The ascent stage is designed to:

Provide a controlled environment for the two astronauts while separated from the CSM.

Provide required visibility for lunar landing, stay, and ascent; and for rendezvous and docking with the CM.

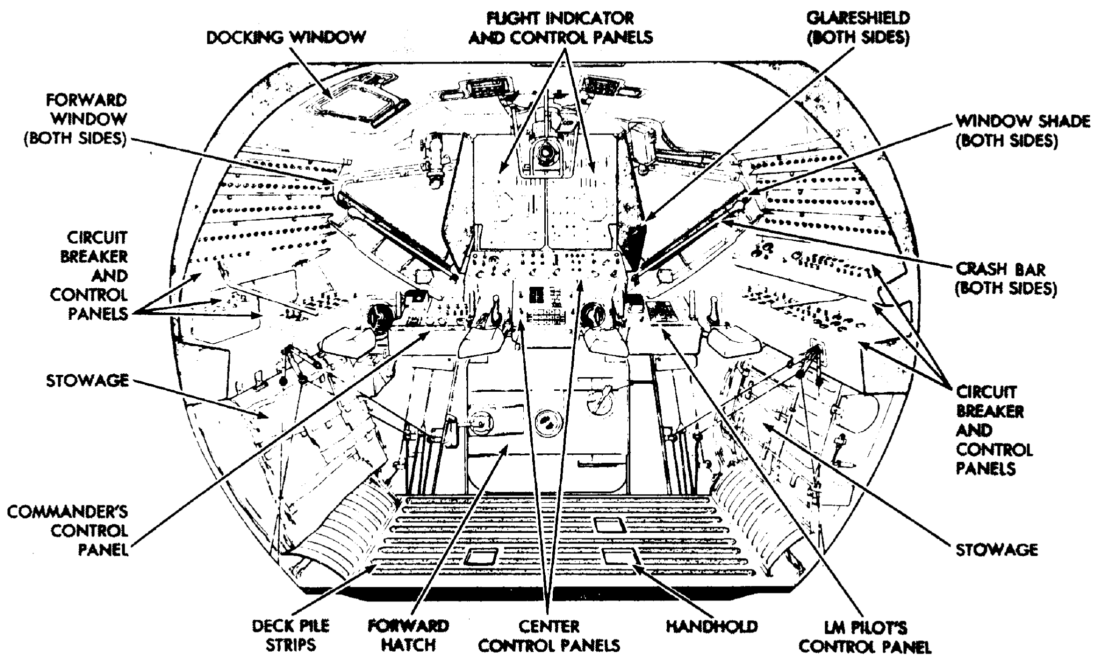
Provide for astronaut and equipment transfer between the LM and CM and between the LM and the lunar surface.

Protect the astronauts and the equipment from micrometeoroid penetration.

CREW COMPARTMENT

The crew compartment is the frontal area of the ascent stage; it is cylindrical (92 inches in diameter and 42 inches deep). The Commander's flight station is at the left; the LM Pilot's at the right. The flight-station centerlines are 44 inches apart. For maximum downward vision the upper part of the compartment is constructed to extend forward of the lower portion. The area has control and display panels, body restraints, landing aids, a front window for each astronaut, a docking window above the Commander's station and other accessory equipment. Each flight station has an attitude controller, a thrust/translation controller, and adjustable armrests. There is a hatch in the front face assembly of the compartment.

A portable life support system (PLSS) donning station is behind the optical alignment station. Attachment points for an S-band in-flight antenna are provided on the front face assembly and for a rendezvous radar antenna on the upper structural beams of the crew compartment.



R-4

Crew Compartment Interior

The crew compartment deck (flight station floor) measures approximately 36 by 53 inches. Nonflammable Velcro pile is bonded to the decks' top surface; a hooked Velcro on the soles of the astronauts' boots provides a restraining force to hold the astronaut to the deck during zero-g flight. Handgrips, aligned with the forward hatch and recessed in the deck, aid ingress and egress.

The control and display panels contain all devices necessary to control, monitor, and observe subsystems performance. The arrangement of the panels permits either astronaut to fly the LM to the CSM. All panels are canted to facilitate viewing. Six of the panels are in front of the flight stations. The upper two panels – one inboard of each flight station – are at eye level. These panels are shock mounted to dampen vibrations. The next two lower panels are centered between the flight stations to enable sharing of the control functions. One of the remaining two front panels is in front of each flight station, at waist height. The Commander's panel contains lighting, mission timer, engine, and thrust chamber controls. The LM Pilot's panel has abort guidance subsystem controls. To the left of the Commander's station are three panels: a five-tier circuit breaker panel at the top, an explosive devices and communications audio control panel, and an earth and lunar orbital rate display panel. To the right of the LM Pilot's station are three panels: the uppermost is a four-tier circuit breaker panel, the center panel contains controls and displays for electrical power, and the bottom panel contains communications controls and displays. The circuit breaker panels are canted to the line of sight so that the white band on each circuit breaker can be seen when the breakers are open.

FORWARD HATCH

The forward hatch is in the front face assembly, just below the lower display panels. The hatch is used for transfer of astronauts and equipment between the LM and lunar surface, or for in-flight extravehicular activity (EVA) while docked with the CM. The hatch is approximately 32 inches square; it is hinged to swing inboard when opened. A cam latch assembly holds the hatch in the closed position; the assembly forces a lip, around the outer circumference of the hatch, into a preloaded elastomeric silicone compound seal secured to the LM structure. Cabin pressurization forces the hatch lip further into the seal, ensuring a pressure-tight contact. A handle is provided on both sides of the hatch, for latch operation. To open the hatch, the cabin must be completely depressurized by opening a cabin relief and dump valve on the hatch. When the cabin is completely depressurized, the hatch can be opened by rotating the latch handle. The cabin relief and dump valve can also be operated from outside the LM. Quick-release pins in the latch plate and hinges may be pulled from inside the LM to open the hatch in an emergency.

An antibacterial filter is stowed at the center of the hatch inside surface. Before depressurizing the cabin for egress to the lunar surface, the filter is affixed to the cabin relief and dump valve to prevent cabin air contaminants from being expelled.

WINDOWS

The two triangular windows in the front face assembly each have approximately 2 square feet of viewing area; they are canted down to the side to permit adequate peripheral and downward visibility. The docking window above the Commander's flight station has approximately 80 square inches of viewing area and provides visibility for docking maneuvers. All three windows consist of two separated panes, vented to space. The outer pane is of low-strength, annealed material that inhibits micrometeoroid penetration. The outer surface of this pane is coated with 59 layers of blue-red thermal control, metallic oxide, to reduce infrared and ultraviolet light transmission. The inner surface of the outer pane has a high-efficiency, antireflective coating. This coating is also a metallic oxide, which reduces the mirror effect of the windows and increases their normal light-transmission efficiency. The inner pane of each window is of chemically tempered, high-strength structural glass. The inner pane of the front windows has a seal (the docking window has two seals) between it and the window frame and is bolted to the frame through a metal retainer. The inner pane has the high-efficiency antireflective coating on its inner surface and a defogging coating on its outer surface.

All three windows are electrically heated to prevent fogging. The temperature of the windows is not monitored. Heater operation directly affects crew visibility; proper operation is, therefore, visually determined by the astronauts.

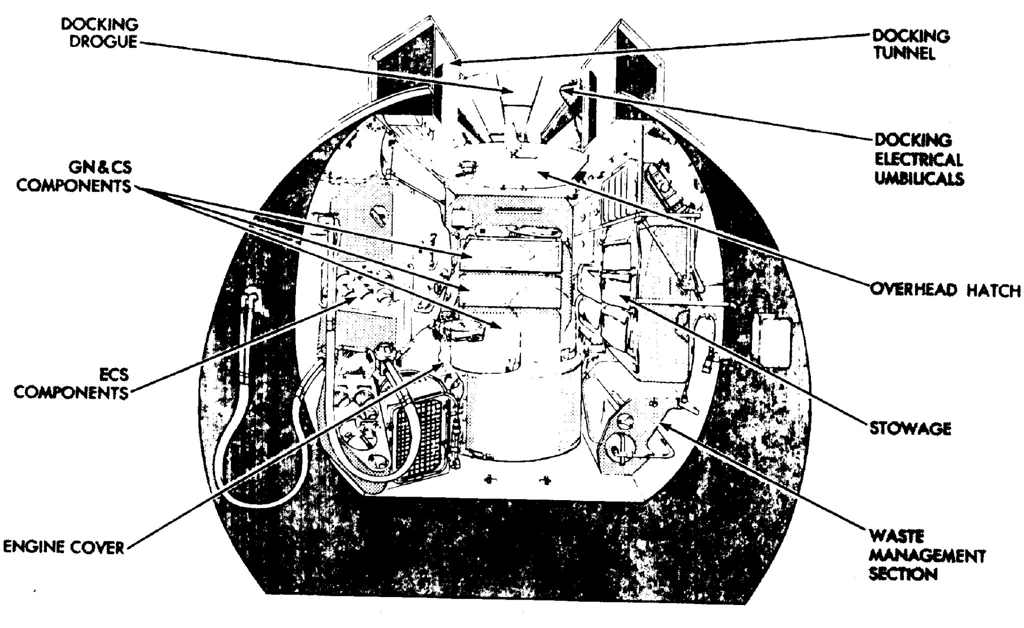
A window shade, with an antireflective coating on its outboard side, is provided for each window. Normally, the shade is rolled up at the window edge. A glareshield mounted between each front window and the control and flight display panels reduces window reflection of internal panel lighting.

EQUIPMENT STOWAGE

Underneath the control and display panels to the right of the LM Pilot's station is a compartmented cabinet. Equipment used during the mission is stowed in this cabinet. This equipment includes food, personal hygiene items, EVA waist tethers, a camera, camera lens filters, a spare light bulb, and a multipurpose special tool having a modified Allen-head. A similar cabinet to the left of the Commander's station contains a spare Environmental Control Subsystem (ECS) lithium hydroxide canister, waste collection containers, a PLSS lithium hydroxide cartridge, and a PLSS condensate container.

