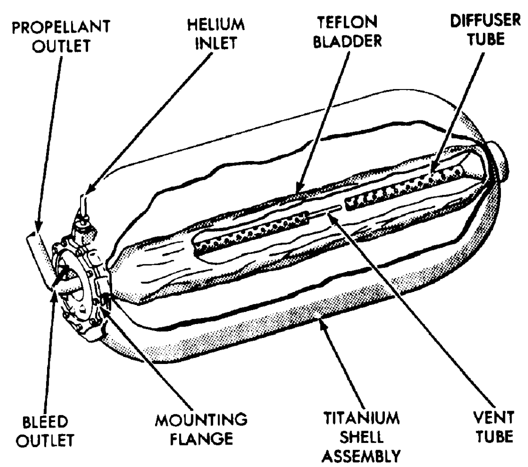
PROPELLANT STORAGE TANKS

The four propellant tanks, one fuel and one oxidizer tank for each system, are cylindrical with hemispherical ends; they are made of titanium alloy. In each tank, the propellant is stored in a Teflon bladder, which is chemically inert and resistant to the corrosive action of the propellants. The bladder is supported by a standpipe running lengthwise in the tank. The propellant is fed into the tank from a fill point accessible from the exterior of the LM. A bleed line that extends up through the standpipe draws off gases trapped in the bladder. Helium flows between the bladder and the tank wall and acts upon the bladder to provide positive propellant expulsion.



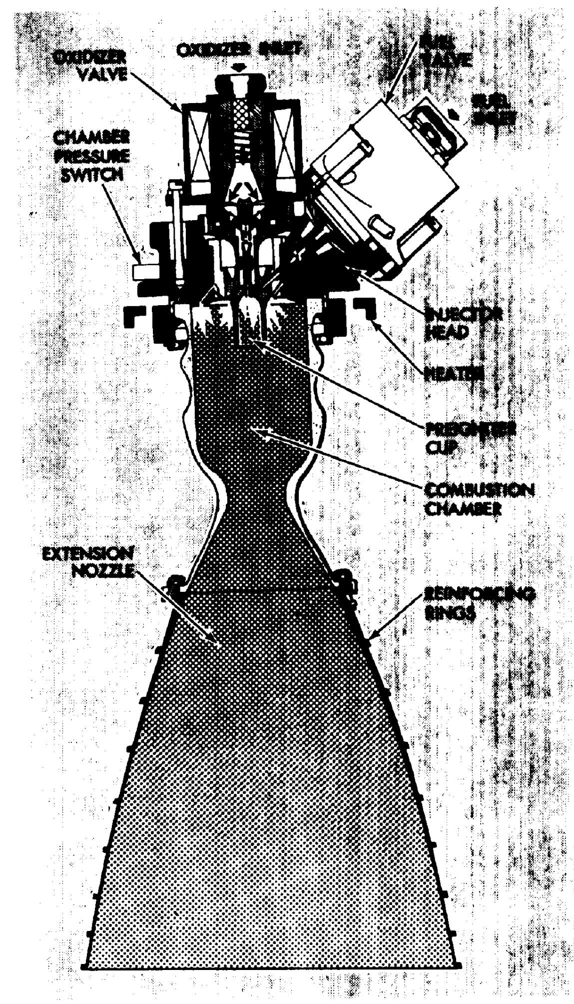
R-94

Propellant Storage Tank

THRUST CHAMBER ASSEMBLIES

The efficiency of a rocket engine is expressed in terms of specific impulse, which is the impulse-producing capacity per unit weight of propellant. The nominal specific impulse of the RCS thrusters at steady-state firing is 281 seconds. The thrusters have a favorable high-thrust to minimum-impulse ratio, meaning that they produce a comparatively high thrust for their size, as well as a very low thrust impulse. In addition, the thrusters have a fast response time. Response time is the elapsed time between a thruster-on command and stable firing at rated thrust, and between a thruster-off command and thrust decay to an insignificant value. Finally, the thrusters have a long cycle life, denoting that the thrusters can be restarted many times.

Each thruster consists of a fuel valve, an oxidizer valve, an injector head assembly, a combustion chamber, an extension nozzle, and thruster instrumentation.



R-95

Reaction Control Thruster

The fuel and oxidizer valves are normally closed, two-coil, solenoid valves that control propellant flow to the injector. Each valve has an inlet filter, an inlet orifice, a spool assembly, a spring, an armature, and a valve seat. The primary and the secondary coils are wound on a magnetic core in the spool assembly. These coils receive the thruster on and off commands. The fuel and oxidizer valves are identical except for the inlet orifice, the valve seat, and the spool assembly. Because the ratio of oxidizer to fuel at the combustion chamber must be approximately 2 to 1, the diameters of the inlet orifices and the valve seat exits differ in the two valves. The spool assembly in the fuel valve produces a faster armature response to open the fuel valve 2 milliseconds before the oxidizer valve. Permitting fuel to enter the combustion chamber first reduces the possibility of ignition delay, which could cause temporary overpressurization (spiking) in the combustion chamber. Spiking is also held to a minimum by preheating and prepressurizing the combustion chamber.

When the thruster-off command is given, the coils deenergize, releasing the armature poppets. Spring and propellant pressure return the armature poppet of each valve to its seat, shutting off propellant flow into the injector.

