GLOSSARY

Ablation – Shedding of excessive heat from a surface by vaporization or melting of specially designed coating materials (ablative material). The Apollo heat shield disperses reentry heat in this manner; the combustion chamber and nozzles of the descent and ascent engines are also ablatively cooled.

Abort – To cut short a launch or mission because of equipment failure or other problems.

Acceleration – Rate of gain in velocity.

Accelerometer – "Speedometer" in spacecraft control system; a device that measures velocity changes along all three axes and sends signals to the guidance computer, displays, etc.

Accumulator – Storage device, such as hydraulic system apparatus, which stores fluid under pressure, or a computer device, which stores a continuously higher sum as it adds incoming numbers to that sum.

Acquisition – Process of locating an orbiting spacecraft to begin tracking or gathering telemetry data.

Activated Charcoal – Substance used in atmospheric revitalization section to remove odors from recirculating cabin and suit oxygen supply.

Actuators – Devices that transform an electrical signal into a mechanical motion, using hydraulic or pneumatic power.

Aerozine – Liquid fuel used in ascent and descent engines; half unsymmetrical dimethylhydrazine and half hydrazine. It is storable, and hypergolic in the presence of nitrogen tetroxide.

Aft Equipment Bay – Unpressurized area in the ascent stage for electronic equipment, batteries, oxygen supply, and cooling equipment.

Ambient – Denotes "normal" environmental conditions such as pressure or temperature. (LM cabin ambient is 4.5 psi at 70° F.)

Analog Computer – Computer that operates on the principal of measuring (linear lengths, voltages, etc.), as distinguished from counting. An analog computer in the Lunar Module converts water-quantity measurements into a form suitable for display.

Apollo – NASA's manned lunar landing program, and the spacecraft built to achieve it. Originally, the Greek god of light.

Ascent Engine – The 3,500-pound thrust engine in the ascent stage, used for launch from the moon's surface and orbital adjustment, or prelanding abort.

Ascent Stage – Upper portion of the Lunar Module; houses crew, controls, and ascent engine. It returns the crew to the Command Module in lunar orbit.

Atmosphere Revitalization – Replenishing, cleaning, dehumidifying, deodorizing, and cooling or heating the air in the Lunar Module atmospheric system.

Attitude – Position or orientation of the spacecraft as determined by the inclination of its axes to some reference line or plane.

Attitude Control Mode – One of two major modes with which system spacecraft attitude is maintained.

Audio Center – Portion of the Lunar Module Communications Subsystem, including earphone and microphone controls, voice-operated relay controls, and the voice recorder.

Axis – Any of three straight lines about which a spacecraft rotates; one of a set of reference lines for a coordinate system.

Backpack – Self-contained portable life support system.

Backup – Item or system available as replacement for one that fails; an astronaut or astronaut crew trained to replace the prime pilot(s) in the event of illness or death.

Biosensors – Small devices attached to crewmembers to sense heartbeat and respiration rate.

Bipropellant – Using two propellants (fuel and oxidizer), which are fed separately into the combustion chamber.

Bit – Abbreviation of binary digit; smallest unit of computer-coded information, carried by a single digit of binary notation.

Blowout Disk – Thin metal diaphragm used as a safety device to relieve excessive gas pressure. (See Burst Diaphragm.)

APOLLO NEWS REFERENCE

Burn – The firing of engines or to fire them. Burn time is the length of the thrusting period.

Burst Diaphragm – Thin metal disk, which ruptures at a predetermined point to relieve excessive pressure. (Also Burst Disk.)

Caution and Warning System – System that monitors spacecraft subsystems and causes master alarm lights to go on and a warning tone to be initiated if malfunctions or critical conditions are detected.

Cavitation – Rapid formation and collapse of vapor pockets in a flowing liquid at low pressure; causes structural damage to rocket components; formation of partial vacuum in a pump, such as fuel pump.

Celestial – Pertaining to the stars. Celestial mechanics pertains to the motion of bodies in gravitational fields. Celestial navigation is onboard navigation, using stars for reference.

Center of Gravity – Central point of a body with regard to the distribution of its mass; the point at which its weight is centered.

Chamber Pressure – Pressure in rocket-engine combustion chamber.

Cold Plates – Equipment mounting surfaces made of sealed parallel flat plates with coolant passages. Water-glycol, circulating through the passages, removes heat from the mounted equipment.

Cold Rails – Same as cold plates except formed of channel- and tube-type extrusions.

Command – A pulse or signal initiating a step or sequence.

Command and Service Module – Combined Command Module and Service Module, which remains in lunar orbit after the Lunar Module descends to the moon. The Command and Service Modules are not separated from each other until shortly before reentry to earth's atmosphere.

Command Module – Apollo spacecraft's control center and living quarters for most of the lunar voyage. A cone 12 feet high by 12 feet 10 inches at the base, it is the only part of the spacecraft that will reenter the earth's atmosphere. It provides about 70 feet of living area per man (nearly double what was available in the Gemini spacecraft), weighs about 12,500 pounds at launch, and is covered by an all-over heat shield.

Command Module Pilot – Title of a member of the flight crew, occupying the center couch in the Command Module; the one crewmember who will not set foot on the lunar surface during a lunar landing mission, but will remain in the Command Module in lunar orbit. He is the expert on Command Module systems, the primary navigator during the trip, and the second man in seniority.

Commander – See Spacecraft Commander.

Comparator – Electronic circuit that compares one set of data with another.

Configuration – Shape; figure or pattern formed by relative position of various things.

Constant Wear Garment – Astronaut flight "underwear" or "shirtsleeves", worn under pressure suit; replaced by liquid-cooled garment during lunar exploration. (Pressure suits will be removed for part of the flight.)

Converter – A unit that changes the language of information from one form to another.

Coupling Data Unit – Assembly of electromagnetic transducers and gears, and displays, to present coordinated data from the guidance and navigation equipment; couples analog signals of IMU and optics, and converts to digital signals for guidance computer.

Crewman Optical Alignment Sight – Range-finder type of device used to help astronauts align the Command or Lunar Modules with each other during docking.

Cryogenic – Supercold, -195° C or less; refers to fuels or oxidizers that are liquid only at very low temperatures.

Daily Metabolic Requirement – For a man of 154 pounds, about 2 pounds of oxygen, 5 pounds of water, and 1 pound of solid food a day. He produces waste products of about 2 pounds of carbon dioxide and 6 pounds of water, urea, minerals, and solids. The intake rate is used as a rule of thumb in loading consumables, such as water and oxygen, for space flight.

Damping – Restraining; slowing down or stopping.

Deadband – In a control system, the range of values through which a measure can be varied without an effective response; the "play" in the control.

Decibel – Measure of sound. The human ear has a comfortable range of 1 to 130 decibels, 1 being the faintest sound a human can hear. Sounds over 130 decibels cause pain.

APOLLO NEWS REFERENCE

Delta P (ΔP) – Differential Pressure.

Delta V (ΔV) – Velocity change.

Descent Engine – Gimbaled engine on the descent stage; may be throttled to any thrust power between 1,050 and 10,500 pounds, operated automatically by the Guidance, Navigation and Control Subsystem or manually by the LM crew. It is used to descend from the Command Module (in lunar orbit) to the surface of the moon.

Descent Stage – Lower portion of the Lunar Module, containing descent engine and propellant tanks, landing gear, and storage sections. It serves as a launching platform for the ascent stage when the crew lifts off from the moon. It remains on the lunar surface.

Digital Computer – Computer that uses the principal of counting as opposed to measuring. (See Analog Computer.)

Destructive Readout – Readout of data stored in a computer memory that results in the data being erased.

Diplexer – Device that permits an antenna system to be used simultaneously by two transmitters.

Display – Visual presentation of data, usually from sensors or measuring devices, processed through a conditioning system.

