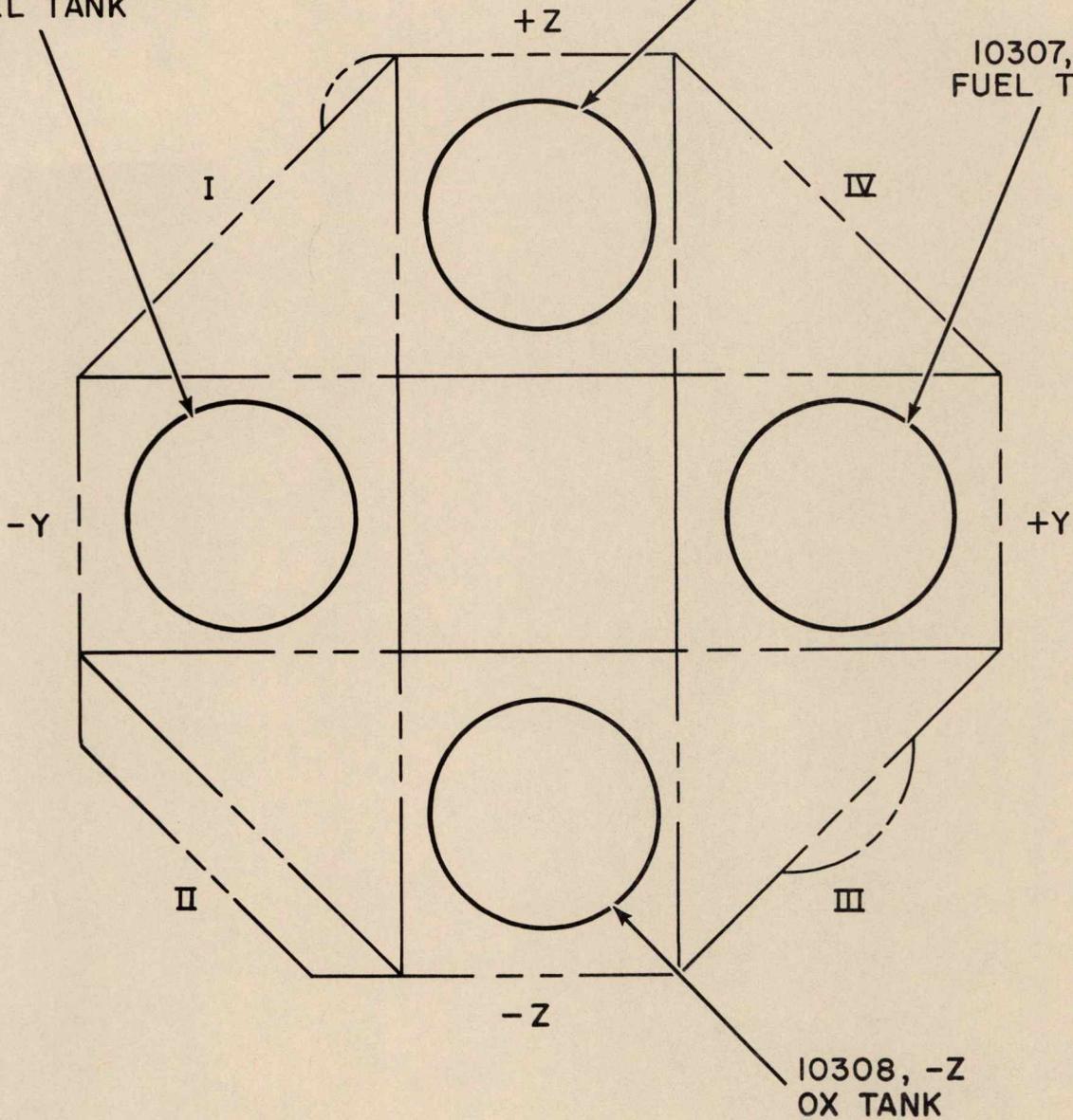
LTA-8 DESCENT STAGE

T30900-124.1

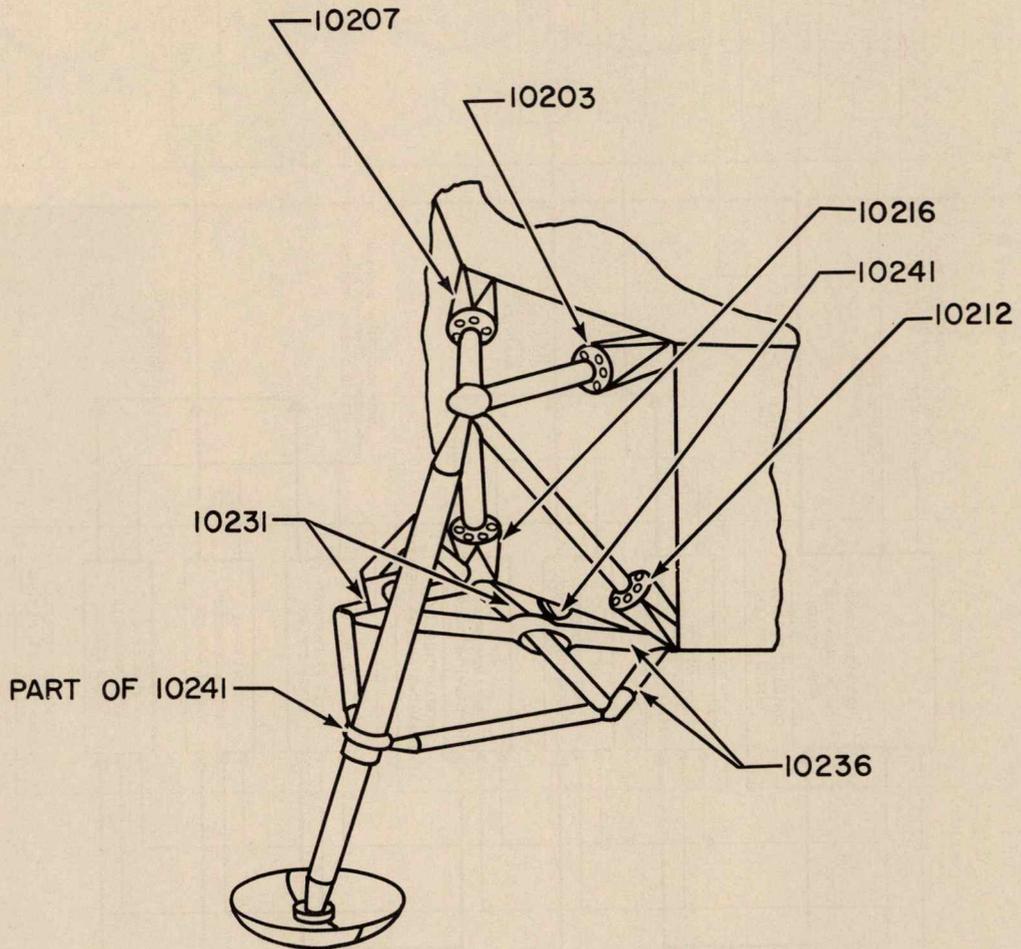
10309, -Y  
FUEL TANK

10310, +Z  
OX. TANK

10307, +Y  