MIDSECTION

From the flight stations, the astronauts have an 18-inch step up into the midsection, which is immediately aft of the crew compartment. Normally, the midsection is not manned; it is traversed by the astronauts upon entering and exiting the LM after docking. The midsection is 54 inches deep and approximately 5 feet high. The internal shape is elliptical, with a minor axis of approximately 56 inches. The midsection houses the ascent engine assembly, part of which protrudes up through the lower deck. ECS components, a water-dispensing fire extinguisher, a container for lunar samples, and life support and communications umbilicals are installed on the right side of the midsection. Along the left side, is the waste management system and an oxygen purge system. This side also contains stowage for food, lunar overshoes, a pilot's reference kit, and miscellaneous containers. Components of the Electrical Power Subsystem (EPS) and the Guidance, Navigation,



Midsection Interior

and Control Subsystem (GN&CS) are mounted on the aft bulkhead. A cylindrical cover protects the accessories section of the protruding part of the engine. The top of the cover is used as a rest position for one of the astronauts and as a platform for initially observing the lunar surface through the overhead (docking) hatch. Above the hatch is a docking tunnel; directly forward of the hatch, PLSS fittings are mounted. These fittings aid the astronauts in donning their PLSS units.

Construction of the midsection is similar to that of the crew compartment, but the midsection has a bulkhead at each end. The aft bulkhead supports the aft equipment bay structure. In addition to the lower deck to which the ascent engine is mounted, there are two others. One of these supports the overhead hatch and the lower end of the docking tunnel; the other, supports the upper end of the docking tunnel and absorbs some of the stresses imposed during docking. All decks are made of integrally stiffened machined aluminum alloy, or reinforced chemically milled web. The exterior structure forms a cradle around the midsection to absorb or transmit all stress loads applied to the ascent stage. Stress loads applied to beams on top of the crew compartment are transmitted through midsection beams, to the aft bulkhead and, in turn, to the interstage fittings. The external structure, along the sides of the midsection, supports propellant subsystem storage tanks and S-band steerable and VHF in-flight antennas. The aft midsection bulkhead supports propellant and ECS tanks, an aft equipment rack assembly and the Reaction Control System (RCS) two aft thrust clusters. A docking target, used for aligning the LM with the CSM during docking, is mounted on the upper left structure of the midsection exterior.

OVERHEAD HATCH

The overhead hatch, approximately 33 inches in diameter, is at the top centerline of the midsection. When the LM and CM are docked, the hatch permits transfer of astronauts and equipment. The astronauts pass through the hatch, head first. Handgrips in the docking tunnel immediately above the hatch aid in crew and equipment transfer. The hatch has an off-center latch that can be operated from either side of the hatch. The hatch is opened inward by rotating the latch handle 90°. A preloaded elastomeric silicone compound seal is mounted in the hatch frame structure. When the latch is closed, a lip near the outer circumference of the hatch enters the seal, ensuring a pressure tight contact. Normal cabin pressurization forces the hatch into its seal. To open the hatch, the cabin must be depressurized by opening a cabin relief and dump valve, which is within the hatch structure. The valve can be operated with a handle on each side of the hatch.

DOCKING TUNNEL

The docking tunnel, immediately above the overhead hatch, provides a structural interface between the LM and the CM to permit transfer of equipment and astronauts without exposure to space environment. The tunnel is 32 inches in diameter and 18 inches long. A ring at the top of the tunnel is compatible with a docking ring on the CM. The CM docking ring has automatic clamping latches. The ring is concentric with the nominal centerline of thrust of the ascent and descent engines. The drogue, a portion of the docking mechanism, is secured below the ring to three mounts in the LM tunnel so that it can mate with the docking probe of the CM. When the CM and LM are docked, the rings are joined; this ensures structural continuity for transmitting midcourse correction and lunar orbit injection stresses throughout vehicle basic structure.

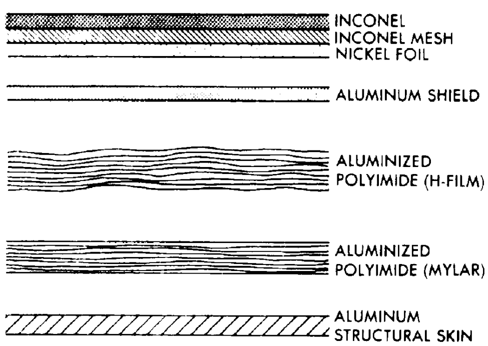
AFT EQUIPMENT BAY

The aft equipment bay is an unpressurized area formed by the aft midsection bulkhead and the equipment rack, which is cantilevered approximately 33 inches aft of the bulkhead. The equipment rack assembly has integral cold rails that transfer heat from electronic and electrical equipment (components of the GN&CS, EPS, and Communications Subsystems) mounted on the rack. The cold rails are mounted vertically in the rack structural frame. Water-glycol flows through the cold rails.

Two gaseous oxygen tanks and two gaseous helium tanks are secured to the truss members between the midsection aft bulkhead and the equipment rack. ECS and Main Propulsion Subsystem components that do not require a pressurized environment or acesss by the astronauts are mounted to the outboard side of the aft bulkhead. The equipment rack and the aft bulkhead support the aft RCS thrust clusters.

THERMAL AND MICROMETEOROID SHIELD

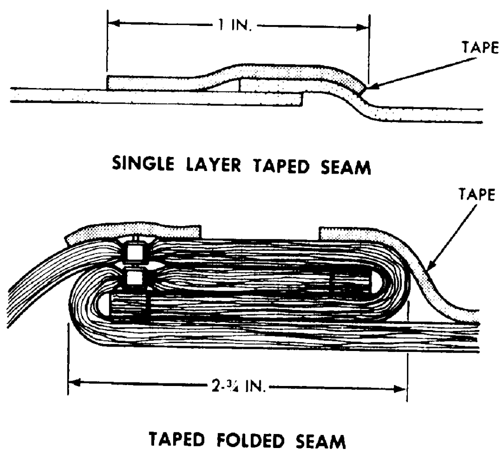
After the LM is removed from the spacecraft-Lunar Module adapter (SLA), it is exposed to micrometeoroids and solar radiation. To protect the LM astronauts and equipment from temperature extremes, active and passive thermal control is used. Active thermal control is provided by the ECS. Passive thermal control isolates the vehicle interior structure and equipment from its external environment to sustain acceptable temperature limits throughout the lunar mission. The entire ascent stage structure is enclosed within a thermal blanket and a micrometeoroid shield. Glass fiber



R-6

Typical Thermal Blanket and Micrometeoroid Shield

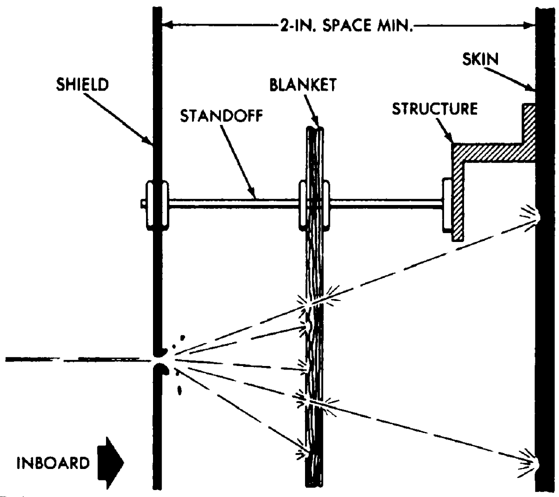
standoffs, of low thermal conductivity, hold the blanket away from the structural skin. Aluminum frames around the propellant tanks prevent contact between tanks and blanket. The thermal blanket consists of multiple-layered (at least 25 layers) of aluminized sheet (mylar or H-film). Each layer is only 0.00015 inch thick and is coated on one side with a microinch thickness of aluminum. To make an even more effective insulation, the polyimide sheets are hand crinkled before blanket fabrication. This crinkling provides a path for venting, and minimizes contact conductance between the layers. Structures with a high thermal conductivity, such as antenna supports and landing gear members, that pass through the thermal blanket also have thermal protection. Individual blanket layers are overlapped and sealed with a continuous strip of H-film tape. To join the multilayered sections, the



R-7

Thermal Blanket Joining Techniques

blanket edges are secured with grommet type fasteners, then the seam is folded and sealed with a continuous strip of tape. Mylar sheets are used predominantly in those areas where temperatures do not exceed 300° F. In areas where higher temperatures are sustained, additional layers of H-film are added to the mylar sheets. H-film can withstand temperatures up to 1000° F, but, because it is a heavier material, it is used only where absolutely necessary. Certain areas of the ascent stage are subjected to temperatures as high as 1800° F due to CSM and LM RCS plume impingement. These areas are thermally controlled by a sandwich material of thin nickel foil (0.0005 inch) interleaved with Inconel wire mesh and Inconel sheet. Finally, the highly reflective surfaces of the shades provided for the front and docking windows reduce heat absorption.



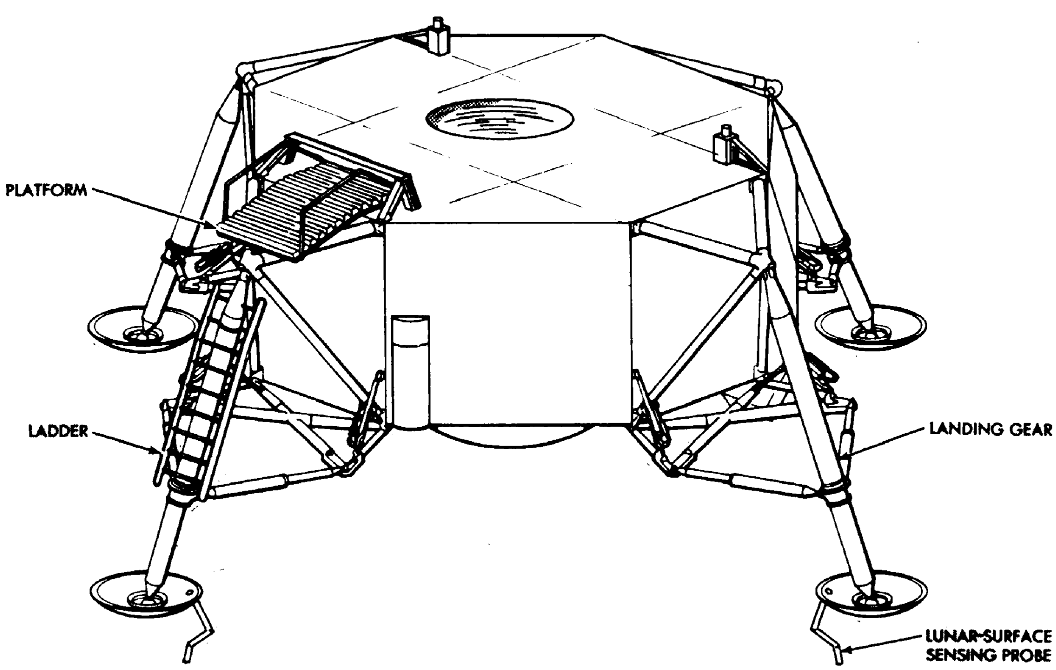
R-8

Typical Micrometeoroid Protection

The micrometeoroid shield, outboard of the thermal blanket, is a sheet of aluminum that varies in thickness from 0.004 to 0.008 inch, depending on micrometeoroid-penetration vulnerability. It is attached to the same standoffs as the thermal blankets. Various thermal control coatings are applied to the outer surface of the shield to provide an additional temperature boundary for vehicle insulation against space environment.