Docking – Closing and mating together two spacecraft, following rendezvous.

Docking Drogue – Latching device, in the Lunar Module, into which the Command Module probe is pushed during docking; may be mounted or removed from the transfer tunnel by the crew.

Docking Latches – Four semiautomatic and eight manual latches to hold the Command and Lunar Modules firmly together when docked; the semiautomatic latches operate the docking probe retraction mechanism when engaged.

Docking Probe – Three-legged extendable device attached to the docking ring on the Command Module. It engages a drogue on the Lunar Module; may be mounted or removed from the transfer tunnel by the crew.

Docking Ring – Aluminum structure just forward of the top Command Module hatch; contain the Lunar/ Command Module seals and a pyro charge and serves as a mounting point for the docking probe and latches.

Docking System – Docking ring, probe, drogue, latches, crewman optical alignment sight, and tubular member device to be used in docking and crew transfer.

Docking Tunnel – Tunnel through which crew transfers between Lunar and Command Modules; located half in the nose of the Command Module and half in the top of the Lunar Module. It contains mounting points for the probe and drogue.

Doppler Effect – Apparent change in the frequency of sound waves (pitch), light, and radio and radar waves when the distance between the source and the observer or receiver is changing.

Doppler Principle – A principle of physics that states that, as the distance between a source of constant vibrations and an observer diminishes or increases, the frequencies appear to be greater or less.

Dosimeter – Device worn on right side of astronaut helmets and in pockets of the constant wear garment, for measuring and recording the amount of radiation to which the astronaut is exposed.

Downlink – Part of the communications link that receives, processes, and displays data from the spacecraft.

Egress – As a verb, to exit the spacecraft, as an adjective, describes the exit hatchway, procedures for exiting, etc.

Event Timer – Instrument that times an event and displays time taken to perform it.

Exploding Bridgewire – Metal wire that disintegrates at high temperature produced by a large electrical pulse; used for initiating stage retro-rockets, separation systems, etc.

Explosive Bolts – Bolts that attach the ascent and descent stages; surrounded by an explosive charge which is actuated by an electrical impulse when stage separation is desired.

Explosive Bridgewire – Wire which heats to a high temperature and burns, thus igniting a charge.

Extravehicular – Indicates that an element, such as an antenna, is located outside the vehicle.

Extravehicular Mobility Unit – Space suit (including water-cooled undergarment, pressure suit, integral thermal micrometeoroid garment, boots, gloves, helmet, visors, and portable life support system) used during lunar stay.

APOLLO NEWS REFERENCE

Flight Director Attitude Indicator – Device on control panel, which displays spacecraft attitude, attitude error, and rate of attitude change. Signals are supplied to the indicator by the Guidance, Navigation, and Control subsystem.

Gimbal – Frame with two or three mutually perpendicular and intersecting axes of rotation on which an engine or other device can be mounted and which allows it to move or swivel in two or three directions.

Guidance Computer – Digital computer, using erasable and fixed memory; computes deviations from required flight path and calculates attitude and thrust commands to correct them.

Guidance System – A system which measures and evaluates flight information, correlates this with target data, converts the result into the conditions necessary to achieve the desired flight path, and communicates this data in the form of commands to the flight control system.

Gyroscope – Device that uses angular momentum of a spinning rotor to sense angular motion of its base about one or two axes at right angles to the spin axis.

Heat Exchanger – Device for transferring heat from one fluid to another without mixing the fluids. In the Lunar Module, unwanted heat is absorbed by a water-glycol mixture and transported to sublimators.

Heat Sink – A contrivance for the absorption or transfer of heat away from a critical part or parts. (See Cold Plates and Cold Rails.)

Helium – Gas used to pressurize propellant tanks and force propellant into feed lines.

Hertz – One cycle per second.

Hover and Translation Maneuver – Maneuver of the Lunar Module, during lunar descent, to remain at a constant attitude above the moon's surface while moving laterally above the landing area.

Hypergolic – Self-igniting. Hypergolic fuel ignites spontaneously upon contact with its oxidizer, thereby eliminating the need for an ignition system.

Inertia – Tendency of an object at rest to remain at rest and of an object in motion to remain in motion in the same direction and at the same speed until gravity or some other force slows or stops it.

Inertial Guidance – Navigation system, using gyroscopic devices and a computer, that functions without external information. It automatically adjusts the vehicle to a predetermined flight path. Basically, it knows where its going and where it is by knowing where it came from and how it got there.

Inertial Measurement Unit – Main unit of the inertial guidance system; consists of a stable platform (inertial platform) that contains three inertial reference integrating gyros, three integrating accelerometers, and three angular differentiating accelerometers. It senses attitude changes or acceleration of the spacecraft.

Inertial Reference Integrating Gyro – Single-degree-of-freedom gyro that senses displacement of the stable platform on which it is mounted and generates signals accordingly.

Ingress – As a verb, getting into the spacecraft; as an noun, the entrance hatch, etc.

Injection – Introduction of fuel and oxidizer into the combustion chamber of an engine. The device that does this is an injector.

Integrated Thermal Micrometeoroid Garment – Bulky outer garmet covering pressure suit and backpack; worn for protection against extremes of heat and micrometeoroids by crewmen exploring the lunar surface. Made of lightweight felt and aluminized mylar, it limits the heat leak into the suit to about 250 Btu per hour.

Interface – Common boundary between one part of the Lunar Module or its subsystems and another; the place where two parts of a subsystem meet.

Integrating Accelerometer – Mechanical and electrical device that measures the force of acceleration along the longitudinal axis, records velocity, and measures the distance traveled.

Interstage – Between Lunar Module stages.

Inverter – Device for converting direct current produced by the Lunar Module batteries to alternating current.

Liquid-Cooled Garment – Undergarment worn beneath the pressure suit during exploration on the lunar surface. A small electrical pump in the backpack circulates water through tiny capillary tubes throughout the garment, and a heat exchanger in the backpack cools it each cycle.

APOLLO NEWS REFERENCE

Lithium Hydroxide – Substance used to remove exhaled carbon dioxide from the oxygen atmosphere of cabin and suits before recirculating the oxygen; carried in 4-pound canisters, 28 of which are sufficient for a 14-day mission.

Lunar Module – The vehicle, consisting of the ascent and descent stages, which will transport two astronauts from the Command Module in lunar orbit, provide a base of operations on the lunar surface and return them to the Command Module; 19 feet tall by 29 feet wide, carried with legs folded in the spacecraft/LM adapter (SLA) during launch. (See Ascent Stage and Descent Stage.)

Lunar Module Pilot – One of the two men who will descend to the lunar surface. He is the primary expert on Lunar Module Subsystems. He occupies the right crew station in the Lunar Module and is primarily responsible for systems management.

Manned Space Flight Network – Worldwide network of 17 land stations (supplemented by 10 DOD Eastern or Western Test Range land stations, eight advanced range instrumentation aircraft, and eight ships), which supports Apollo manned flights with nearly continuous radar tracking, command signals, telemetry reception, and voice contact. MSFN, which includes the Mission Control Center in Houston, the Launch Control Center at Cape Kennedy, and a computing and communications center at Goddard Space Flight Center, is the responsibility of Goddard. Tracking stations are divided into three groupings: lunar mission support stations, equipped with 85-foot dual antennas; earth orbital and limited lunar mission support stations, equipped with S-band facilities; and the near-earth-orbital mission support stations, most of them modified Gemini network stations without S-band facilities.

Man-Rated – Adjective applied to spacecraft, test items such as a centrifuge, and test chambers, which have achieved the standards of reliability and safety considered acceptable for human occupancy or for use on a manned flight.

Memory – Portion of a computer; records and stores instructions and other data. Information is retrievable automatically or upon request.