FUEL TANK



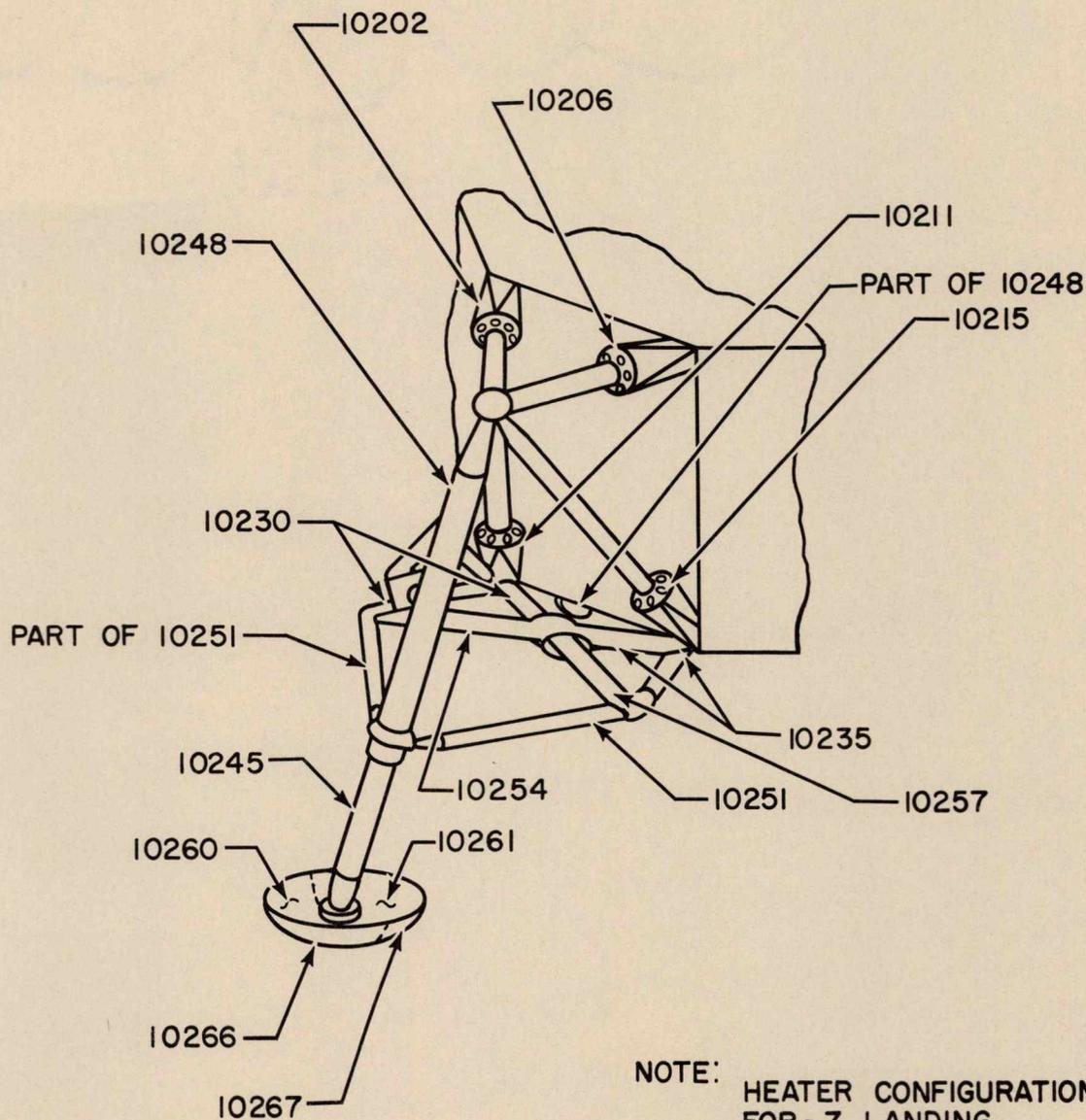
LTA-8 DESCENT STAGE TANK HEATERS



NOTE:  
HEATER  
CONFIGURATION  
FOR -Y LANDING  
GEAR IS SIMILAR

LTA-8 -Y LANDING GEAR HEATERS