DESCENT STAGE

The descent stage is the unmanned portion of the LM; it represents approximately two-thirds of the weight of the LM at the earth-launch phase. This is because the descent engine is larger than the ascent engine and it requires a much larger propellant load. Additionally, its larger proportion of



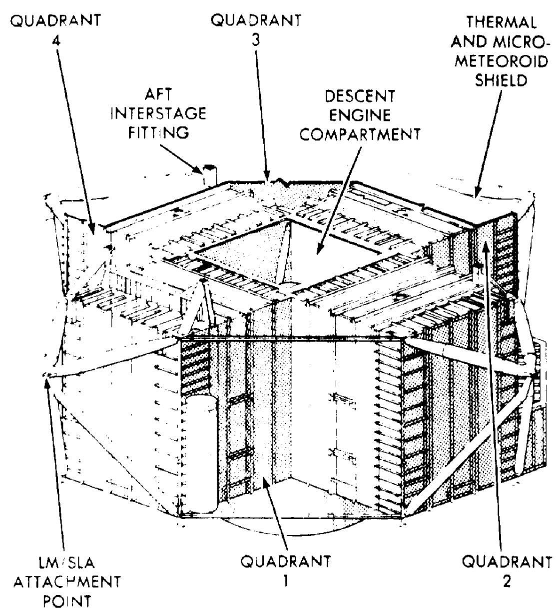
R-9

Descent Stage

weight results from necessity of the descent stage to:

(1) Support the entire ascent stage.
(2) Provide for attachment of the landing gear.
(3) Support the complete LM in the SLA.
(4) Provide structure to support the scientific and communications equipment to be used on the lunar surface.
(5) Act as the launching platform of the ascent stage.

The main structure of the descent stage consists of two pairs of parallel beams arranged in a cruciform, with a deck on the upper and lower surfaces, approximately 65 inches apart. The ends of the beams, approximately 81 inches from the center, are closed off by aluminum beams to provide five



Descent Stage Structure

equally sized compartments: a center compartment, one forward and one aft of the center compartment, and one right and one left of the center compartment. A four-legged truss (outrigger) at the end of each pair of beams serves as a support for the LM in the SLA and as the attachment point for the upper end of the landing gear primary strut. Two of the four interstage fittings for attachment of the ascent stage are mounted on the forward compartment beams. The other two fittingss are on the aft beam of theide compartments. The five compartments formed by the main beams house Main Propulsion Subsystem components. The center compartment houses the descent engine, which is supported by truss members and an engine gimbal ring. Descent engine fuel and oxidizer tanks are in the remaining compartments.

Struts between the ends of all main beams form triangular bays, or quadrants, to give the descent stage its octagon shape. The quadrants are designated 1 through 4, beginning at the left of the forward compartment and continuing counterclockwise (as viewed from the top) around the center. The quadrants house components from the various subsystems. In addition, the S-band antenna to be erected by the astronauts on the lunar surface is stowed in quad No. 1; and the modularized equipment stowage assembly (MESA), in quad No. 4.

The MESA consists of television equipment, equipment for obtaining and stowing lunar samples, and PLSS components to be used by the astronauts during the lunar stay.

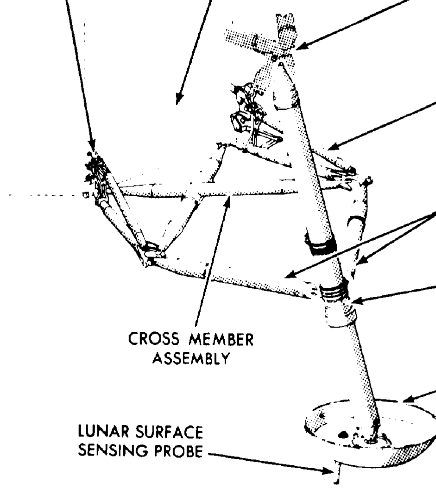
THERMAL AND MICROMETEOROID SHIELD

The entire descent stage structure is enveloped in a thermal and micrometeoroid shield similar to that used on the ascent stage. Because the top deck and side panels of the descent stage are subjected to engine exhaust and RCS plume impingement, these areas are extensively protected with a nickel inconel mesh sandwich outboard of the mylar and H-film blankets. A teflon-coated titanium blast shield that deflects the ascent engine exhaust out of and away from the descent engine compartment is secured to the upper side of the compartment, below the thermal blanket. Layers of H-film, joined to the blast deflector, act as an ablative membrane which protects the descent stage from ascent engine exhaust gases that are deflected outward, between the stages, during lift-off from the lunar surface. The engine compartment and the bottom of the descent stage are subjected to temperatures in excess of 1800° F when the descent engine is fired. A special base heat shield protects the descent stage structure and internal components. It consists of a titanium shield attached to descent stage structure. The heat shield supports a thermal blanket on each of its sides. The thermal blanket that faces the engine nozzle consists of multiple layers of nickel foil and glass wool and an outer layer of H-film. This blanket acts as a protective membrane to withstand engine exhaust gas back pressures at lunar touchdown and prevent heat, absorbed by the lunar surface during LM landing, from radiating back into the descent stage. Twenty-five layers of H-film make up the blanket on the other side of the titanium. A flange-like ring of columbium backed with a fibrous (Min-K) insulation is attached directly to the engine nozzle extension and joined to the base heat shield by an annular bellows of 25-layer H-film. This bellows arrangement permits descent engine gimbaling, but prevents engine heat from leaking into the engine compartment.

LANDING GEAR

The landing gear provides the impact attenuation required to land the LM on the lunar surface, prevents tipover of the LM on a lunar surface with a 6° general slope having 24-inch depressions or protuberances, and supports the LM during lunar stay and lunar launch. Landing impact is attenuated to load levels that preserves the LM structural integrity. At earth launch, the landing gear is retracted to reduce the overall size. It remains retracted until the docked CSM and LM attain lunar orbit and the astronauts have transferred to the LM. Before the LM is separated from the CSM, the Commander in the LM operates the landing gear deployment switch to extend the gear. At this time landing gear uplocks are explosively released, allowing springs in deployment mechanisms to extend the gear. Once extended, the landing gear is locked in place by downlock mechanisms.

The cantilever landing gear consists of four assemblies, each connected to an outrigger that extends from the ends of the structural parallel beams. The landing gear assemblies extend from the front, rear, and both sides of the descent stage. Each assembly consists of struts, trusses, a footpad, lock and deployment mechanisms, and a lunar surface sensing probe. A ladder is affixed to the forward gear assembly.

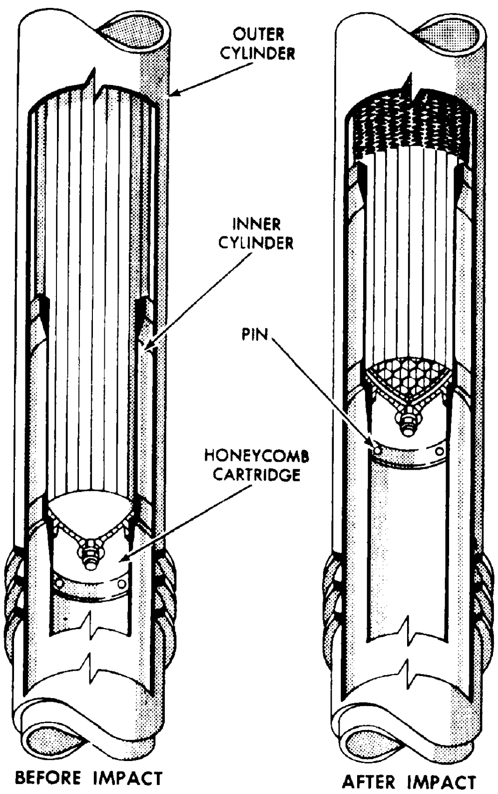


Landing Gear Assembly

The landing gear can withstand: (1) a 10-foot/second vertical velocity of the LM when the horizontal velocity is zero feet/second, (2) a 7-foot/second vertical velocity with a horizontal velocity not exceeding 4 feet/second, and (3) a vehicle attitude within 6° of the local horizontal when the rate of attitude change is 2°/second or less.

PRIMARY STRUT

The upper end of the primary strut is attached to the outboard end of the outrigger; the lower end has a ball joint for the footpad. The strut is of the piston-cylinder type; it absorbs the compression load of the lunar landing and supports the LM on the lunar surface. Compression loads are attenuated by a crushable aluminum-honeycomb cartridge in each strut. Maximum compression length of the primary strut is 32 inches. The aluminum honeycomb has the shock-absorbing capability of accepting one lunar landing. This may include one or two bounces of the LM, but after the full weight of the LM is on the gear, the shock-absorbing medium is expended. Use of compressible honeycomb cartridges eliminated the need for thick-walled, heavyweight, pneudraulic-type struts.



Landing Gear Primary Strut

The footpad, attached to the strut by a ball-socket fitting, is aluminum-honeycomb; its diameter is 37 inches. This large diameter ensures minimal penetration of the LM on low load-bearing-strength lunar surface. During earth launch, four restraining straps hold the pads in a fixed position on the strut. The straps shear or bend on pad contact with the lunar surface, permitting the pad to conform to surface irregularities.