Meteoroid – Solid particle of matter traveling in space at considerable speed. (See Micrometeoroid.)

Micrometeoroid – Solid particle of matter, less than a millimeter in size, traveling in space.

Mission Profile – Flight plan showing all pertinent scheduled events.

Multiplexer – Device for sharing of a circuit by two or more coincident signals; a device that collects data from many sources and arranges it for simultaneous transmission over a single network. That transmission is called multiplexing. The signals may be separated by time division, frequency division or phase division.

Nautical Mile – Distance of 6,076.1 feet, or about 1.15 statute miles.

Navigation Base – Rigid supporting structure for inertial measurement unit and telescope.

Nitrogen Tetroxide (N_2O_4) – Oxidizer used in the ascent and descent engines. The fuel used with a mixture of unsymmetrical dimethyl hydrazine and hydrazine.

Noise – Any unwanted sound or disturbance on a useful frequency band, which interferes with clear reception of radio or radar signals.

Non-destructive Readout – Readout of data stored in a computer memory; data is retained in memory.

Omnidirectional Antenna – Antenna having a nondirectional pattern in azimuth and a directional pattern in elevation.

Open Loop – Control system in which there is no self-correction as there is in a closed-loop system.

Orbit – Spacecraft's path around earth or the moon, beginning and ending at a fixed point in space and requiring only 360° of travel. (The point on earth where the orbit began will not be the same because, during the period of orbit, earth will have revolved in the same direction.)

Oxidizer – Substance that supplies the oxygen necessary for burning (normal burning on earth uses the free oxygen in the atmosphere).

Parallel Redundancy – Describes two components, methods, or systems working at the same time to accomplish the same task, although either could handle it alone.

Parameter – Characteristic element or constant factor or value; often, a limiting value or set of values.

Parking Orbit – Intermediate orbit around earth or the moon, where a spacecraft can await the proper moment for injection into a trajectory.

Pitch – Attitude movement of the Lunar Module, in which the Z-axis tips up or down, rotating around the Y-axis.

APOLLO NEWS REFERENCE

Portable Life Support System – Backpack containing oxygen, water circulation and cooling, air-conditioning, telemetry and communications equipment; worn during exploration of the lunar surface.

Premodulation Processor – Assimilation, integration, and distribution center for all forms of spacecraft data (telemetry, data storage, television, central timing and audio signals) and incoming voice and command signals. The processor mixes and switches the signals to the appropriate transmitter.

Pressure Garment Assembly – Space suit, including inner comfort layer, pressure layer, and outer restraint layer; boots; gloves; cloth earphone cap; and helmet.

Pseudorandom Noise – Signals, in the S-band frequency range transmitted from MSFN to the Lunar Module for ranging and tracking purposes.

Pulse-Code-Modulation Telemetry – Pulse modulation in which the signal is periodically sampled, and each sample is quantized and transmitted as digital code. Transmitted information is contained in the prime position of the pulse in relation to a known reference point. Pulse-code-modulation telemetry equipment in the Lunar Module combines signals from various sources into a single signal, which is sent to the premodulation processor.

Quick-Disconnect Fitting – Fitting designed for instant disconnection (umbilical cords, etc.).

Rate Gyro Assembly – Three rate gyros in the Lunar Module, which emit signals relative to indicating the rate of angular motion (attitude change rate) to the flight director attitude indicators and to automatic control equipment.

Real Time – As it happens. Term is usually applied to reporting of events as they happen or to computation of data as they are received, with nearly instantaneous read-outs.

Redundancy – Alternative provision for accomplishing a task; as an adjective, redundant. (See Parallel Redundancy.)

Rendezvous – Meeting of spacecraft in orbit at a planned time and place.

Residual Water – Small amount of water in bottom of Lunar Module tanks not accessible for use.

Reticle Pattern – Pattern engraved on the crew optical alignment sight. Used in docking procedure.

Revolution – Circuit of earth or the moon beginning and ending at a fixed point on earch or the moon rather than a fixed point in space. Because the earth is revolving in the same direction, while the spacecraft is circling it, the point at which the revolution began has moved further ahead and the spacecraft must "catch up" with the reference point at the end of the revolution. A revolution is therefore more than 360° of travel and takes approximately 6 minutes longer than an orbit.

Roll – Rotation of the Lunar Module around its Z-axis.

S-Band – A 2100- to 2300-mHz band; carries voice, PCM telemetry, television, scientific data, coherent two-way Doppler, and tracking updata during all phases of the flight. In deep space, during the lunar mission, it is the primary voice link. Seventeen MSFN stations with unified S-band capability, are located around earth.

Signal-Conditioning Equipment – Devices that convert signals from sensors and transducers to proper format for transmission to MSFN.

Slant Range – Distance of the Lunar Module from the selected lunar landing site. Measured in a straight line from the landing radar antenna.

Slush Point – Temperature at which water-glycol starts to freeze.

Spacecraft – The Command, Lunar, and Service Modules, as distinguished from the Saturn launch vehicle.

Spacecraft Commander – Commander of the three-man Apollo crew; occupies the left couch in the Command Module and the left crew station in the Lunar Module. He is first in seniority and is trained in the skills of the Command Module Pilot and Lunar Module Pilot. He runs the mission from the standpoint of the crew, performs most of the engine burns, and is one of two men who descend to the lunar surface.

Spacecraft-Lunar Module Adapter – The 28-foot-high tapered cylinder between the Service Module and the launch vehicle instrument unit; it encloses the Lunar Module during launch and earth orbit. After translunar injection, a detonating fuse separates the Command and Service Module from the booster's third stage (S-IVB) and the Lunar Module. As the CSM turns around to dock with the Lunar Module, explosive charges and spring-loaded cables open the four hinged sections of the adapter like the petals of a flower. The CSM pulls the Lunar Module out of the adapter.

APOLLO NEWS REFERENCE

Stable Member – Major part of an all-inertial guidance system, composed of an assembly of gimbals that hold three accelerometers in a fixed position in relation to inertial space. The accelerometers are mounted perpendicular to each other to measure accelerations along the three reference axes. These accelerations can be fed to a computer to determine instantaneous velocity and position in space.

Staging (Stage Separation) – Separation of Lunar Module ascent and descent stages.

Station Keeping – Remaining in a particular, precise orbit with a constant velocity, usually at a given distance from a companion body.

Sublimation – Process utilizing space vacuum to transform ice to steam without first passing through liquid state. Lunar Module sublimators remove excess heat from water-glycol solution.

Telemetry – Technique of transforming sensed information into coded signals and transmitting it to a ground station, where it is decoded and fed into a computer for tabulation and readout. Telemetry measures the quantity or degree of such things as vehicle performance, medical information, temperature, pressure, radiation, velocity, heat rate, and angle of attack of the spacecraft.

Thrust – Push; the force developed by a rocket engine, measured by multiplying the propellant mass flow rate by the exhaust velocity relative to the vehicle, and expressed in pounds.

Thrust Chamber – Combustion chamber of a rocket engine; the place where fuel is burned in the presence of an oxidizer to produce high-velocity gases, which exit through the engine nozzle to produce thrust.

Thrust Vector – Direction of thrust. Thrust vector control is achieved by moving the gimbal-mounted descent engine so that the direction of thrust can be changed in relation to the Lunar Module center of gravity, producing a turning movement. (The Reaction Control Subsystem thrusters are mounted in sets and aimed in different directions, rather than on gimbals.)

Thruster – One of the 16 100-pound-thrust Reaction Control Subsystem engines used for attitude control of the Lunar Module. They are grouped in clusters of four. All use aerozine and nitrogen tetroxide.

Torquing Command – Command given to gyros to maintain vehicle attitude.

Tracking – Following a target by radar, optical sighting, or photography.