The injector head assembly supports the fuel and oxidizer valves and the mounting flange for the combustion chamber. The propellant impingement and chamber cooling arrangement in the injector consists of four concentric orifice rings and a preigniter cup. Initial combustion occurs in the preigniter cup (a precombustion chamber) where a single fuel spray and oxidizer stream impinge. This provides a smoother start transient because it raises the main combustion chamber pressure for satisfactory ignition. The main fuel flow is routed through holes in a tube to a chamber that channels the fuel to an annulus. The annulus routes fuel to three concentric fuel rings. The outermost ring sprays fuel onto the combustion chamber wall, where it forms a boundary layer for cooling. The middle ring has eight orifices that spray fuel onto the outer wall of the preigniter cup to cool the cup. Eight primary orifices of the middle ring eject fuel to mix with the oxidizer. The main oxidizer flow is routed through holes in the oxidizer preigniter tube, to a chamber that supplies the eight primary oxidizer orifices of the innermost ring. The primary oxidizer and fuel orifices are arranged in doublets, at angles to each other, so that the emerging propellant streams impinge. Due to the hydraulic delay built into the injector, ignition at these eight doublets occurs approximately 4 milliseconds later than ignition inside the preigniter cup.

The combustion chamber is made of machined molybdenum, coated with silicon to prevent oxidation of the base metal. The chamber is cooled by radiation and by a film of fuel vapor. The extension nozzle is fabricated from L605 cobalt base alloy; eight stiffening rings are machined around its outer surface to maintain nozzle shape at high temperatures. The combustion chamber and extension nozzle are joined together by a large coupling nut and lockring.

HEATERS

Two redundant, independently operating heating systems are used simultaneously to heat the RCS clusters. Two electric heaters, one from each system, encircle the injector area of each thruster. The heaters normally operate in an automatic mode; redundant thermal switches (two connected in parallel for each thruster) sense injector temperature and turn the heaters on and off to maintain the temperature close to +140° F. The heaters of the primary heating system are powered directly from their circuit breakers. Power to the redundant system is routed through switches that permit the astronauts to operate this system for each cluster individually, either under automatic thermal switch control or with heaters continuously on, or off.

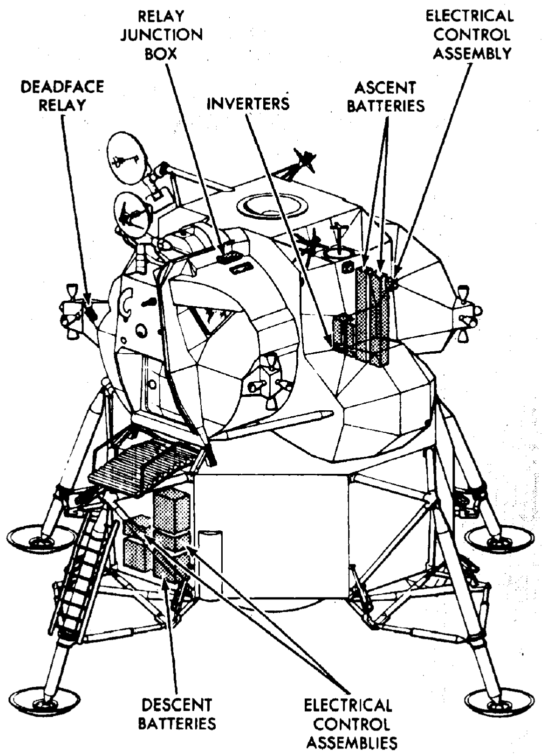
ELECTRICAL POWER

QUICK REFERENCE DATA

A-C Section	
Inverter input voltage	24 to 32 volts dc
Inverter output (with internal sync)	115±1.2 volts rms, 400 Hz, single phase
Normal load range	0 to 350 volt-amperes (at power factors 0.65 lagging to 0.80 leading)
Maximum overload at constant voltage output	525 volt-amperes for 10 minutes
D-C Section	
Steady-state bus voltage limits	26.5 to 32.5 volts dc
Nominal supply bus voltage	28 volts dc
Transient voltages	50 volts above or below nominal supply voltage
Descent battery	
Number of batteries	4
Capacity	400 ampere-hours
Nominal voltage	30.0 volts dc
Minimum voltage	28.0 volts dc
Maximum voltage	32.5 volts dc
Weight	135 pounds
Construction	Silver-zinc plates, 20 cells
Electrolyte	Potassium hydroxide
Ascent battery	
Number of batteries	2
Capacity	296 ampere-hours
Nominal voltage	30.0 volts dc
Minimum voltage	27.5 volts dc
Maximum voltage	32.5 volts dc
Weight	125 pounds
Construction	Silver-zinc plates, 20 cells
Electrolyte	Potassium hydroxide

The Electrical Power Subsystem (EPS) is the principal source of electrical power necessary for the operation of the LM. The electrical power is supplied by six silver-zinc batteries: four in the descent stage and two in the ascent stage. The batteries provide dc for the EPS d-c section; two solid-state inverters supply the a-c section. Both sections supply operating power to respective electrical buses, which supply all LM subsystems through circuit breakers. Other batteries supply power to trigger explosive devices, to operate the portable life support system, and to operate scientific equipment.

The descent stage batteries power the LM from T-30 minutes until the docked phases of the mission, at which time the LM receives electrical power from the CSM. After separation from the CSM, during the powered descent phase of the mission, the descent stage batteries are paralleled with the ascent stage batteries. Paralleling the batteries ensures the minimum required voltage for all possible LM operations. Before lift-off from the lunar surface, ascent stage battery power is introduced, descent battery power is terminated, and descent battery feeder lines are deadfaced and severed. Ascent stage battery power is then used



Major Electrical Power Equipment Location

until after final docking and astronaut transfer to the CM. The batteries are controlled and protected by electrical control assemblies, a relay junction box, and a deadface relay box, in conjunction with the control and display panel.