LUNAR SURFACE SENSING PROBE

The lunar surface sensing probe attached to each landing gear footpad is an electromechanical device. The probes are retained in the stowed position, against the primary strut, until landing gear deployment. During deployment, mechanical interlocks are released permitting spring energy to extend the probes so that the probe head is approximately 5 feet below the footpad. When any probe touches the lunar surface, pressure on the probe head will complete the circuit that advises the astronauts to shut down the descent engine. This shutdown point which determines LM velocity at impact, is a tradeoff between landing gear design weight and the thermal and thrust reactions caused by the descent engine operating near the lunar surface. Each probe has indicator plates attached to it, which, when aligned, indicate that the probes are fully extended.

SECONDARY STRUTS

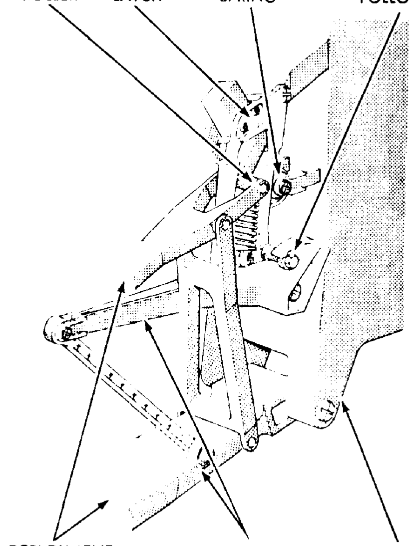
Each landing gear assembly has two secondary struts. The outboard end of each strut is attached to the primary strut; the inboard ends are attached to a deployment truss assembly. Each strut is a piston-cylinder-type device that contains compressible aluminum honeycomb capable of absorbing compression and tension loads. The design and the location of the secondary struts in relation to the primary strut enables the LM to land on an unsymmetrical surface or to land when the LM is moving laterally over the lunar surface.

UPLOCK ASSEMBLY

One uplock assembly is attached to each landing gear assembly. It consists of a fixed link (strap) and two end detonator cartridges in a single case. The fixed link, attached between the primary strut and the descent stage structure, holds the landing gear in its retracted position. When the Commander operates the landing gear deployment switch, it activates an electrical circuit which explosively severs the fixed link to permit the deployment mechanism to extend the landing gear. When detonated, either end cartridge has sufficient energy to sever the fixed link.

DEPLOYMENT AND DOWNLOCK MECHANISM

The deployment portion of the deployment and downlock mechanism consists of a truss assembly, two clock-type deployment springs, and connecting linkage. The truss, connecting the secondary struts and descent stage structure, comprises two side frame assemblies separated by a crossmember. The deployment springs are attached, indirectly, to the side frame assemblies through connecting



Deployment and Downlock Mechanism

linkage. The downlock portion of the mechanism consists of a spring-loaded lock and a cam follower. The follower rides on a cam attached to the deployment portion of the mechanism. When the fixed link of the uplock assembly is severed, the deployment springs pull the connecting linkage and, indirectly, the deployment truss. This action drives the landing gear from the stowed to the fully deployed position. At full gear deployment, the cam follower reaches a point that permits the spring-loaded lock to snap over a roller on the truss assembly. The lock cannot be opened. A landing gear deployment talkback advises the astronauts that the landing gear is fully deployed.

LADDER

The ladder affixed to the primary strut of the forward landing gear assembly has nine rungs between two railings. The rungs are spaced nine inches apart; the railings have approximately 20 inches between centers. The top of the ladder is approximately 18 inches below the forward end of the platform on the outrigger; the ladder extends down to within 30 inches of the footpad. This allows the primary strut to telescope when the LM impacts on the lunar surface.

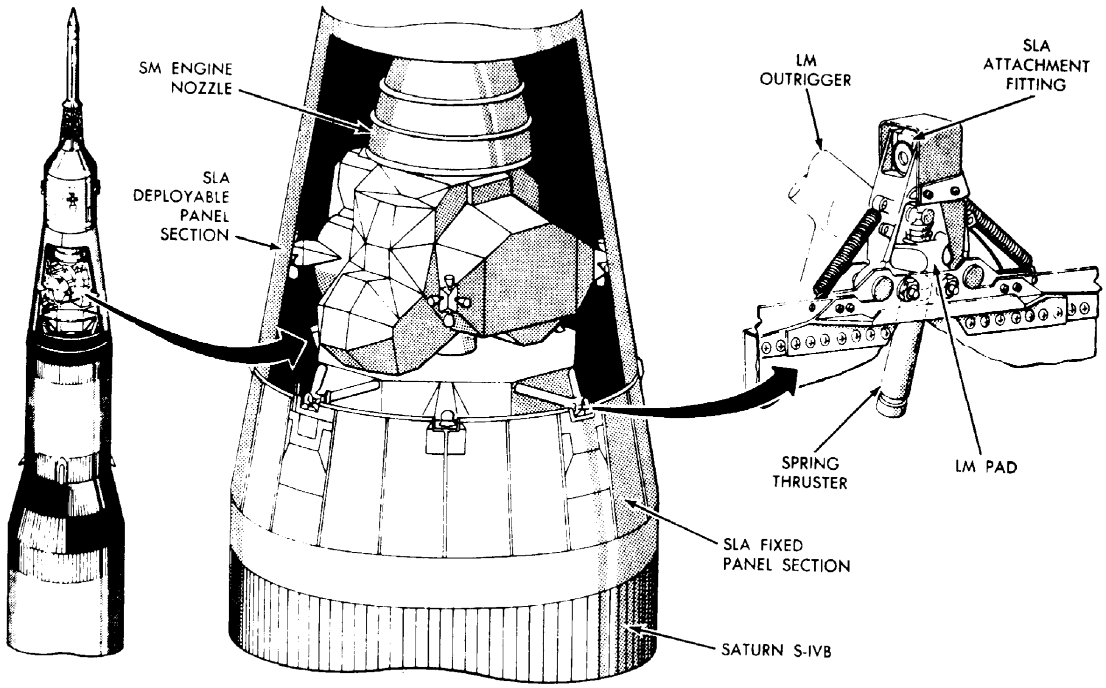
PLATFORM

An external platform, approximately 32 inches wide and 45 inches long is mounted over the forward landing gear outrigger. The platform is just below the forward hatch. The upper surface is corrugated to facilitate hand and foot holds. The platform, in conjunction with the ladder below it provides the astronauts with a means of access between the vehicle and the lunar surface and between the LM interior and free space for EVA.

INTERFACES.

At earth launch, the LM is housed within the SLA, which has an upper and a lower section. The upper section has deployable panels, which are jettisoned; the lower section has fixed panels. The upper panels are deployed and jettisoned when the CSM is separated from the SLA. During this separation phase, an explosive charge separates an umbilical line that connectes the LM, SLA, and launch umbilical tower. Before earth launch, this umbilical enables monitoring, purging, and control of the LM environment.

After transposition, the CSM docks with the LM. A ring at the top of the ascent stage docking tunnel provides a structural interface for joining the CSM to the LM. The ring is compatible with a clamping mechanism in the CSM docking ring. A drogue, which mates with the CSM docking probe, is installed in the docking tunnel, just below the ring. The probe provides initial vehicle soft docking and attenuates impact imposed by contact of the CSM and LM. After the CSM probe and drogue have joined, latches around the periphery of the CSM docking ring engage to effect full structural continuity and a pressure-tight seal between the vehicles. After docking has been completed, the astronauts connect electrical umbilicals in the CSM and the LM. These umbilicals provide electrical power to the LM, for separation from the SLA.



LM Interface with SLA

Pads at the apex of the descent stage outriggers mate with attachment fittings in the SLA. Tiedown tension straps, which are explosively released hold the pads against the LSA attachment fittings. When the CSM and the LM have docked, an astronaut in the CM initiates severence of the tiedown straps. After the straps are severed, preloaded spring thrusters provide positive separation of the LM from the SLA.

EXPLOSIVE DEVICES

The explosive devices are electro chemical devices, which are operated by the astronauts to perform the following functions:

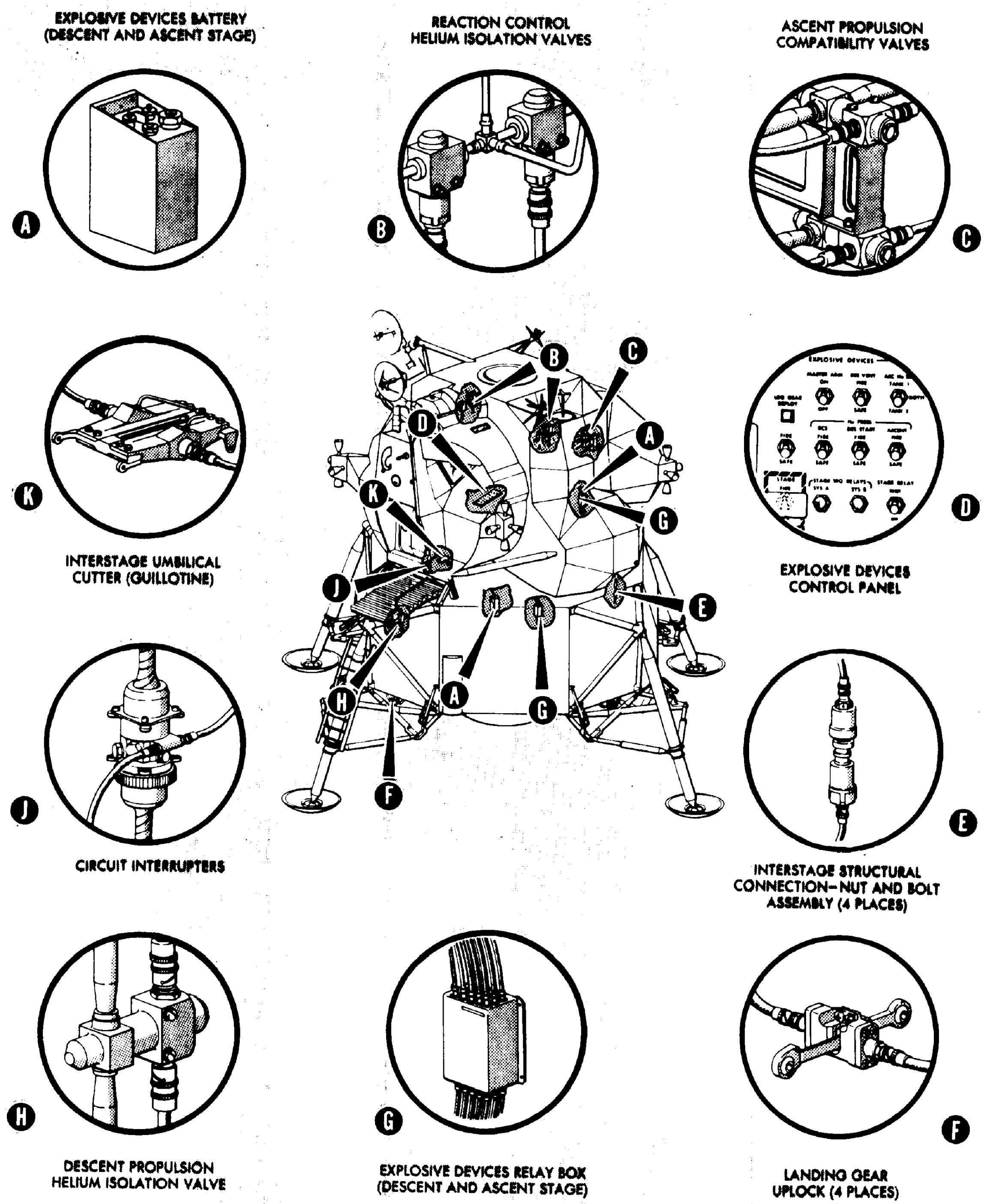
Propellant tank pressurization, so that the ascent engine, descent engine, and Reaction Control Subsystem can be operated