Trajectory – Flight path traced by vehicle under power or as a result of power.

Transceiver – Radio or radar transmitter and receiver combined into one unit, as is used in a transponder.

Transducer – Device that converts energy from one form to another; it is actuated by energy from one transmission system and supplies it to another system in a different form.

Transfer Tunnel – Passageway between Lunar and Command Modules when they are docked, for transfer of astronauts from one module to the other; reached by forward tunnel hatches in the Command Module and the overhead hatch in the Lunar Module.

Transponder – Radio or radar device triggered by a received signal of a certain frequency; transmits or returns the signals to the interrogator automatically. It is used in positive tracking and identification.

Tunnel Pressure – Pressure of the atmosphere (oxygen) in the tunnel connecting the Command and Lunar Modules (See Transfer Tunnel.)

Ullage – Volume above the surface of the liquid in a tank, partially a function of temperature. An ullage maneuver is a quick thrust of the vehicle made before firing the engines, to shift the propellant to the bottom of the tanks so that it will feed properly.

Umbilical – One of two electrical power cables connected between the Command and Lunar Modules before Lunar Module power is activated; hoses and electrical power cable between the pressure suit and vehicle and an oxygen line to the backpack.

Unsymmetrical Dimethylhydrazine – Component of Aerozine.

Updata Link – UHF/FM unified S-band receiver and decoding device (updata digital decoder); receives data from MSFN stations, decodes it, and routes it to the proper system.

Uplink Data, or Updata – Telemetry information from MSFN stations to spacecraft.

Vector – Magnitude of speed plus direction; short form of velocity vector, which is the speed of the vehicle's center of gravity at a certain point on the flight path and the angle between the local vertical and the direction of the speed. Vector control or vector steering is control of vehicle flight by tilting the descent engine to change thrust direction and produce a turning movement.

Velocity – Rate of motion (speed) in a given direction. (See Vector.)

VHF Multiplexer – Permits simultaneous transmission and receipt of VHF signals with a single antenna system.

Voice-Operated Relay – Transmit/receive circuitry, which is automatically switched to "transmit" by the sound of the astronaut's voice and returns to "receive" when the sound ceases.

Water-Glycol – Mixture of water and ethylene glycol; used to cool cabin atmosphere and space suits. It is, in turn, cooled by circulation through the sublimators.

X-Axis – Vehicle axis running up through the overhead hatch; associated with yaw maneuvers, in which the spacecraft rolls or spins around its X-axis.

Y-Axis – Lateral axis running through the spacecraft; associated with pitch maneuvers, in which the spacecraft turns or twists about its Y-axis.

Z-Axis – Fore-aft axis running through the spacecraft; associated with roll maneuvers, in which the spacecraft turns or twists about its Z-axis.

CONTRACTORS

EQUIPMENT SUPPLIED	CONTRACTOR
Abort Electronics Assembly Abort Guidance Section Abort Sensor Assembly	TRW, Inc. TRW Systems Group Redondo Beach, California
Absolute and Differential Pressure Transducers	Whittaker Corp. Instrument System Div. Chadsworth, California
Absolute Pressure Switch	Fairchild Hiller Corp. Stratos Div. Manhattan Beach, California
Actuator Bellows Assembly	Stainless Steel Products Burbank, California
Air Filter	Mectron Industries South El Monte, California
Ambient Helium Tanks	Sargent Industries, Inc. Airite Div. El Segundo, California
Ascent and Descent Batteries	Eagle-Picher Company Joplin, Missouri
Ascent - GOX Tanks Ascent Helium Storage Tanks	Sargent Industries Airite Div. El Segundo, California
Ascent Engine - Injector and Combustion Chamber	North American Rockwell Rocketdyne Div. Canoga Park, California
Ascent Engine - Skirt and Valves	Bell Aerosystems Co. Niagara Falls Blvd. Buffalo, New York
Ascent Propellant Tanks	Aerojet General Corp. Downey Plant Downey, California
Attitude and Translation Control Assembly	RCA Aerosystems Div. Burlington, Massachusetts
Attitude Control Assemblies	Honeywell, Inc. Aeronautical Div. Minneapolis, Minnesota
Bacteria Filter	American Air Filter St. Louis, Missouri
Bulkhead Feedthrough Connectors	ITT Cannon Electric Co. Los Angeles, California
Burst Disk	Parker Hannifin Corp. Systems Div. Los Angeles, California

EQUIPMENT SUPPLIED	CONTRACTOR
C-Band Transponder Antenna	Melpar Falls Church, Virginia
Cable Cutter Explosive Devices	Explosive Technology, Inc. Fairfield, California
Caution and Warning Electronic Assembly	Ambac Industries Arma Div. Garden City, New York
Caution and Warning Indicators	Penn Keystone Derby, Connecticut
Circuit Breakers	Mechanical Products Jackson, Michigan
Circuit Interrupter	ITT Cannon Electric Co. Phoenix, Arizona
Circular Connectors	The Deutsch Co. Electronic Component Div. Banning, California
CO_2 Sensor	Perkin-Elmer Electro-Optical Div. Norwalk, Connecticut
Coaxial Switches and Connectors	Quantatron, Inc. Santa Monica, California
Cold Plate Assemblies	AVCO Corp. Aerostructures Div. Nashville, Tennessee
Communication Subsystem	RCA Communications Div. Camden, New Jersey
Component Caution Indicators	Penn Keystone Derby, Connecticut
Control Electronic Section	Ambac Industries, Inc. Arma Division Garden City, New York
Coupling Disconnects	J. C. Carter Co. Costa Mesa, California
Coupling Test Points	Schulz Tool and Mfg. Co. San Gabriel, California
Data Storage Electronic Assembly	Leach Corp. Controls Div. Azusa, California
Descent Engine	TRW, Inc. TRW Systems Group Redondo Beach, California

APOLLO NEWS REFERENCE

EQUIPMENT SUPPLIED	CONTRACTOR
Descent Engine Control Assembly	RCA Aerosystems Div. Burlington, Massachusetts
Data Entry Display Assembly	TRW, Inc. TRW Systems Group Redondo Beach, California
Descent Propellant Tanks (LM4 and 5)	General Motors Corp. Allison Div. Indianapolis, Indiana
Descent Propellant Tanks (LM 6 and sub)	Sargent Industries Airite Div. El Segundo, California
Digital Uplink Assembly	AVCO Corp. Electronics Div. Cincinnati, Ohio
Diplexer	Ramtec Division Emerson Electric Company Celabasas, California
Disconnect	Fairchild Hiller Corp. Stratos Div. Manhattan Beach, California
Disconnect, Flight Half	Seaton-Wilson Co. Burbank, California
Discrete Transducers	Metals and Controls Div. Texas Instruments Inc. Attleboro, Massachusetts
Docking Lights	Eimac Div. Varian, Inc. San Carlos, California
Electrical Control Assembly	General Electric Co. Specialty Control Dept. Waynesboro, Virginia
Electroluminescent Lamps	General Electric Co. Miniature Lamp Div. Nella Park Cleveland, Ohio
End Detonator Cartridges	Space Ordnance Systems El Segundo, California
Environmental Control Subsystem	United Aircraft Corp. Hamilton Standard Div. Windsor Locks, Connecticut
Event Timer	Sylvania Electronics Needham Heights, Massachusetts
Explosive Nut and Bolt Assembly	Space Ordnance Systems El Segundo, California

