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STRUCTURE OF THE NASA/GRUMMAN LUNAR MODULE

The LM consists of a descent stage (with landing gear) and an ascent stage. Provision is made for separating the stages and the interconnecting umbilicals at lunar launch. The weight of the LM at earth launch is approximately 32,000 pounds.

ASCENT STAGE

The ascent stage is the manned portion of the LM spacecraft and will carry two astronauts. Power and coasting descent, lunar landing, lunar launch, power ascent, and rendezvous and docking with the Command/Service Modules (CSM) are controlled from the crew compartment. The crew compartment, a pressurized shell, is also the operations center for the astronauts during the lunar stay. The entire pressurized compartment of the ascent stage is called the cabin. In addition to the crew compartment, the ascent stage consists of the mid section, the aft equipment bay, tank sections, engine supports, windows, tunnels, and hatches. Pressure and temperature within the crew compartment are controlled by the Environmental Control System (ECS).

Crew Compartment (Cabin)

The ascent stage is constructed of aluminum alloy. A structural skin surrounded by a composite layer of insulation and a thin aluminum skin provides thermal and micrometeoroid protection for the astronauts. The outer skin is approximately three inches from

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the structural skin. The cabin (crew compartment) is a 92-inch diameter cylinder stiffened by two-inch deep circumferential frames. The frames are spaced approximately 10 inches apart and are located between the structural skin and the thermal shield. The compartment has two triangular cabin windows in the front-face bulkhead, an overhead docking window on the left side, a forward ingress/egress hatch, an upper docking hatch, controls and displays, and items necessary for astronaut comfort and support.

Midsection

The midsection is a smaller compartment directly behind the cabin. The ascent engine is aligned with the center of gravity in the midsection. The ascent engine plumbing and valving is accessible when the removable cover that extends above the deck in the midsection is removed. In addition, the midsection contains the overhead docking hatch, Environmental Control System (ECS), and stowage for equipment that must be accessible to the astronauts.

Tunnels

The upper docking tunnel, at the top centerline of the ascent stage, is used for docking when transposition is performed, for transfer of two astronauts to the LM spacecraft after injection into lunar orbit, for docking after rendezvous in lunar orbit, and for transfer of the LM crew and scientific payload to the Command Module. The ingress/egress hatch, at the lower portion of the forward cabin section, is used on the lunar surface. Pressure-tight, plug-type

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hatches in each tunnel are manually controlled, and are sealed with preloaded silicone elastomeric seals. The ingress/egress hatch leads to an external platform upon which the astronauts step after leaving and before entering the LM.

Aft Equipment Bay

The aft equipment bay is unpressurized and is aft of the mid-section pressure-tight bulkhead. It contains an equipment rack with integral cold plates on which electronic replaceable assemblies (ERA's) are mounted. It includes two gaseous oxygen (GOX) tanks for ascent stage main propellant pressurization, inverters, and batteries for the Electrical Power System (EPS).

Tank Sections

The propellant tank sections are on either side of the mid-section, outside the pressurized area. The tank sections contain ascent engine fuel and oxidizer tanks, and fuel, oxidizer, and helium tanks for the Reaction Control System (RCS). Because the ratio of oxidizer to fuel is 1.6 to 1 by weight, the ascent engine propellant tanks are offset to one side to maintain the lateral center of gravity on the X-axis. Two ECS water tanks are in the overhead of the ascent stage, and two gaseous oxygen storage tanks are in the aft equipment bay.

Windows

Two triangular cabin windows in the front-face bulkhead of the forward cabin section (crew compartment) provide visibility during

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descent, lunar landing, and rendezvous phases of the LM mission. The windows have approximately two square feet of viewing area and are canted down to the side to permit adequate peripheral and downward visibility. Each window consists of two panes separated from each other and vented to space environment. The outer pane is thermal and radiation-protective (Vycor) glass and the inner pane is strong, flexible (Chemcor) glass. A clamp-type seal consisting of a teflon jacket surrounding a metallic spring seals the inner pane.

An overhead window, similar in construction to the forward windows, is on the left side of the forward cabin section directly over the commander's head, and provides the commander with visibility during docking. The window contains a sighting reticle as an aid in lining up the CSM with the LM spacecraft. The field-of-view is at least plus or minus 10° each side of the window centerline, and minus 5° and plus 40° from the vertical centerline. Visibility is obtained by the commander leaning backward and looking up from his normal duty station. The approximate visible opening of the window is 5 inches wide and 12 inches long.