Ascent and descent stage separation to allow the ascent stage to take off from the lunar surface, or for a mission abort

Descent propellant tank venting after landing

Landing gear deployment

The LM has two types of explosive devices. Generally, these devices consist of detonator cartridges, containing high-explosive charges of high yield; and pressure cartridges, containing propellant charges of relatively low yield. An electrical signal, originated by the Commander through control switches, triggers an initiator, which fires the cartridges.



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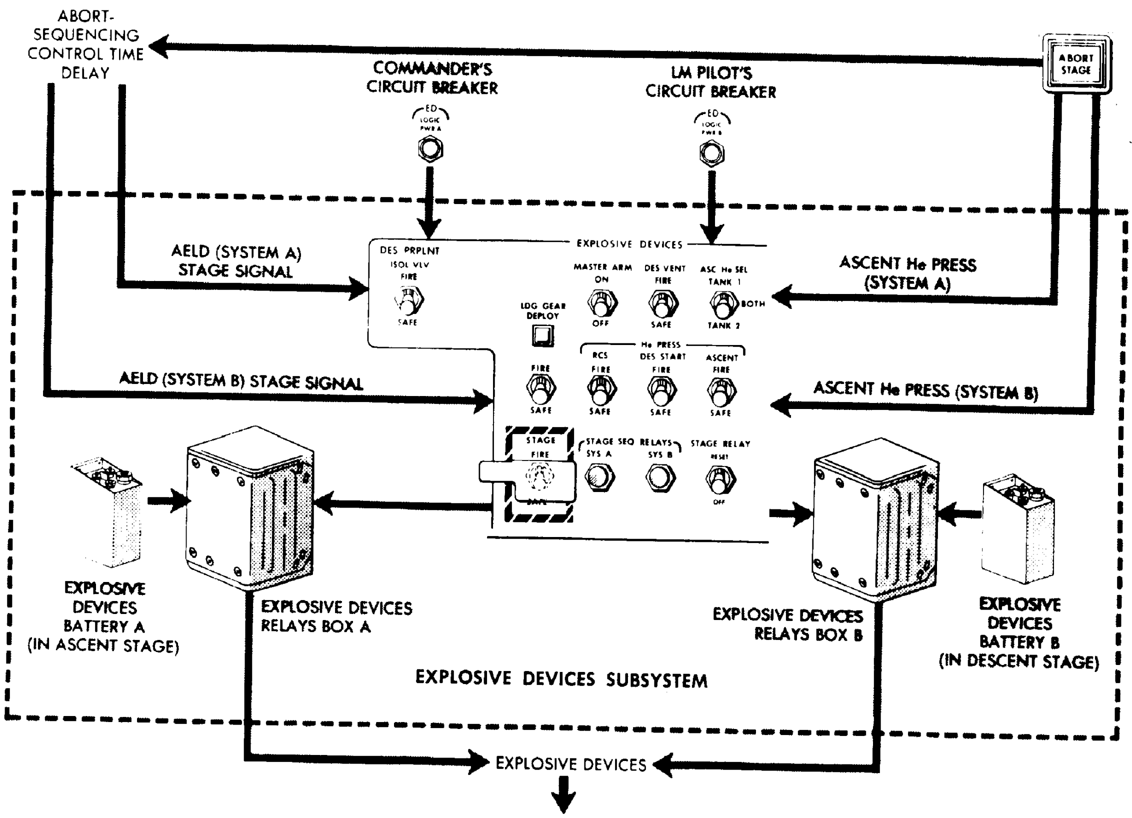
Major Explosive Devices Equipment Location



FUNCTIONS

- LANDING GEAR DEPLOYMENT
- DESCENT PROPELLANT TANK PRESSURIZATION AND COMPATIBILITY VALVE ACTUATION
- DESCENT PROPELLANT VENTING
- ASCENT PROPELLANT TANK PRESSURIZATION AND COMPATIBILITY VALVE ACTUATION
- RCS PROPELLANT PRESSURIZATION
- INTERSTAGE STRUCTURAL CONNECTIONS (NUTS AND BOLTS) SEPARATION
- ELECTRICAL CIRCUIT INTERRUPTION
- INTERSTAGE UMBILICAL SEVERANCE (CABLE CUTTER ASSEMBLY)

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Diagram of Explosive Devices

LANDING GEAR DEPLOYMENT

Each of the four landing gear assemblies is restrained in the stowed position by an uplock assembly that contains two detonator cartridges. While the LM is docked with the CM in lunar orbit, the LM Commander fires both detonator cartridges in each uplock assembly to deploy the landing gear. When all four landing gear assemblies have been deployed, a landing gear deployment indicator flag (talkback) on the control panel turns gray.

REACTION CONTROL SUBSYSTEM PROPELLANT TANK PRESSURIZATION

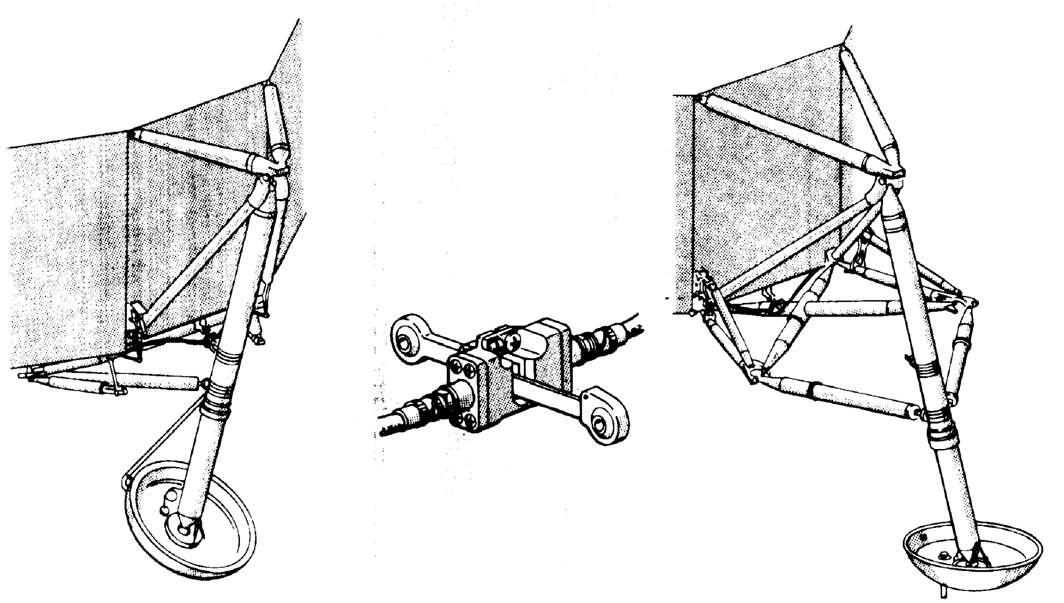
The Reaction Control Subsystem fuel and oxidizer tanks are pressurized immediately before landing gear deployment. The Commander fires two cartridges, which open dual, parallel helium isolation valves, to pressurize the tanks. The subsystem can then be operated to separate the LM from the CM.

DESCENT PROPELLANT TANK PRESSURIZATION

After the LM and CM separate, the astronauts start the descent engine. However, before initiating the start, the descent propellant tanks must be pressurized. The Commander fires the compatibility valve cartridges, explosively opening the valves. He then fires cartridges to explosively open the ambient helium isolation valve. After the descent engine is started, the cryogenic helium flows freely to the descent engine fuel and oxidizer tanks, pressurizing them.

DESCENT PROPELLANT TANK VENTING

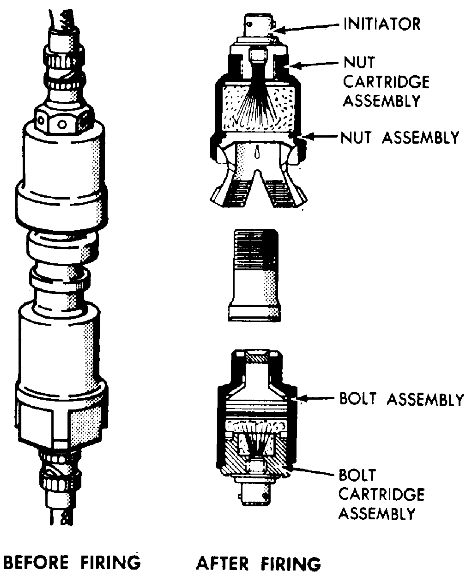
After lunar landing, the Commander simultaneously opens two explosive vent valves to accomplish planned depressurization of the descent propellant tanks. This protects the astronauts, when outside the LM, against untimely venting of the tanks through the relief valve assemblies.