EQUIPMENT SUPPLIED	CONTRACTOR
Explosive Valves	Pelmec Div. Quantic Industries San Carlos, California
Exterior Tracking Light	Dynamics Corp. of America Reeves Instrument Co. Div. Garden City, New York
Fire-In-The-Hole (FITH) Connector	ITT Cannon Electric Co. Phoenix, Arizona
Flag Indicators (Talkbacks)	Honeywell, Inc. Aeronautical Div. Minneapolis, Minnesota
Flex Lines	Avica Newport, Rhode Island
Flight Director Attitude Indicators	Lear Siegler Instrument Div. Grand Rapids, Michigan
Gimbal Angle Sequencing Transformation Assembly	Lear Siegler Instrument Div. Grand Rapids, Michigan
Gimbal Drive Actuators	The Garrett Corp. Airesearch Mfg. Co. Los Angeles, California
H_2O Bacteria Filter	Aircraft Porous Media Glen Cove, New York
Heat Exchanger (Discrete Engine)	Stewart Warner South Wind Div. Indianapolis, Indiana
Heater Assembly (RCS)	Cox and Co. New York City, New York
Helium Explosive Valves	Pelmec Corp. Quantic Industries San Carlos, California
Helium Filter	Aircraft Porous Media Glen Cove, New York
Helium Filter	Vacco Industries South El Monte, California
Helium Latch Valve	M. C. Manufacturing Co. Lake Orion, Michigan
Helium Pressure Valve	Parker Aircraft Corp. Los Angeles, California
Helium Quad Check Valve	Accessory Products Co. Whittier, California
Helium Relief Valve	Calmec Mfg. Corp. Los Angeles, California

APOLLO NEWS REFERENCE

EQUIPMENT SUPPLIED	CONTRACTOR
Helium Temperature Pressure Indicator	General Precision, Inc. Kearfott Systems Div. Little Falls, New Jersey
Helium Valve - Descent Regulator	Parker Aircraft Corp. Los Angeles, California
High Pressure O_2 Control Assembly	Parker Aircraft Corp. Los Angeles, California
Initiator	Space Ordnance Systems El Segundo, California
Interior Floodlight	Grimes Mfg. Co. Urbana, Ohio
Interrupter	ITT Cannon Electric Co. Phoenix, Arizona
Interstage Disconnect	Fairchild Hiller Corp. Stratos Division Manhattan Beach, California
Inverter	United Aircraft Corporation Hamilton Standard Div. Windsor Locks, Connecticut
Landing Gear Uplock Cutter Assembly	Space Ordnance Systems El Segundo, California
Landing Radar and Rendezvous Radar Subsystem	RCA Aerosystems Div. Burlington, Massachusetts
Latching Valve	Parker Aircraft Corp. Los Angeles, California
Lighting Control Assembly	Dynamics Corporation of America Reeves Instrument Div. Garden City, New York
Miniature Switch	Metals and Controls Div. Texas Instruments, Inc. Attleboro, Massachusetts
Mission Timer	Bulova Watch Company, Inc. Systems and Instrument Division Flushing, New York
Mission Timer	Sylvania Electronics Needham Heights, Massachusetts
Oxygen Fill Disconnect	Purolator, Inc. Aerospace Div. Newbury Park, California
Oxygen Hose	R. E. Darling Company Gaithesburg, Maryland

EQUIPMENT SUPPLIED	CONTRACTOR
Panel Overlay	Precise Engraving Company Garden City, New York
PLSS Condensate Collector Assembly	Lundy Electronics and Systems, Inc. Glen Head, New York
Portable Utility Light	Grimes Manufacturing Co. Urbana, Ohio
Potentiometer	Technology Instrument Corp. Newbury Park, California
Pressure Garment Assembly O_2 Connectors	Air Lock Corp. Melford, Connecticut
Pressure Relief Valve	Parker Aircraft Corp. Los Angeles, California
Program Reader Assembly	Fairchild Camera Space and Defense Systems Syosset, New York
Propellant Filter	Purolator Products, Inc. Aerospace Division Newbury Park, California
Propellant Filters	Aircraft Porous Media Glen Cove, New York
Propellant Level Detectors	Simmonds Precision Products Long Island City, New York
Propellant Quantity Gaging System	Trans-Sonics, Inc. Lexington, Maine
Propellant Quantity Indicator	General Precision, Inc. Kearfott Systems Division Little Falls, New Jersey
Propellant Quantity Measuring Device	Electro-Optical Systems Subsidiary of Xerox Corp. Pasadena, California
Propellant Solenoid Valve	Parker Aircraft Corp. Los Angeles, California
Propellant Tanks	Bell Aerosystems Co. Buffalo, New York
Pulse Code Modulation/Timing Electronic Assembly	Radiation, Inc. Palm Bay, Florida
Pushbutton Switch	Honeywell, Inc. Aeronautical Division Minneapolis, Minnesota
Pyro Battery	Electro-Storage Battery Raleigh, North Carolina

APOLLO NEWS REFERENCE

EQUIPMENT SUPPLIED	CONTRACTOR
Quad Check Valve	Parker Aircraft Corp. Los Angeles, California
Range/Altitude Indicator	Bendix Corp. Eclipse-Pioneer Div. Teterboro, New Jersey
RCS Explosive Cartridge	Space Ordnance Systems El Segundo, California
Reaction Control Subsystem	The Marquardt Corp. Van Nuys, California
Regulating Valve	Fairchild Stratos Western Branch Manhattan Beach, California
Relays	Filtors, Inc. Huntington, New York
Relief Valve	M. C. Manufacturing Co. Lake Orion, Michigan
Retractable Cable	Haveg Industries Supertemp Wire Div. Winooski, Vermont
RF Signal Sampling Sensor	Melpar, Inc. Falls Church, Virginia
Rotary Switch	Daven Div. Thomas A. Edison Industries West Orange, New Jersey
Rough Combustion Cutoff	Thiokol Chemical Corp. Reaction Motors Div. Denville, New Jersey
Self-Luminous Devices	Minnesota Mining and Mfg. Co. St. Paul, Minnesota
Sensor Probe	EDO Corp. College Point, New York
Signal Conditioning Electronics Assembly	Ambac Industries, Inc. Arma Division Garden City, New York
Signal Strength Meters	Honeywell, Inc. Aeronautical Div. Minneapolis, Minnesota
Solenoid Valve	Valcor Engineering Corp. Kenilworth, New Jersey
Steam Vent Divider	Stainless Steel Products Burbank, California
Suit Loop Switch	Parker Hannifin Corp. Systems Div. Los Angeles, California
Supercritical Helium Tanks	The Garrett Corp. Airesearch Mfg. Co. Los Angeles, California
Surge Tank Disconnect	Seaton-Wilson Burbank, California
Synchros	General Precision, Inc. Kearfott Systems Division Little Falls, New Jersey
Target Assembly	Minnesota Mining and Mfg. Co. St. Paul, Minnesota
Thrust/Weight Indicator	Bendix Corp. Pioneer Central Division Davenport, Iowa
Time Delay	Lear Siegler Instrument Division Grand Rapids, Michigan
Toggle Switch	Metals and Controls Div. Texas Instruments, Inc. Attleboro, Massachusetts
Transducer	Hy-Cal Engineering Corp. Santa Fe Springs, California
Transistors	Metals and Controls Div. Texas Instruments, Inc. Attleboro, Massachusetts
TTCA Transducer	Bournes, Inc. Riverside, California
Universal Ball Joint	Stainless Steel Products Burbank, California
Waste Management System	Lundy Electronics and Systems Glen Head, New York
Waveguides	Electronic Specialty Co. Connecticut Division Thomaston, Connecticut
Window Panel Assembly	Corning Glass Works Corning, New York
Windows	Corning Glass Works Corning, New York
Wire	Haveg Industries, Inc. Supertemp Wire Division Winooski, Vermont
X (Cross) - Pointers	Honeywell, Inc. Aeronautical Div. Minneapolis, Minnesota

APOLLO NEWS REFERENCE

LUNAR MODULE DERIVATIVES FOR FUTURE SPACE MISSIONS

The assets of the Apollo Program collectively represent a major resource for future United States space missions. These assets include test, production, tracking, and launch facilities; trained astronauts; spacecraft; launch vehicles; and the experienced government/industry/university team.