In addition to being the primary source of electrical power for the LM during the mission, the EPS is the distribution point for externally generated power during prelaunch and docked operations. Prelaunch d-c and a-c power is initially supplied from external ground power supplies until approximately T-7 hours. At this time, the vehicle ground power supply unit is removed and d-c power from the launch umbilical tower is connected. From launch until LM-CSM transition and docking, the EPS distributes internally generated d-c power. After docking, LM power is shut down and the CSM supplies d-c power to the LM. Before LM-CSM separation, all LM internally supplied electrical power is restored.

FUNCTIONAL DESCRIPTION

The outputs of the four descent stage batteries and two ascent stage batteries are applied to four electrical control assemblies. The two descent stage electrical control assemblies provide an independent control circuit for each descent battery. The two ascent stage electrical control assemblies provide four independent battery control circuits, two control circuits for each ascent battery. The electrical control assembly monitors reverse-current, overcurrent, and overtemperature within each battery. Each battery control circuit can detect a bus or feeder short. If an overcurrent condition occurs in a descent or ascent battery, the control circuit operates a main feed contactor associated with the malfunctioning battery to remove the battery from the distribution system.

Ascent and descent battery main power feeders are routed through circuit breakers to the d-c buses. From these buses, power is distributed through circuit breakers to all LM subsystems. The two inverters, which make up the a-c section power source, are connected to either of two a-c buses. Either inverter, when selected, can supply the LM a-c requirements.

Throughout the mission, the astronauts monitor the primary a-c and d-c voltage levels, d-c current levels, and the status of all main power feeders. The electrical power control and indicator panel in the cabin has talkbacks that indicate main power feeder status, indicators that display battery and bus voltages and currents, and component caution lights. The component caution lights are used to detect low bus voltages, out-of-limit, a-c bus frequencies, and battery malfunctions. Backup a-c and d-c power permits the astronauts to disconnect, substitute, or reconnect batteries, feeder lines, buses, or inverters to assure a continuous electrical supply.

EQUIPMENT

DESCENT STAGE BATTERIES

The four descent stage batteries are identical. Each battery is composed of silver-zinc plates, with