Landing Gear Deployment

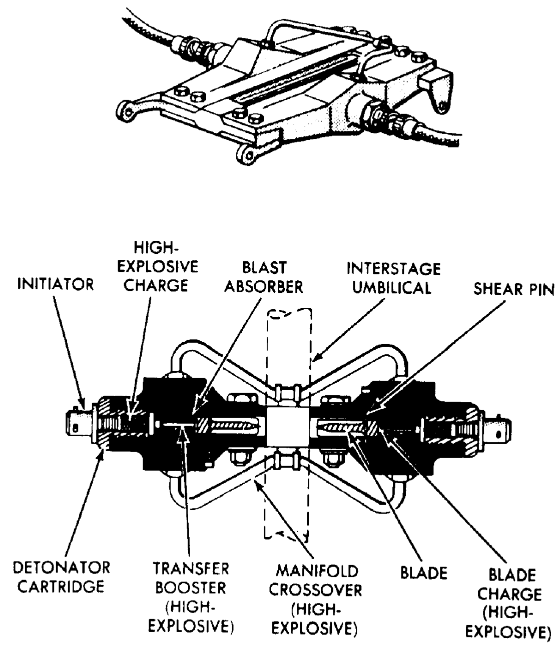
ASCENT PROPELLANT TANK PRESSURIZATION

After lunar stay, the astronauts take off from the lunar surface in the ascent stage. This requires pressurization of the ascent propellant tanks shortly before initial start of the ascent engine. To accomplish pressurization, the Commander fires explosive valve cartridges, which simultaneously open helium isolation valves and fuel and oxidizer compatibility valves. This permits helium to pressurize the ascent fuel and oxidizer tanks.



R-18

Explosive Nuts and Bolts

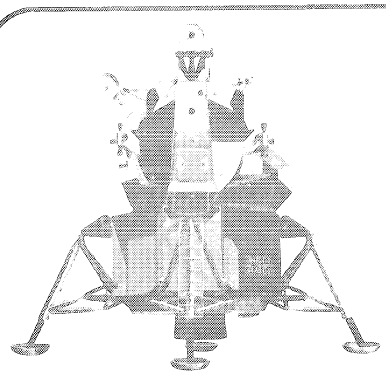


R-19

Explosive Guillotine

STAGE SEPARATION

The ascent and descent stages are separated immediately before lunar lift-off or in the event of mission abort. The Commander sets control switches to initiate a controlled sequence of stage separation. First, all signal and electrical power between the two stages is terminated by explosive circuit interrupters. Next, explosive nuts and bolts joining the stages are ignited. Finally, an explosive guillotine (cable cutter assembly) automatically severs all wires, cables, and water lines connected between the stages. Stage separation completed, operation of its engine can propel the ascent stage into lunar orbit for rendezvous with the CM.



APOLLO LUNAR MODULE

PRIMARY OBJECTIVES:

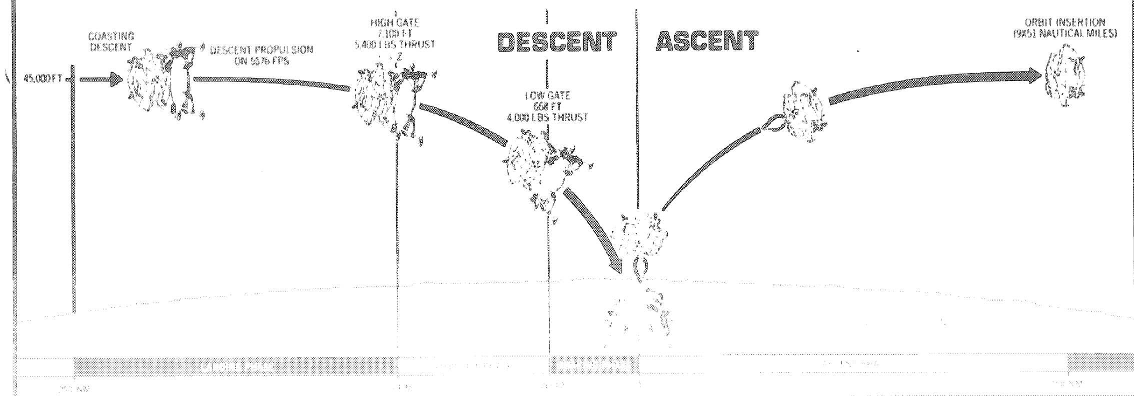
Manned lunar landing and return within the decade (1960's); scientific exploration of the moon.

PROGRAM MANAGEMENT:

National Aeronautics and Space Administration/ Johnson Space Center

PRIME CONTRACTOR:

Grumman Aerospace Corporation, Bethpage, N.Y.

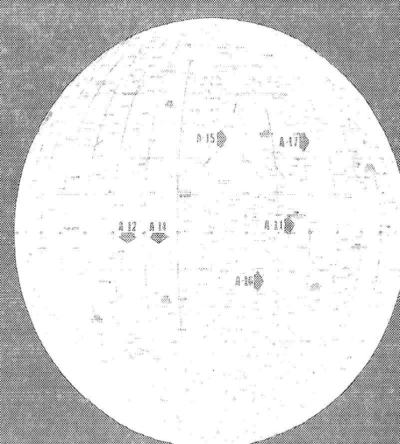


MISSION SUMMARY

APOLLO	LM	LAUNCH (E.S.T.)	LUNAR TOUCH-DOWN	LUNAR STAYTIME (HRS:MIN)	SURFACE EVA'S (HRS:MIN)	COMMANDER CSM PILOT LM PILOT	PURPOSE
4	LTA-10R	9 NOV 67 07:00:01	—	—	—	UNMANNED	LM TEST ARTICLE, LAUNCH & BOOST ENVIRONMENT
5	LM-1	22 JAN 68 17:48:08	—	—	—	UNMANNED	UNMANNED PROPULSION SYSTEM VERIFICATION
6	LTA-2R	4 APR 68 07:00:00	—	—	—	UNMANNED	LM TEST ARTICLE, LAUNCH & BOOST ENVIRONMENT
9	LM-3 "SPIDER"	3 MAR 69 11:00:00	—	—	—	JAMES A. McDIVITT DAVID R. SCOTT RUSSELL L. SCHWEIKART	1ST MANNED LM FLIGHT, EARTH ORBIT
10	LM-4 "SNOOPY"	18 MAY 69 11:49:00	—	—	—	THOMAS P. STAFFORD JOHN W. YOUNG EUGENE A. CERNAN	MANNED, LUNAR ORBIT, LOW PASS OVER LUNAR SURFACE
11	LM-5 EAGLE	16 JUL 69 08:32:00	20 JUL 69 15:17:40 1ST LUNAR STEP 21:56:15	21:36	2:31	NEIL A. ARMSTRONG MICHAEL COLLINS EDWIN E. ALDRIN	1ST LUNAR LANDING
12	LM-6 INTREPID	14 NOV 69 11:22:00	20 NOV 69 01:54:36	31:31	3:56 3:49	CHARLES CONRAD, JR. RICHARD F. GORDON ALAN L. BEAN	2ND LUNAR LANDING
13	LM-7 AQUARIUS	11 APR 70 14:13:00	—	—	—	JAMES A. LOVELL JOHN L. SWIGERT FRED W. HAISE, JR.	ABORTED IN TRANS-LUNAR COAST DUE TO LOSS OF SERVICE MODULE CRYOGENIC OXYGEN
14	LM-8 ANTARES	31 JAN 71 16:03:02	5 FEB 71 04:18:11	33:31	4:48 4:35	ALAN SHEPARD, JR. STUART A. ROOSA EDGAR D. MITCHELL	3RD LUNAR LANDING
15	LM-10 FALCON	26 JUL 71 08:34:00	30 JUL 71 15:16:29	66:55	6:33 7:12 4:50	DAVID R. SCOTT ALFRED J. WORDEN JAMES B. IRWIN	4TH LUNAR LANDING
16	LM-11 ORION	16 APR 72 12:54:00	20 APR 72 21:36:29	71:02	7:11 7:23 5:40	JOHN W. YOUNG THOMAS K. MATTINGLY, II CHARLES M. DUKE, JR.	5TH LUNAR LANDING
17	LM-12 CHALLENGER	7 DEC 72 00:33:00	11 DEC 72 14:54:57	75:00	7:12 7:37 7:15	EUGENE A. CERNAN RONALD EVANS HARRISON SCHMITT	6TH LUNAR LANDING

LUNAR LANDING SITES

APOLLO MISSION	SITE	COORDINATES	SAMPLES OBTAINED
11	SEA OF TRANQUILITY	0°41'15"N 23°26'00"E	48.5 POUNDS
12	OCEAN OF STORMS	3°12'S 23°24"W	74.7 POUNDS (PLUS PARTS FROM SURVEYOR 3)
14	FRA MAURO	3°40'24"S 17°27'55"W	96 POUNDS
15	RIMA HADLEY	26°6'4"N 3°39'10"E	170 POUNDS
16	DESCARTES	8°59'29"S 15°30'52"E	213 POUNDS
17	TAURUS LITTROW	20°9'41"N 30°45'26"E	243 POUNDS



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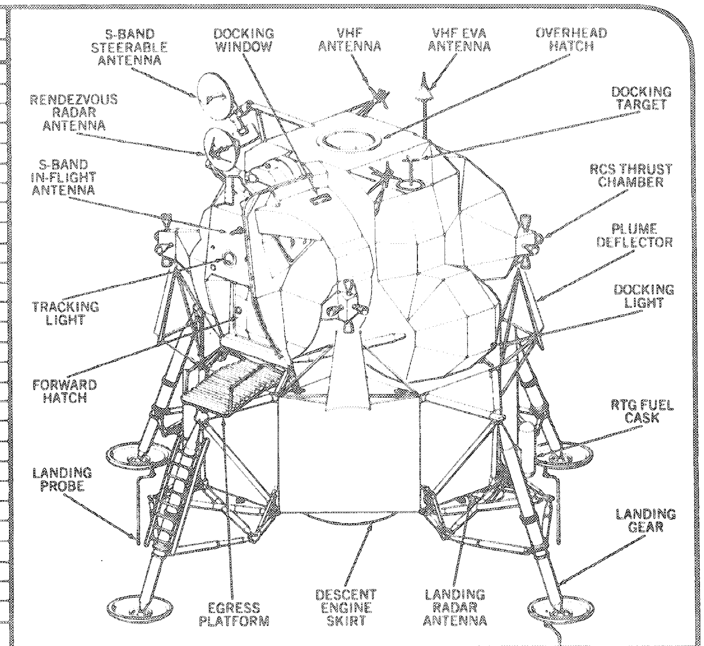
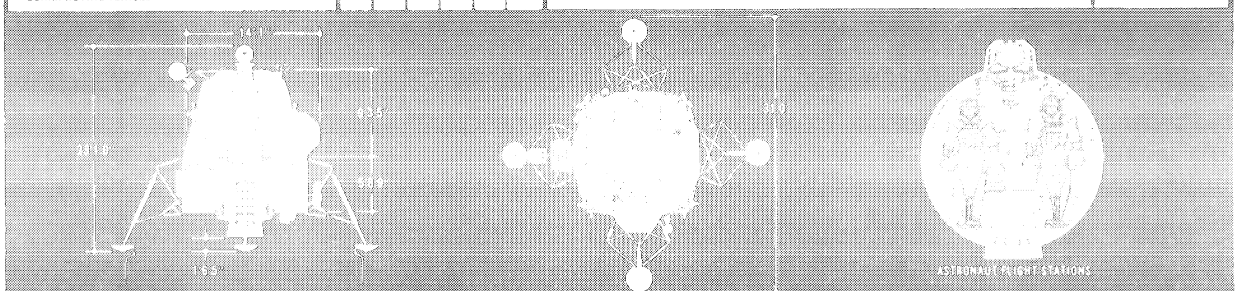
LUNAR SURFACE EXPERIMENTS & EQUIPMENT