In particular, the Lunar Module's versatility, ability to fly manned or unmanned, propulsive capability, and payload volume envelope offer attractive options to achieve significant space objectives in the future. These include increases in scientific knowledge, benefits to Man, space technology, and mission time.

A variety of LM-derived vehicles for use in earth or lunar orbit, and on the lunar surface, are described in this portfolio. Missions of 2-month duration in earth orbit (longer with revisits) and at least 2-week duration on the moon for a variety of important space objectives have been continually refined for more than 5 years. These missions apply the experience gained from earlier LM missions, to reduce costs while greatly increasing mission and scientific objectives throughout the 1970's. Additionally, these missions serve as the springboard for significant future space ventures.

APOLLO NEWS REFERENCE

APOLLO LUNAR MODULE

This—the basic Apollo Lunar Module, or LM—is the two-stage spacecraft from which all the concepts shown are derived. For Project Apollo, the LM mission is essentially this:

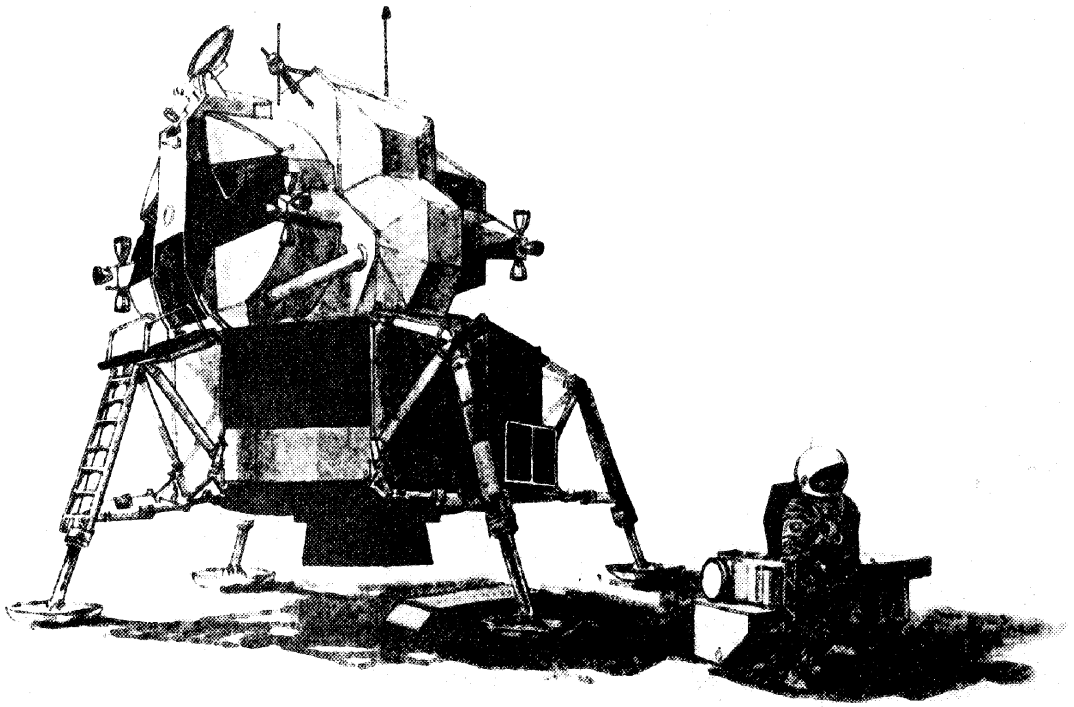
Ferry two astronauts to the surface of the moon from the Command and Service Module (CSM) parked in lunar orbit.

Sustain the lives of the men during their lunar stay

Explore, and obtain scientific data and samples

Return the astronauts safely to the CSM through an ascent and rendezvous maneuver.

The descent stage carries the equipment and expendables used during the descent to the moon and lunar exploration; the equipment includes the engine, propellant, the landing gear, and the Apollo Lunar Scientific Experiment Package. The ascent stage contains the crew's life support equipment, expendables, and storage provisions for return of scientific samples; this stage contains most of the spacecraft's other operating subsystems including the engine and propellants used to return the astronauts to the CSM. As designed for Project Apollo, the LM can sustain the astronauts for 48 hours away from the CSM, carry a 300-pound scientific payload to the moon, and transport a 100-pound payload on its return trip to the CSM.

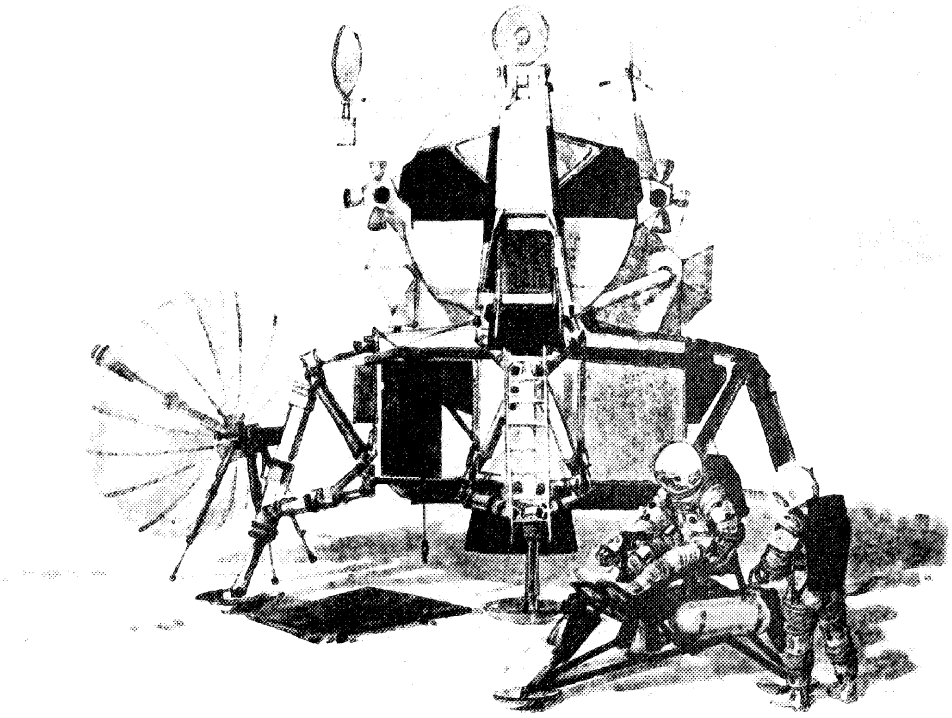


R-139

LMD-2

Grumman

APOLLO NEWS REFERENCE



R-140

EXTENDED LM

For single-launch missions, experience gained from the initial Apollo LM lunar landings may permit an increase in LM payload with no increase in the size or capacity of the descent propellant tanks. The added payload could extend astronaut time on the moon to three days and provide the astronauts with as much as 1,000 pounds of scientific equipment, including Lunar Flying Vehicles (LFV's) or a small Lunar Roving Vehicle (LRV).