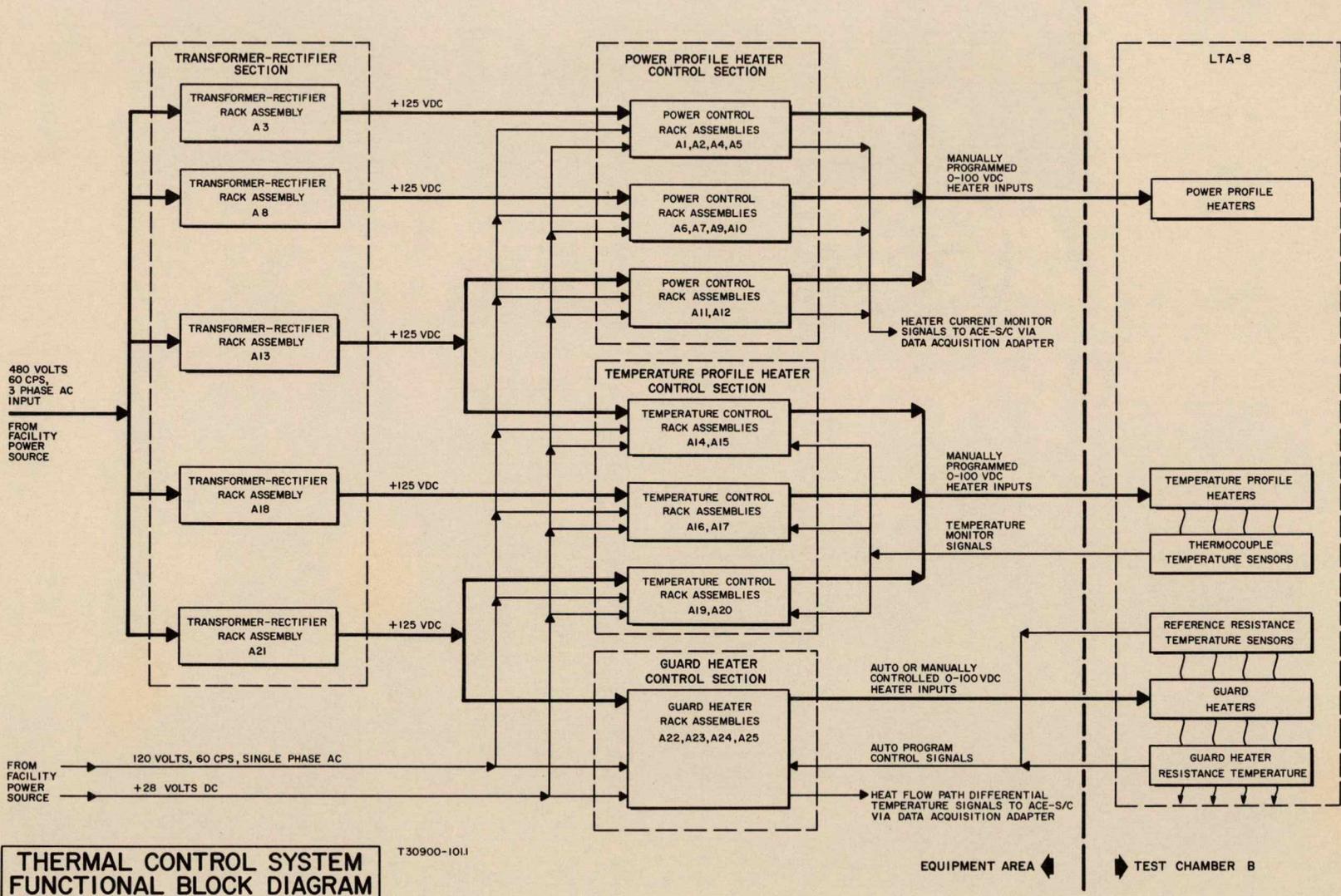
T30900-118.1



NOTE: HEATER CONFIGURATION FOR - Z LANDING GEAR IS SIMILAR

LTA-8 +Z LANDING GEAR HEATERS

T30900-117.1



**THERMAL CONTROL SYSTEM  
FUNCTIONAL BLOCK DIAGRAM**

T30900-1011

EQUIPMENT AREA      TEST CHAMBER B



**GRUMMAN AIRCRAFT ENGINEERING CORPORATION**  
**BETHPAGE • LONG ISLAND • NEW YORK**