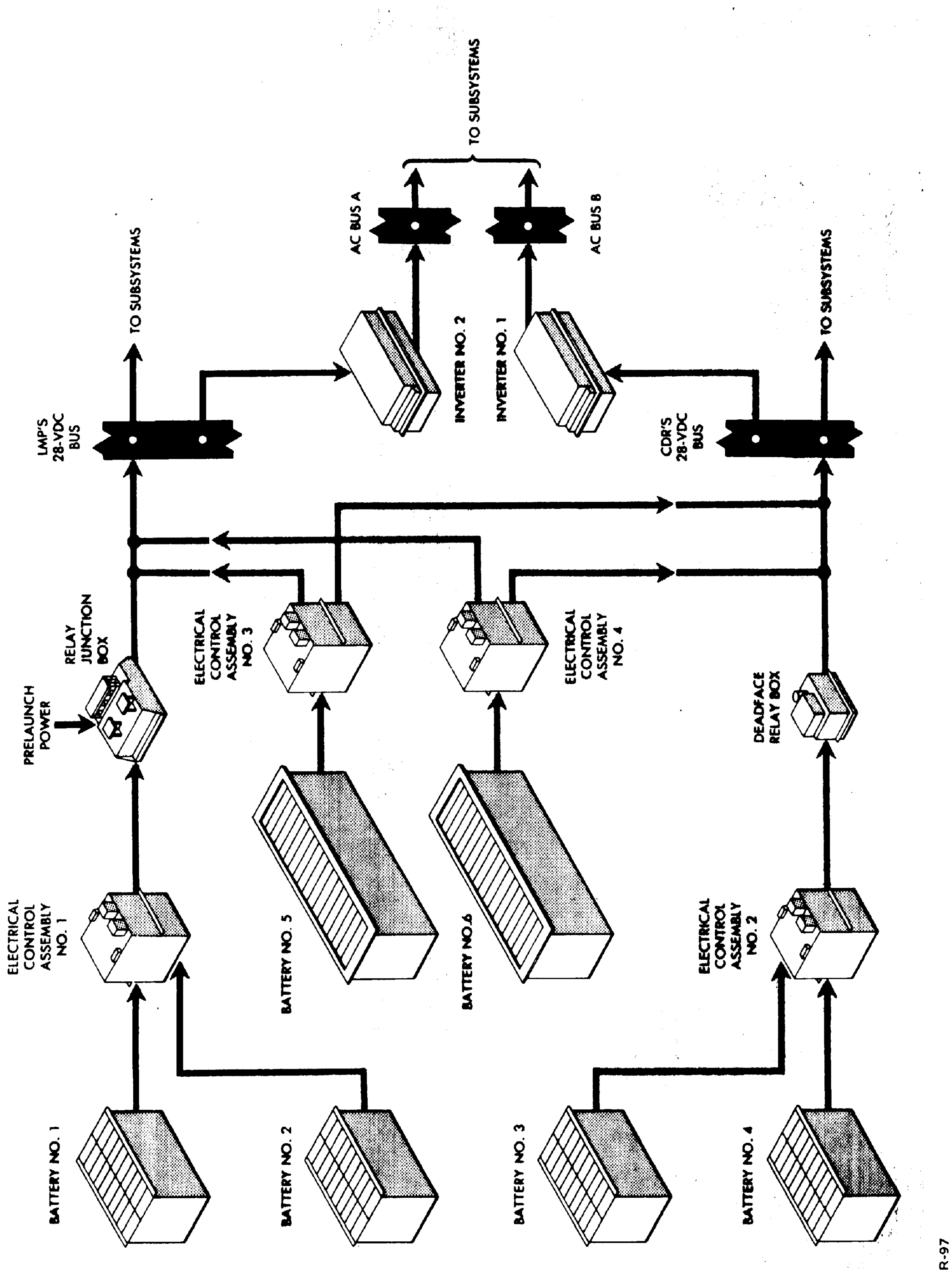


Diagram of Electrical Power Subsystem

Grumman

EP-3

a potassium hydroxide electrolyte. Each battery has 20 cells, weighs 135 pounds, and has a 400-ampere-hour capacity (25 amperes at 28 volts dc for 16 hours, at +80° F). Normally, the descent stage batteries are paralleled so that they discharge equally. The batteries can operate in a vacuum while cooled by an Environmental Control Subsystem (ECS) cold rail assembly to which the battery heat sink surface is mounted. Five thermal sensors monitor cell temperature limits (+145°±5° F) within each battery; they cause a caution light to go on to alert the astronaut to a battery overtemperature condition. The batteries initially have high-voltage characteristics; a low-voltage tap is provided (at the 17th cell) for use from T-30 minutes through transposition and docking. The high-voltage tap is used for all other normal LM operations. If one descent stage battery fails, the remaining descent stage batteries can provide sufficient power.

ASCENT STAGE BATTERIES

The two ascent stage batteries are identical. Each battery is composed of silver-zinc plates, with a potassium hydroxide electrolyte. Each battery weighs 125 pounds, and has a 296-ampere-hour capacity (50 amperes at 28 volts for 5.9 hours, at +80° F). To provide independent battery systems, the batteries are normally not paralleled during the ascent phase of the mission. The batteries can operate in a vacuum while cooled by ECS cold rails to which the battery heat sink surface is mounted. The nominal operating temperature of the batteries is approximately +80° F. Battery temperature in excess of +145° ±5° F closes a thermal sensor, causing a caution light to go on. The astronaut then takes corrective action to disconnect the faulty battery. The batteries ordinarily supply the d-c power requirements, from normal staging to final docking of the ascent stage with the orbiting CSM or during any malfunction that requires separation of the ascent and descent stages. If one ascent stage battery fails, the remaining battery provides sufficient power to accomplish safe rendezvous and docking with the CSM during any part of the mission.

DESCENT STAGE ELECTRICAL CONTROL ASSEMBLIES

The two descent stage electrical control assemblies control and protect the descent stage batteries. Each assembly has a set of control circuits for each battery accommodated. A failure in one set of battery control circuits does not affect the other set. The protective circuits of the assembly automatically disconnect a descent stage battery if an overcurrent condition occurs and cause a caution light to go on if a battery overcurrent, reverse-current, or overtemperature condition is detected.

The major elements of each assembly are high- and low-voltage main feed contactors, current monitors, overcurrent relays, reverse-current relays, and power supplies. An auxiliary relay supplies system logic contact closures to other control assemblies in the LM power distribution system.

The reverse-current relay causes a caution light to go on when current flow in the direction opposite to normal current flow exceeds 10 amperes for at least 6 seconds. Unlike the overcurrent relay, the reverse-current relay does not open the related main feed contactor and is self-resetting when the current monitor ceases to detect a reverse-current condition. During reverse-current conditions, the related contactor must be manually switched open. The control assembly power supplies provide ac for current-monitor excitation and regulated dc for the other circuits.

ASCENT STAGE ELECTRICAL CONTROL ASSEMBLIES

The two ascent stage electronic control assemblies individually control and protect the two ascent stage batteries in nearly the same manner as the descent stage control assemblies. Each assembly contains electrical power feed contactors, an overcurrent relay, a reverse-current relay, and a current monitor. Each ascent stage battery can be connected to its normal or backup main feeder line via the normal or the backup main feed contactor in its respective assembly. Both batteries are thereby connected to the primary d-c power buses. The normal feeder line has overcurrent protection; the backup feeder line does not.

RELAY JUNCTION BOX

The relay junction box provides the following:

Control logic and junction points for connecting external prelaunch power (via the launch umbilical tower) to the LM Pilot's d-c bus

Control and power junction points for connecting descent stage and ascent stage electronic control assemblies to the LM Pilot's d-c bus

Deadfacing (electrical isolation) of half of the power feeders between the descent and ascent stages.

The relay junction box controls all low-voltage contactors (on and off) from the launch umbilical tower and CSM, and all low- and high-voltage descent power contactors (off) on receipt of an abort stage command. The junction box includes abort logic relays, which, when energized by an abort stage command, close the ascent stage battery main feed contactors and open the deadface main feed contactors and deadface relays. The deadface relay is manually opened and closed or automatically opened when the abort logic relays close. The deadface relay in the junction box deadfaces half of the main power feeders between the descent and ascent stages; the other half of the power feeders is deadfaced by the deadface relay in the deadface relay box. The ascent stage then provides primary d-c power to the LM.

DEADFACE RELAY BOX

The deadface relay box controls the output of the other two descent stage batteries in the same manner as the relay junction box. Two individual deadfacing facilities (28 volts for each circuit breaker panel) are provided.