LUNAR RECONNAISSANCE MODULE

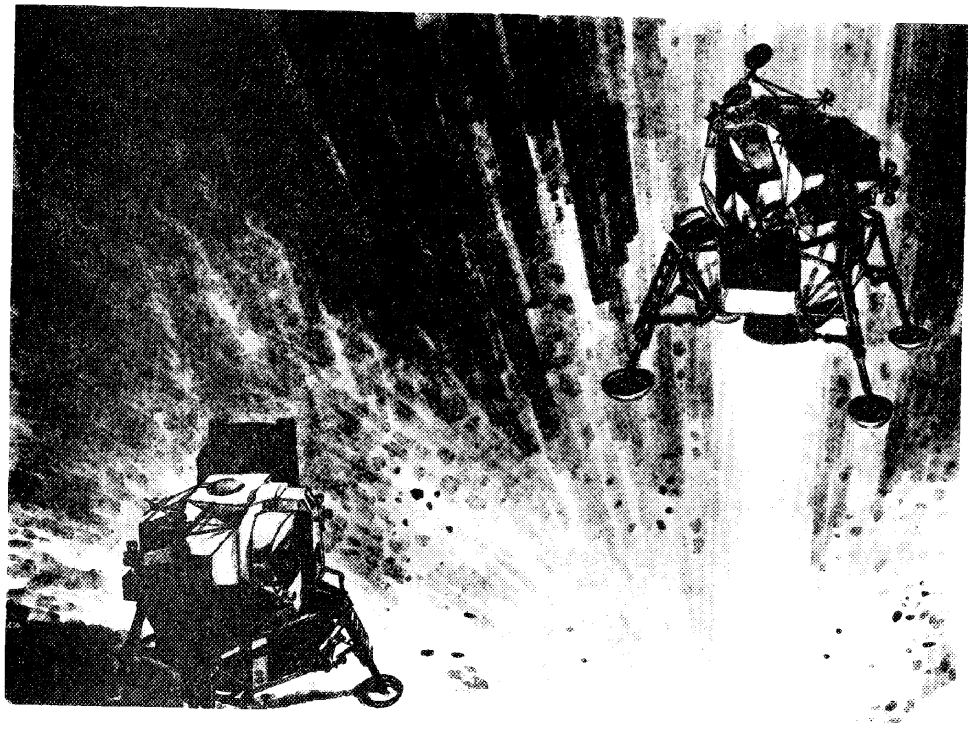
The Lunar Reconnaissance Module (LRM) is an orbiting version of the LM equipped with extensive photo-mapping, geochemical, and electromagnetic surveying equipment. Docked to the CSM, it is inserted into a lunar polar orbit from which, for the first time, the surface, subsurface, and near-lunar environment is surveyed.

The LM descent stage is used for initial Lunar Orbit Insertion (LOI), after which it is jettisoned. The ascent stage, stripped of its Propulsion and Reaction Control Subsystems, contains all the sensors for the reconnaissance mission.

The LRM carries its own equipment thermal control system and electrical power supply system, in addition to navigation and control equipment for the descent engine docked burn.

The LRM completely surveys the moon during 14 days in lunar orbit. Normal equipment servicing, such as film reloading, is accomplished in a shirtsleeve environment.

APOLLO NEWS REFERENCE



R-141

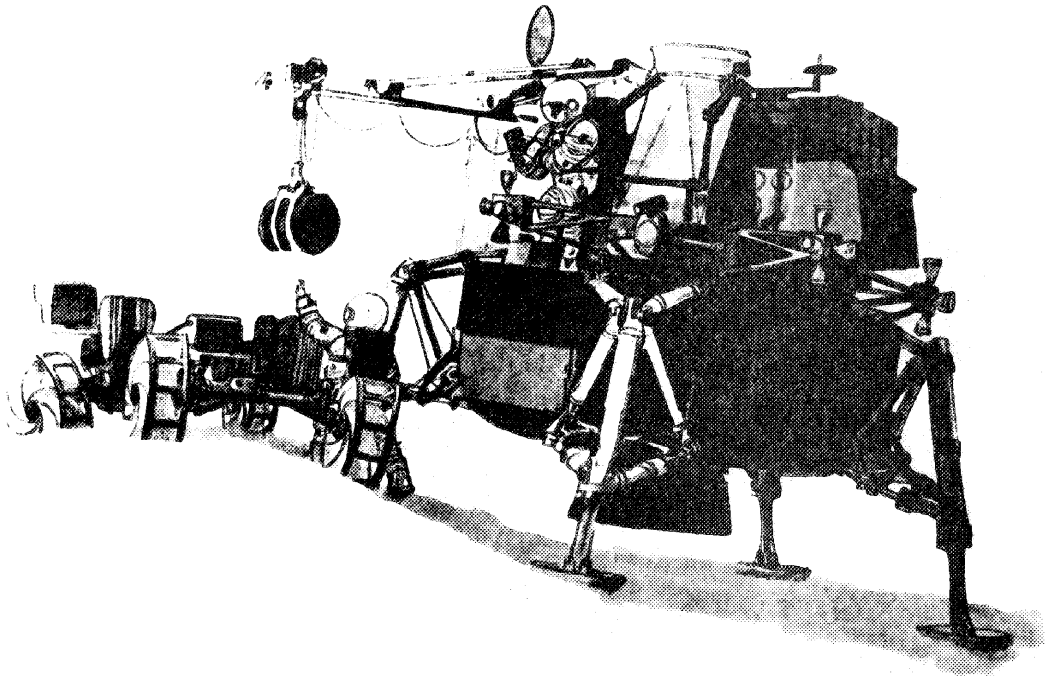
LM TAXI

Outwardly identical with the Apollo LM, the LM Taxi differs from its parent spacecraft by a few subtle modifications to accommodate the slightly different nature of its mission. The LM Taxi ferries two astronauts to the moon on the second leg of a dual launch, following the successful unmanned landing of a LM Truck/Shelter on the first leg.

The Taxi carries the same life support provisions as the Apollo LM. The astronauts will shut down and store the Taxi after landing, and transfer quarters to the Shelter vehicle for the 14-day stay. During this period, the status of mission-critical Taxi hardware is monitored on earth via MSFN.

During quiescent storage, the propellants, engines, and much of the Taxi equipment must be thermally controlled, to permit rapid abort. The Apollo LM thermal control system has been modified to include a hatch cover, window shades, and isotope heat sources. Additional instrumentation has been added to enable complete evaluation of Taxi status at all times. A Radioisotope Thermoelectric Generator (RTG) supplements the battery power supply capability. All subsystems are qualified for the extended life requirements of the Taxi.

APOLLO NEWS REFERENCE



R-142

LM TRUCK

The LM Truck is an unmanned lunar lander that transports cargo in the volume otherwise occupied by the LM ascent stage. Components from the removed ascent stage that are vital to the Truck mission are relocated in a central docking structure attached to the existing interstage fittings on an unmodified descent stage.

The docking structure enables CSM transposition and docking with the Truck in lunar orbit and extraction of the Truck from the Spacecraft LM Adapter (SLA). Thereupon, an astronaut from the CSM can reach into the structure through the docking tunnel and, using a keyboard stored in the structure, update the Truck's Guidance, Navigation, and Control Subsystem so that the spacecraft's trajectory to landing is held within acceptable tolerances.

A typical mission payload, shown in the artist's rendering, might comprise a Lunar Roving Vehicle for surface transportation, resupply modules for supporting two men on the lunar surface for as long as 14 days, and a 5,300-pound, 900-cubic-foot scientific cargo.

APOLLO NEWS REFERENCE

LM SHELTER

The Shelter is an Apollo LM minus its ascent propulsion system and modified to: (1) make an unmanned landing on the moon, (2) remain quiescent for as long as 60 days, and (3) support two men for 14 days. Successful launch and landing of a Shelter would be followed by a manned Taxi in a dual-launch mission. Shelter payload could consist of expendables, mobility aids, a 30-meter lunar drill, and an advanced Apollo Lunar Surface Equipment Package.

Removal of the ascent engine increases the habitable volume of the cabin. Special hammocks provide more comfortable sleeping quarters for the astronauts. An airlock, attached to the forward hatch, serves as an EMU station and eliminates the need to depressurize the cabin before lunar surface egress.