LUNAR SURFACE EXPERIMENTS & EQUIPMENT	APOLLO MISSION 11	12	14	15	16	17
PASSIVE SEISMIC	o	o	o	o	o	o
ACTIVE SEISMIC			o		o	
LUNAR SURFACE MAGNETOMETER		o		o	o	
SOLAR WIND SPECTROMETER		o		o		
SUPRATHERMAL ION DETECTOR		o	o	o		
HEAT FLOW				o	o	o
CHARGED PARTICLE LUNAR ENVIRONMENT			o			
COLD CATHODE GAGE		o	o	o		
LUNAR FIELD GEOLOGY	o	o	o	o	o	o
LASER RANGING RETRO REFLECTOR	o		o	o		
SOLAR WIND COMPOSITION	o	o	o	o	o	
COSMIC RAY DETECTOR (SHEETS)					o	o
PORTABLE MAGNETOMETER			o		o	
TRAVERSE GRAVIMETER						o
LUNAR SOIL MECHANICS	o	o	o	o	o	o
FAR ULTRAVIOLET CAMERA/SPECTROSCOPE					o	
LUNAR EJECT AND METEORITES						o
LUNAR SEISMIC PROFILING						o
SURFACE ELECTRICAL PROPERTIES						o
LUNAR ATMOSPHERIC COMPOSITION						o
LUNAR SURFACE GRAVIMETER						o
LUNAR NEUTRON PROBE						o
LUNAR DUST DETECTOR		o	o			
RADIOISOTOPE THERMOELECTRIC GENERATOR	o	o	o	o	o	o
B&W TV	o					
COLOR TV		o	o	o	o	o
PHOTOGRAPHIC CAMERAS	o	o	o	o	o	o
MOBILE EQUIPMENT TRANSPORTER			o			
LUNAR ROVING VEHICLE				o	o	o

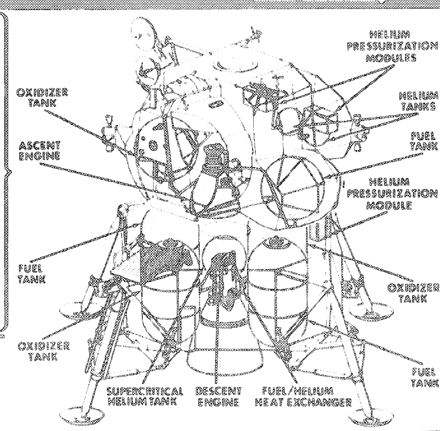




PROPULSION

DESCENT ENGINE
- RESTARTABLE
- NOMINAL THRUST (FULL THROTTLE)—9900 #
- MINIMUM THRUST (LOW STOP) —1280 #
- PRESSURE FED, HYPERGOLIC, LIQUID PROPELLANT
  - —OXIDIZER N_2O_4
  - —FUEL 50/50 MIX N_2H_4 AND UDMH
  - —O/F RATIO 1:6:1
- 6° GIMBALLING FOR C.G. TRIMMING
- APPROXIMATE WEIGHT 348 #
- OVERALL LENGTH 95"
- NOZZLE EXIT DIAMETER 63"

ASCENT ENGINE
- RESTARTABLE
- PRESSURE FED, HYPERGOLIC, LIQUID PROPELLANT
  - —OXIDIZER N_2O_4
  - —FUEL 50/50 MIX N_2H_4 AND UDMH
  - —O/F RATIO 1:6:1
- NO GIMBALLING
- APPROXIMATE WEIGHT 200 #
- OVERALL LENGTH 47"
- NOZZLE EXIT DIAMETER 31"



INSTRUMENTATION

- MONITOR SUBSYSTEM STATUS
- CAUTION AND WARNING INDICATIONS
- IN-FLIGHT AND LUNAR SURFACE CHECKOUT
- PRECISION TIMING
- VOICE AND DATA STORAGE
- TELEMETRY
  - —277 ANALOG CHANNELS
  - — 77 DIGITAL CHANNELS

EXPLOSIVE DEVICES

- LANDING GEAR DEPLOYMENT
- PROPELLANT TANK PRESSURIZATION AND VENTING
- INTERSTAGE CONNECTORS
- INTERSTAGE UMBILICAL SEVERANCE
- ELECTRICAL CIRCUIT INTERRUPTION (UMBILICAL)

LANDING GEAR

- IMPACT ATTENUATION, PRIMARY STRUTS
  - —32" CRUSHABLE HONEY COMB CARTRIDGE
  - —MAX 10 FPS VERTICALLY; 7 FPS VERTICALLY AND 4 FPS HORIZONTALLY
- DEPLOYED PRIOR TO LM/CSM SEPARATION
- FOOT PADS—37" DIAMETER
- LUNAR CONTACT SENSING PROBES—5 FT. LONG

REACTION CONTROL SYSTEM

- PROVIDES ATTITUDE AND TRANSLATION CONTROL
- 4 CLUSTERS, 4 ENGINES EACH
- TWO REDUNDANT INDEPENDENT SYSTEMS
- NOMINAL ENGINE THRUST 100 #
- PRESSURE FED FROM POSITIVE EXPULSION BLADDER TANKS
- HYPERGOLIC LIQUID PROPELLANTS
  - —OXIDIZER N_2O_4
  - —FUEL 50/50 MIX N_2H_4 AND UDMH
  - —O/F RATIO 2:1
- APPROXIMATE ENGINE WEIGHT 5.25 POUNDS
- OVERALL LENGTH 13.5"
- NOZZLE EXIT DIAMETER 5.75"

COMMUNICATIONS

- LM-EARTH/LM-CSM/LM-EVA
- VOICE
- TELEVISION
- RANGING
- TELEMETRY
- COMPUTER UPLINK COMMAND
- EMERGENCY KEY
- ANTENNAS
  - —S-BAND, STEERABLE 26" PARABOLIC REFLECTOR
  - —S-BAND OMNI (2)
  - —VHF OMNI (2)
  - —VHF OMNI EVA

TYPICAL WEIGHT (LM-10 THROUGH 12 CONFIGURATION)—POUNDS

	ASCENT STAGE	DESCENT STAGE	TOTAL
STRUCTURE	1385	1470	2855
STABILIZATION AND CONTROL	79	13	92
NAVIGATION AND GUIDANCE	343	44	387
CREW PROVISIONS	146	234	380
ENVIRONMENTAL CONTROL	297	206	503
INSTRUMENTATION	132	8	140
ELECTRICAL POWER SUPPLY	737	787	1524
PROPULSION	469	1089	1558
REACTION CONTROL	242	0	242
COMMUNICATIONS	114	0	114
CONTROLS AND DISPLAYS	232	3	235
EXPLOSIVE DEVICES	29	26	55
LANDING GEAR	0	486	486
LUNAR EXPERIMENTS AND EQUIPMENT	406	1212	1618
LIQUIDS & GASES (EXCLUDING PROP)	136	555	691
INERT WEIGHT	4747	6133	10880
PROPELLANTS			
MAIN	5230	19507	24737
RCS	605	0	605
TOTAL WEIGHT—POUNDS	10582	25640	36222
—(KILOGRAMS)	(4804)	(11641)	(16448)

ELECTRICAL POWER SYSTEM

- BATTERIES PROVIDE PRIMARY POWER
- SILVER ZINC PLATES, 20 CELLS
- POTASSIUM HYDROXIDE ELECTROLYTE
- 2 ASCENT STAGE BATTERIES, 296 A-H EACH
- 4 DESCENT STAGE BATTERIES, 400 A-H EACH (LM-10 TO 12, 5 BATTERIES, 415 A-H EACH)
- NOMINAL VOLTAGE—30V (28V BUS VOLTAGE)
- TWO SOLID STATE INVERTERS, 115V, 400 Hz, SINGLE PHASE

GUIDANCE, NAVIGATION AND CONTROL

- INERTIAL GUIDANCE, OPTICAL AND RADAR NAVIGATION
- PRIMARY GUIDANCE COMPUTER
  - —FIXED AND ERASABLE MEMORY (36,864 WORDS, 2,048 WORDS)
- ABORT GUIDANCE COMPUTER
  - —FIXED AND ERASABLE MEMORY (2,048 WORDS EACH)
- LANDING RADAR
  - —VELOCITY, FROM ALTITUDE OF 24,000′
  - —ALTITUDE, 10 TO 40,000′
- RENDEZVOUS RADAR
  - —LM/CSM RANGE AND RANGE RATE
  - —80 FEET TO 400 N.MI: ± 4900 FPS

ENVIRONMENTAL CONTROL SYSTEM

- CONTROLLED ENVIRONMENT FOR SHIRT SLEEVE OR PRESSURE SUIT OPERATION
- ATMOSPHERE—100% OXYGEN, 4.8 PSIA, 75°F
- PRESSURIZED VOLUME 235 FT³
- WATER FOR DRINKING, FOOD PREP, WASTE HEAT REJECTION SUBLIMATORS, FIRE EXTINGUISHING
- ELECTRONIC EQUIPMENT THERMAL CONTROL
- COOLANT—35% ETHYLENE GLYCOL, 65% WATER
- RECHARGE PORTABLE LIFE SUPPORT SYSTEM WITH OXYGEN AND WATER

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CREW PERSONAL EQUIPMENT

Crew personal equipment includes a variety of mission-oriented equipment required for life support and astronaut safety and accessories related to successful completion of the mission.