INVERTERS

Two identical redundant, 400-Hz inverters individually supply the primary a-c power required in the LM. Inverter output is derived from a 28-volt d-c input. The output of the inverter stage is controlled by 400-Hz pulse drives developed from a 6.4-kilopulse-per-second (kpps) oscillator, which is, in turn, synchronized by timing pulses from the Instrumentation Subsystem. An electronic tap changer sequentially selects the output of the tapped transformer in the inverter stage, converting the 400-Hz square wave to an approximate sine wave of the same frequency. A voltage regulator maintains the inverter output at 115 volts ac during normal load conditions by controlling the amplitude of a dc-to-dc converter output. The voltage regulator also compensates for variations in the d-c input and a-c output load. When the voltage at a bus is less than 112 volts ac, or the frequency is less than 398 Hz or more than 402 Hz, a caution light goes on. The light goes off when the malfunction is remedied.

CIRCUIT BREAKER AND EPS CONTROL PANELS

All primary a-c and d-c power feed circuits are protected by circuit breakers on the Commander's and LM Pilot's buses. The two d-c buses are electrically connected by the main power feeder network. Functionally redundant LM equipment is placed on both d-c buses (one on each bus), so that each bus can individually perform a mission abort.

SENSOR POWER FUSE ASSEMBLIES

Two sensor power fuse assemblies, in the aft equipment bay, provide a secondary d-c bus system that supplies excitation to transducers in other subsystems that develop display and telemetry data. During prelaunch procedures, primary power is supplied to the assemblies from the Commander's 28-volt d-c bus. Before launch, power from the launch umbilical tower is disconnected, and power is supplied to the sensor power fuse assemblies from the LM Pilot's 28-volt d-c bus. Each assembly comprises a positive d-c bus, negative return bus, and 40 fuses. All sensor return lines are routed to a common ground bus.

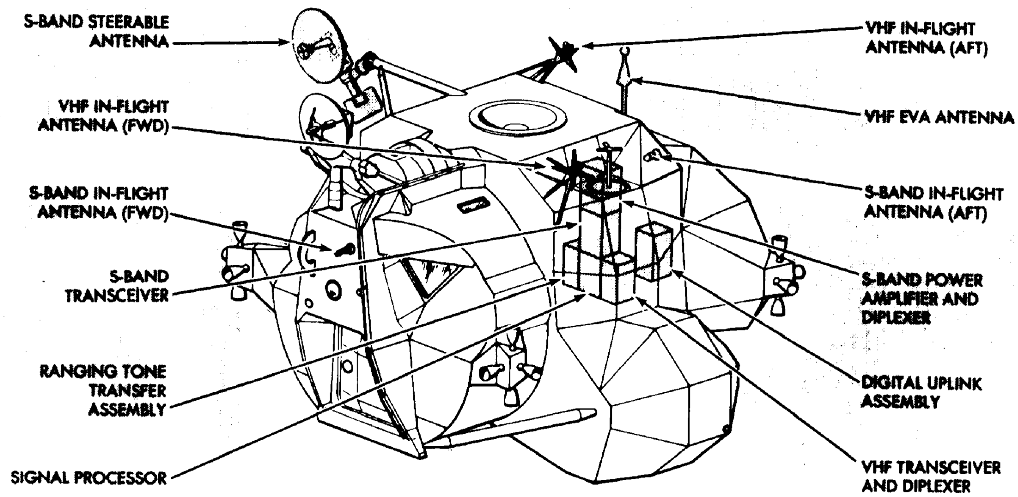
COMMUNICATIONS

QUICK REFERENCE DATA

RF electronic equipment	
S-band transceiver assembly	
Frequency	
Transmit	2282.5 mHz (downlink)
Receive	2101.8 mHz (uplink)
Output power	0.75 watts (minimum)
Input power requirement	36 watts
Application	LM-MSFN communications
S-band power amplifiers	
Frequency	2282.5 mHz
Output power	
Primary amplifier	18.6 watts (minimum)
Secondary amplifier	14.8 watts (minimum)
Input power requirement	72 watts
Application	Amplify S-band transmitter output
VHF transceiver assembly	
Frequency	
Channel A	296.8 mHz
Channel B	259.7 mHz
Output power	5.0 watts
Input power requirement	
VHF A transmitter	30 watts
VHF A receiver	1.2 watts
VHF B transmitter	31.7 watts
VHF B receiver	1.2 watts
Application	LM-CSM and LM-EVA communications
Signal-processing equipment	
Signal processor assembly	
Input power requirement	12.7 watts
Application	Switching center for most signals in the Communications Subsystem
Digital uplink assembly	
Input power requirements	12.5 watts
Application	Processes MSFN signal to update LM guidance computer and provides MSFN voice backup
Ranging tone transfer assembly	
Input power requirements	5.0 watts
Application	Provides CSM-LM ranging in conjunction with VHF transceiver assembly
Microphones	Noice-cancelling, dynamic
Headsets	Dual muff (suits) Ear plug (lightweight)

Signal-processing equipment (cont)