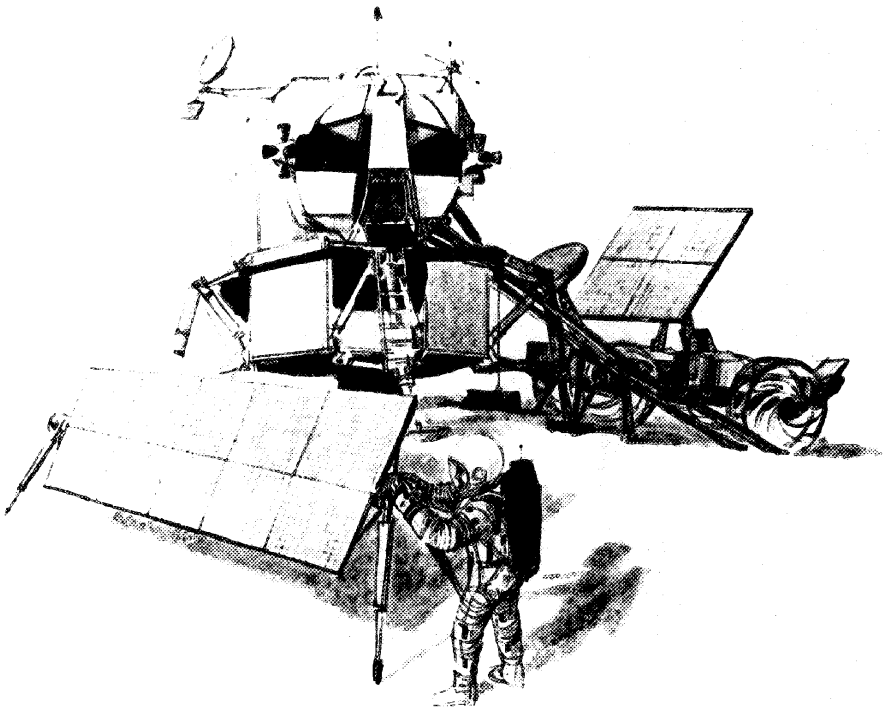
LM TRUCK

This alternate LM Truck is a modification wherein all ascent stage components needed for unmanned landing are integrated into the descent stage. The vacated ascent stage volume can be filled with a 9,000-pound payload.

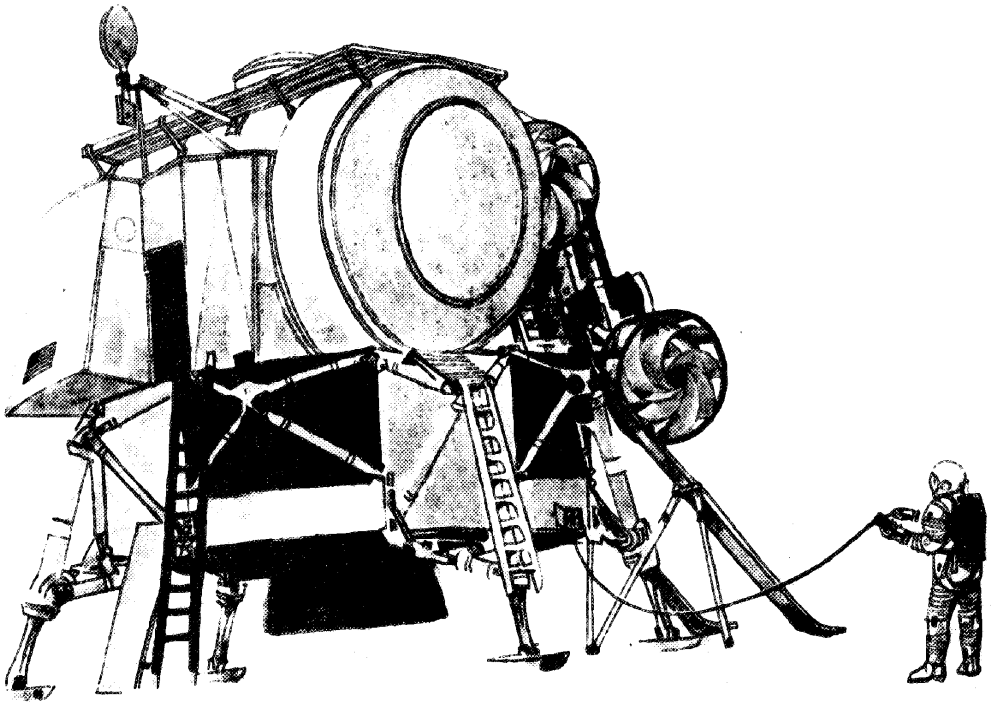
The representative payload shown consists of 760-cubic-foot fixed crew living quarters, Lunar Roving Vehicle, crew provisions for as long as 14 days, and a 4,800-pound, 550-cubic-foot scientific cargo.

A Truck landing represents only half of a dual-launch mission. After the payload arrives successfully on the moon, a second earth launch of a LM Taxi dispatches astronauts who use the life-support and scientific equipment in the LM Shelter in performing their duties during long-duration lunar explorations.

APOLLO NEWS REFERENCE



R-143

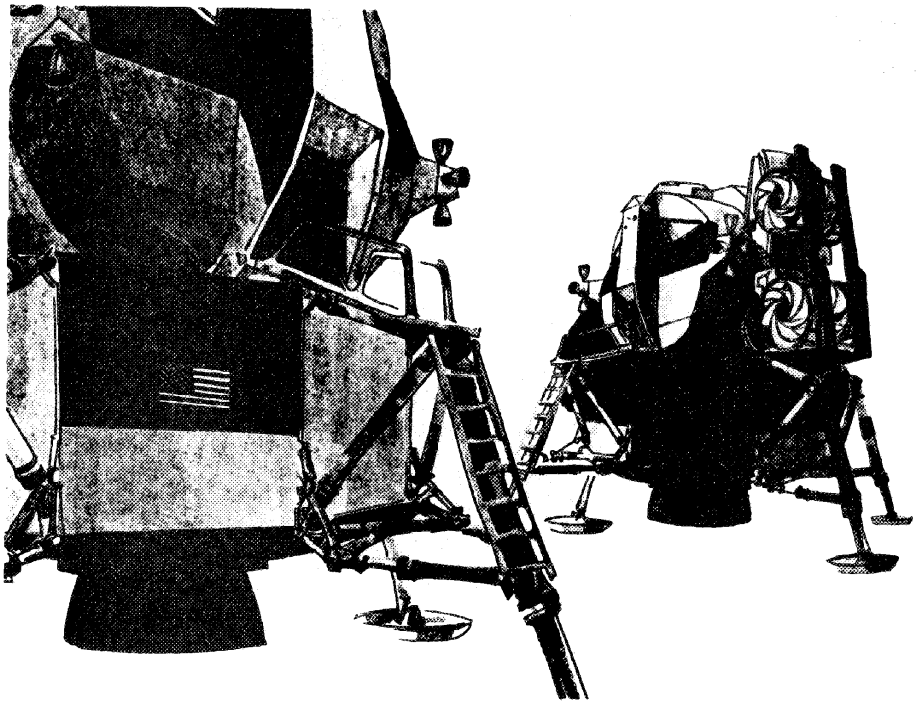


R-144

Grumman

LMD-7

APOLLO NEWS REFERENCE



R-145

LUNAR PAYLOAD MODULE

Unlike the LM Truck, the Lunar Payload Module retains the basic LM ascent stage, but is stripped of the ascent propulsion system and components unnecessary for lunar landing. In this configuration, the existing ascent and descent stage structures can accommodate a 7,300-pound payload within a useful volume of approximately 800 cubic feet.

Otherwise, its mission is similar to the other shelter vehicles launched at the start of a dual-spacecraft mission. The payload module, landed unmanned, replenishes shelter and astronaut supplies.