These equipments range from astronaut space suits and docking aids to personal items stored throughout the cabin. The Modularized Equipment Stowage Assembly (MESA) and the early Apollo scientific experiments payload (EASEP) is stored in the descent stage and on the MESA.

This equipment is used for sample and data collecting and scientific experimenting. The resultant data will be used to derive information on the atmosphere and distance between earth and moon.

The portable life support system (PLSS) interfaces with the Environmental Control Subsystem (ECS) for refills of oxygen and water. The pressure garment assembly (PGA) interfaces with the ECS for conditioned oxygen, through oxygen umbilicals, and with the Communications and Instrumentation Subsystems for communications and bioinstrumentation, through the electrical umbilical.

EXTRAVEHICULAR MOBILITY UNIT

The extravehicular mobility unit (EMU) provides life support in a pressurized or unpressurized cabin, and up to 4 hours of extravehicular life support.

In its extravehicular configuration, the EMU is a closed-circuit pressure vessel that envelops the astronaut. The environment inside the pressure vessel consists of 100% oxygen at a nominal pressure of 3.75 psia. The oxygen is provided at a flow rate of 6 cfm. The extravehicular life support equipment configuration includes the following:

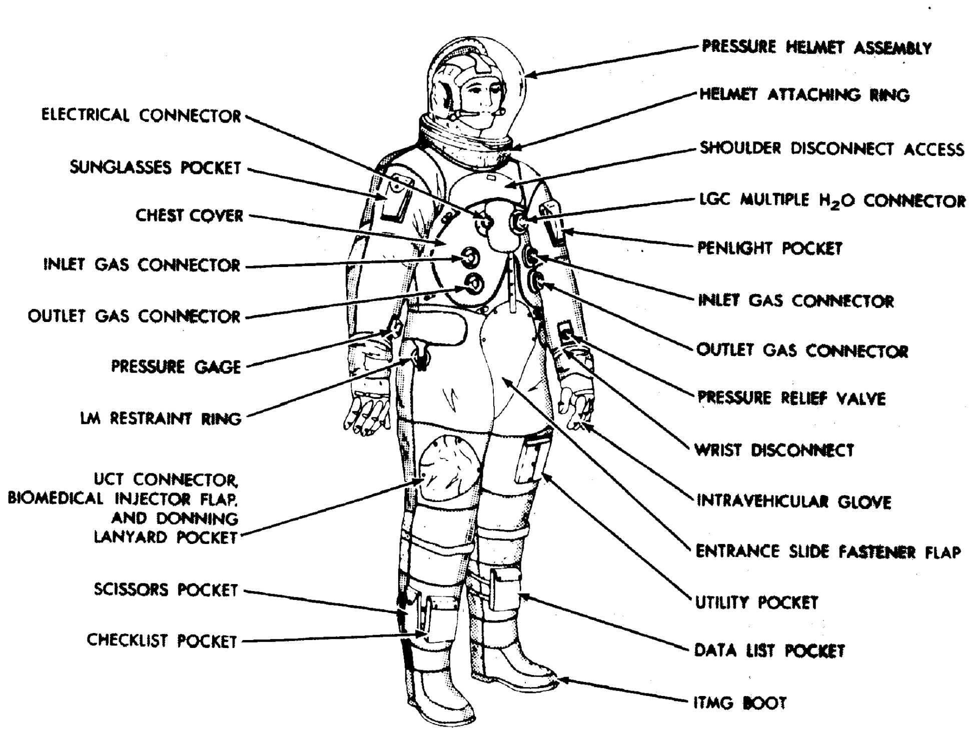
Liquid cooling garment (LCG)
Pressure garment assembly (PGA)
Integrated thermal micrometeoroid garment (ITMG)
Portable life support system (PLSS)
Oxygen purge system (OPS)
Communications carrier
EMU waste management system
EMU maintenance kit
PLSS remote control unit
Extravehicular visor assembly (EVVA)
Biomedical belt

LIQUID COOLING GARMENT

The liquid cooling garment (LCG) is worn by the astronauts while in the LM and during all extravehicular activity. It cools the astronaut's body during extravehicular activity by absorbing body heat and transferring excessive heat to the sublimator in the PLSS. The LCG is a one-piece, long-sleeved, integrated-stocking undergarment of netting material. It consists of an inner liner of Beta cloth, to facilitate donning, and an outer layer of Beta cloth into which a network of Tygon tubing is woven. The tubing does not pass through the stocking area. A double connector for incoming and outgoing water is located on the front of the garment. Cooled water, supplied from the PLSS, is pumped through the tubing. Pockets for bioinstrumentation signal conditioners are located around the waist. A zipper that runs up the front is used for donning and doffing the LCG; an opening at the crotch is used for urinating. Dosimeter pockets and snaps for attaching a biomedical belt are part of the LCG.

PRESSURE GARMENT ASSEMBLY

The pressure garment assembly (PGA) is the basic pressure vessel of the EMU. It provides a mobile life-support chamber if cabin pressure is lost due to leaks or puncture of the vehicle. The PGA consists of a helmet, torso and limb suit, intravehicular gloves, and various controls and instrumentation to provide the crewman with a controlled environment. The PGA is designed to be worn for 115 hours, in an emergency, at a regulated pressure of 3.75 ± 0.25 psig, in conjunction with the LCG.



R-20

Pressure Garment Assembly

The torso and limb suit is a flexible pressure garment that encompasses the entire body, except the head and hands. It has four gas connectors, a PGA multiple water receptacle, a PGA electrical connector, and a PGA urine transfer connector for the PLSS/PGA and ECS/PGA interface. The PGA connectors have positive locking devices and can be connected and disconnected without assistance. The gas connectors comprise an oxygen inlet and outlet connector, on each side of the suit front torso. Each oxygen inlet connector has an integral ventilation diverter valve. The PGA multiple water receptacle, mounted on the suit torso, serves as the interface between the LCG multiple water connector and PLSS multiple water connector. A protective external cover provides PGA pressure integrity when the LCG multiple water connector is removed from the PGA water receptacle. The PGA electrical connector, provides a communications, instrumentation, and power interface to the PGA. The PGA urine transfer connector on the suit right leg is used to transfer urine from the urine collection transfer assembly (UCTA) to the waste management system.

The urine transfer connector, permits dumping the urine collection bag without depressurizing the PGA. A pressure relief valve on the suit sleeve, near the wrist ring, vents the suit in the event of overpressurization. If the valve does not open, it can be manually overridden. A pressure gage on the other sleeve indicates suit pressure.

The helmet is a Lexan (polycarbonate) shell with a bubble-type visor, a vent-pad assembly, and a helmet attaching ring. The vent-pad assembly permits a constant flow of oxygen over the inner front surface of the helmet. The astronaut can turn his head within the helmet neck-ring area. The helmet does not turn independently of the torso and limb suit. The helmet has provisions on each side for mounting an extravehicular visor assembly (EVVA). When the LM is unoccupied, the helmet protective bags are stowed on the cabin floor at the crew flight stations. Each bag has a hollow-shell plastic base with a circular channel for the helmet and the EVVA, two recessed holes for glove connector rings, and a slot for the EMU maintenance kit. The bag is made of Beta cloth, with a circumferential zipper; it folds toward the plastic base when empty.

The intravehicular gloves are worn during operations in the LM cabin. The gloves are secured to the wrist rings of the torso and limb suit with a slide lock; they rotate by means of a ball-bearing race. Freedom of rotation, along with convoluted bladders at the wrists and adjustable anti-ballooning restraints on the knuckle areas, permits manual operations while wearing the gloves.

All PGA controls are accessible to the crewman during intravehicular and extravehicular operations. The PGA controls comprise two ventilation diverter valves, a pressure relief valve with manual override, and a manual purge valve. For intravehicular operations, the ventilation diverter valves are open, dividing the PGA inlet oxygen flow equally between the torso and helmet of the PGA. During extravehicular operation, the ventilation diverter valves are closed and the entire oxygen flow enters the helmet. The pressure relief valve accommodates flow from a failed-open primary oxygen pressure regulator. If the pressure relief valve fails open, it may be manually closed. The purge valve interfaces with the PGA through the PGA oxygen outlet connector. Manual operation of this valve initiates an 8 pound/hour purge flow, providing CO_2 washout and minimum cooling during contingency or emergency operations.

A pressure transducer on the right cuff indicates pressure within the PGA. Biomedical instrumentation comprises an EKG (heart) sensor, ZPN (respiration rate) sensor, dc-to-dc converter, and wiring harness. A personal radiation dosimeter (active) is attached to the integrated thermal micrometeoroid garment for continuous accumulative radiation readout. A chronograph wristwatch (elapsed-time indicator) is readily accessible to the crewman for monitoring.

COMMUNICATIONS CARRIER

The communications carrier (cap) is a polyurethane-foam headpiece with two independent earphones and microphones, which are connected to the suit 21-pin communications electrical connector. The communications carrier is worn with or without the helmet during intravehicular operations. It is worn with the helmet during extravehicular operations.

INTEGRATED THERMAL MICROMETEOROID GARMENT

The ITMG, worn over the PGA, protects the astronaut from harmful radiation, heat transfer, and micrometeoroid activity. It is a one-piece, form-fitting, multilayered garment that is laced over the PGA and remains with it. The EVVA, gloves, and boots are donned separately. From the outer layer in, the ITMG is made of a protective cover, a micrometeoroid-shielding layer, a thermal-barrier blanket (multiple layers of aluminized mylar), and a protective liner. A zipper on the ITMG permits connecting or disconnecting umbilical hoses. For extravehicular activity, the PGA gloves are replaced with the extravehicular gloves. The extravehicular gloves are made of the same material as the ITMG to permit handling intensely hot or cold objects outside the cabin and for protection against lunar temperatures. The extravehicular boots (lunar overshoes) are worn over the PGA boots for extravehicular activity. They are made of the same material as the ITMG. The soles have additional insulation for protection against intense temperatures.

The EVVA provides protection against solar heat, space particles, and radiation, and helps to maintain thermal balance. The two pivital visors of the EVVA may be attached to a pivot mounting on the PGA helmet. The lightly tinted (inner) visor reduces fogging in the helmet. The outer visor has a vacuum deposited, gold-film reflective surface,