Television camera	
Bandwidth	10 Hz to 500 kHz
Scan	10 fps, 320 lines 5/8 fps, 1,280 lines
Input power requirement	7.5 watts
Antenna equipment	
S-band steerable antenna	
Operating frequency	
Transmit	2282.5 mHz
Receive	2101.8 mHz
Type	Cross-sleeved dipoles over ground plane with parabolic reflector
Slew movement	
Azimuth	174°
Elevation	330°
S-band in-flight antennas	
Operating frequency	
Transmit	2282.5 mHz
Receive	2101.8 mHz
Type	Omnidirectional, right-hand circularly polarized
S-band erectable antenna	
Operating frequency	
Transmit	2282.5 mHz
Receive	2101.8 mHz
Dimension	
Stowed	10-inch-diameter cylinder, 39 inches long
Erected	10-foot parabola
VHF In-flight antennas	
Operating frequency	259.7 to 296.8 mHz
Type	Omnidirectional, right-hand circularly polarized
VHF EVA antenna	
Operating frequency	259.7 to 296.8 mHz
Type	Omnidirectional, conical, 8-inch monopole with 12-inch radials



Major Communications Equipment Locations

The Communications Subsystem (CS) provides in-flight and lunar surface communications links between the LM and CSM, the LM and MSFN, and the LM and the extravehicular astronaut (EVA). When both astronauts are outside the LM, the LM relays communications between the astronauts and MSFN. The CS consists of S-band and VHF equipment.

IN-FLIGHT COMMUNICATIONS

In flight, when the LM is separated from the CSM and is on the earth side of the moon, the CS provides S-band communications with MSFN and VHF communications with the CSM. When the LM and the CSM are on the far side of the moon, VHF is used for communications between them.

EARTH SIDE (LM-MSFN)

In-flight S-band communications between the LM and MSFN include voice, digital uplink signals, and ranging code signals from MSFN. The LM S-band equipment transmits voice, acts as transponder to the ranging code signals, transmits biomedical and systems telemetry data, and provides a voice backup capability and an emergency key capability.

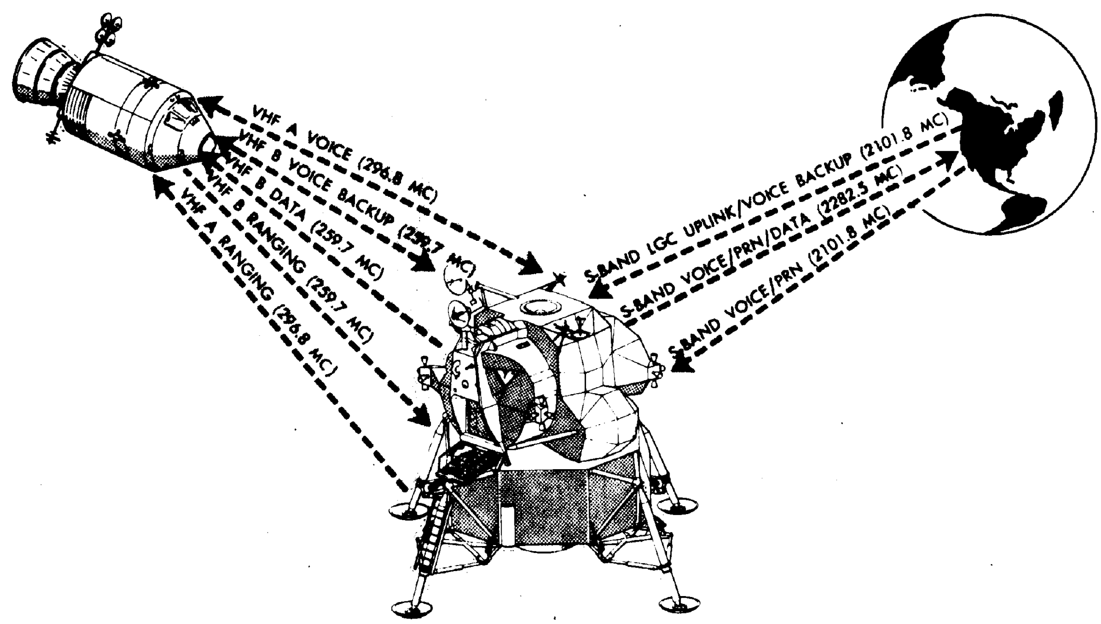
S-band voice is the primary means of communication between MSFN and the LM. Backup voice communication from MSFN is possible, using the digital uplink assembly, but this unit is normally used by the MSFN to update the LM guidance computer. In response to ranging code signals sent to the LM, the S-band equipment supplies MSFN with a return ranging code signal that enables MSFN to track, and determine the range of the LM. The LM transmits biomedical data pertinent to astronaut heartbeat so that MSFN can monitor and record the physical condition of the astronauts. The LM also transmits systems telemetry data for MSFN evaluation; voice, using redundant S-band equipment; and, in case there is no LM voice capability, provides an emergency key signal so that the astronauts can transmit Morse code to MSFN.

EARTH SIDE (LM-CSM)

In-flight VHF communications between the LM and CSM include voice, backup voice, and tracking and ranging signals. Normal LM-CSM voice communications use VHF channel A simplex. Backup voice communication is accomplished with VHF channel B simplex. VHF ranging, initiated by the CSM, uses VHF channels A and B duplex.