Hatches

Two hatches in the ascent stage permit ingress and egress to and from the LM. The upper or docking hatch, used mainly for docking, is in the midsection directly above the ascent engine cover. Three recesses in the hatch permit use of a ladder for observation while on the lunar surface. The forward hatch is beneath the center instrument

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console (controls and displays) and is used for ingress and egress on the lunar surface. Each hatch contains a dump valve and manually-operated single detent mechanism which preloads the hatch against its seal.

Each hatch has a preloaded elastomeric silicone compound seal mounted in the structure of the spacecraft. When the hatch is closed, a lip near the outer circumference of the hatch enters the seal, ensuring a pressure-tight contact. Both hatches open inward, and normal cabin pressurization forces the hatch into the seal. To open either hatch, it is necessary to depressurize the cabin through the dump valve, and unfasten the latch.

DESCENT ENGINE

The descent stage is the unmanned portion of the LM spacecraft. It consists of that equipment necessary for landing on the lunar surface (e.g., landing gear) and serves as a platform for launching the ascent stage after completion of the lunar stay. In addition to the descent engine and its related components, the descent stage houses scientific equipment to be used on the lunar surface, tanks for water and oxygen used by the ECS, four batteries located in the battery storage bay for the EPS, and six spare PLSS batteries.

The descent stage is constructed of aluminum alloy. Chem-milling is used extensively to reduce weight. The inner structural skin is surrounded by a composite layer of insulation and a thin aluminum-alloy skin that forms a modified octagonal shape around the descent

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stage and thermally protects and isolates the structure. The beams are of conventional skin and stringer construction. All joints are fastened with standard mechanical fasteners. The space between the intersections of the beams forms the center compartment, which contains the descent engine.

Outriggers that extend from the end of each of the two pairs of beams provide support and attachment for the landing gear legs. Four main propellant tanks surround the engine; two oxidizer tanks and two fuel tanks are mounted within the cruciform structure. Scientific equipment, helium oxygen, and water tanks, the lunar surface antennas, EPS batteries, and PLSS batteries are in the bays adjacent to the propellant tanks.

Landing Gear

The landing gear is of the cantelever type. It consists of four sets of legs connected to outriggers that extend from the ends of the descent stage structural beams. The legs extend from the front, rear, and sides of the LM. Each landing gear leg consists of a primary strut and footpad, a drive-out mechanism, two secondary struts, two downlock mechanism, and a truss. In addition, all footpads, but the one on the forward landing gear leg, have lunar surface sensing probes extending below each footpad. All struts have crushable shock absorbing honeycomb inserts. The primary struts absorb compresion loads. The secondary struts absorb compression and tension loads. The forward landing gear has a boarding ladder

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on the primary strut, which is used to climb to and from the ascent stage forward hatch.

The landing gear is in a retracted position until shortly after the astronauts enter the LM during lunar orbit. The landing gear uplocks are then explosively released and springs in each driveout mechanism extend the landing gear and lunar surface sensing probes. Once extended, each landing gear is locked in place by the two down-lock mechanisms.

Interstage Attachments, Umbilicals, and Separations

At earth launch, the LM spacecraft is within the Spacecraft LM Adapter (SLA) between the Service Module and the S-IV booster. The outriggers to which the landing gear is attached provide for attachment of the LM to the lower section of the SLA at their apex. Before transposition, the upper section of the SLA is explosively separated into four segments. These segments are hinged to the lower section and jettisoned. After transposition, the lower section is released, separating the SLA and the booster from the LM spacecraft.

Four explosive nuts and bolts connect the ascent and descent stages. At lunar launch, or for an abort, the two stages are separated by firing these explosive devices. Interstage wiring umbilicals are explosively disconnected and hardlines are mechanically severed at stage separation.

Electroexplosive Devices (EED)

Explosive devices are used to release the landing gear for deployment; to enable helium pressurization of the Ascent Propulsion, Descent, or Reaction Control systems; and for stage separation. The electroexplosive devices are exploded by a standard Apollo initiator controlled by switches on the Explosive Devices Panel.

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