Link	Mode	Band	Purpose
MSFN-LM-MSFN	Pseudorandom noise (PRN)	S-band	Ranging and tracking by MSFN
LM-MSFN	Voice	S-band	In-flight and lunar surface communications
LM-CSM	Voice	VHF simplex	In-flight communications
CSM-LM-MSFN	Voice	VHF and S-band	Conference (with LM as relay)
LM-CSM	Low-bit-rate telemetry	VHF (one way)	CSM records and retransmits to earth
CSM-LM-CSM	Ranging	VHF duplex	Ranging and tracking by CSM
MSFN-LM	Voice	S-band	In-flight and lunar surface communications
MSFN-LM	Uplink data or uplink voice backup	S-band	Update LM guidance computer or voice backup for in-flight communications
LM-MSFN	Television	S-band	Provides lunar televised data
LM-MSFN	Biomed-PCM telemetry	S-band	Transmission of biomedical and vehicle status data
LM-MSFN-CSM	Voice	S-band	Conference (with earth as relay)
EVA-LM-EVA	Voice and data; voice	VHF duplex	EVA direct communication
EVA-LM-MSFN	Voice and data	VHF, S-band	Conference (with LM as relay)
CSM-MSFN-LM-EVA	Voice and data	S-band, VHF	Conference (via MSFN-LM relay)

Communication Links



R-99

In-Flight Communications

FAR SIDE (LM-CSM)

When the LM and CSM are behind the moon, contact with MSFN is not possible. VHF channel A is used for simplex LM-CSM voice communications. VHF channel B is used as a one-way data link to transmit system telemetry signals from the LM, to be recorded and stored by the CSM. When the CSM establishes S-band contact with MSFN, the stored data are transmitted by the CSM at 32 times the recording speed.

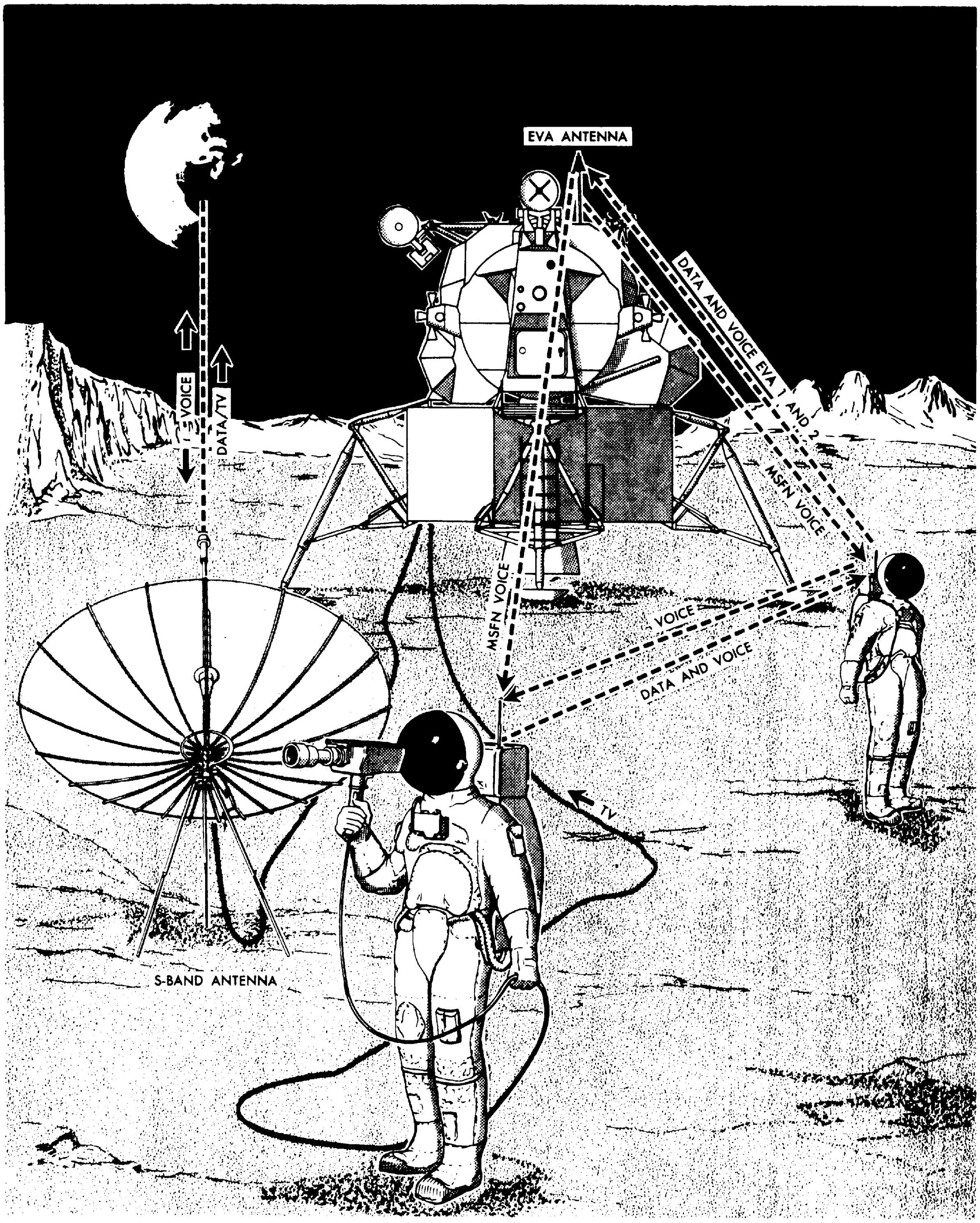
LUNAR SURFACE COMMUNICATIONS

When the LM is on the lunar surface, the CS provides S-band communications with MSFN and VHF communications with the EVA. The LM relays VHF signals to MSFN, using the S-band.

Communications with the CSM may be accomplished by using MSFN as a relay. LM-MSFN S-band capabilities are the same as in-flight capabilities, except that, in addition, TV may be transmitted from the lunar surface in an FM mode.

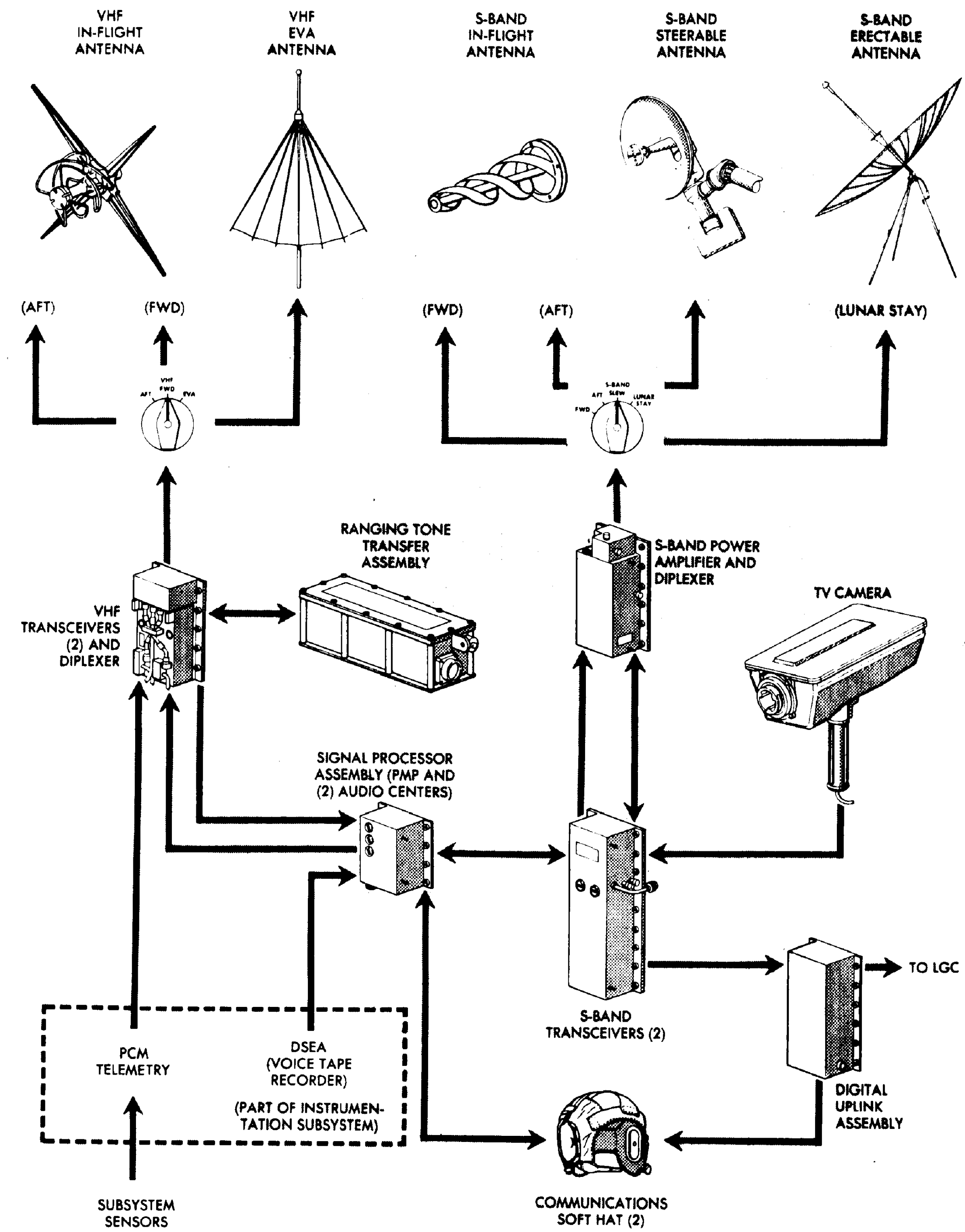
Information	Frequency or Rate	Subcarrier Modulation	Subcarrier Frequency	RF Carrier Modulation
	UPLINK: 2101.8 mHz			
Voice	300 to 3000 Hz	FM	30 kHz	PM
Voice backup	300 to 3000 Hz	FM	70 kHz	PM
PRN ranging code	990.6 kilobits/sec			PM
Uplink data	1.0 kilobits/sec	FM	70 kHz	PM
	DOWNLINK: 2282.5 mHz			
Voice	300 to 3,000 Hz	FM	1.25 mHz	PM or FM
Biomed	14.5-kHz subcarrier	FM	1.25 mHz	PM or FM
Extravehicular mobility unit	3.9-, 5.4-, 7.35- and 10.5-kHz subcarriers	FM	1.25 mHz	PM or FM
Voice	300 to 3000 Hz	None	None	Direct PM base-band modulation
Biomed	14.5 kHz subcarrier	None	None	Direct PM base-band modulation
Extravehicular mobility unit	3.9-, 5.4-, 7.35-, and 10.5-kHz subcarriers	None	None	Direct PM base-band modulation
Voice backup	300 to 3000 Hz	None	None	Direct PM base-band modulation
PRN ranging code (turnaround)	990.6 kilobits/sec			PM
Emergency keying	Morse code	AM	512 kHz	PM
Pulse-code-modulation nonreturn-to-zero data	High bit rate: 51.2 kilobits/sec or Low bit rate: 1.6 kilobits/sec	Phase shift keying (PSK)	1.024 mHz	PM or FM
TV	10 to 500 Hz			FM baseband modulation

S-Band Communications Capabilities



R-100

Lunar Surface Communications



R-101

Diagram of Communications Subsystem

FUNCTIONAL DESCRIPTION

Each astronaut has his own audio center. The audio centers have audio amplifiers and switches that are used to route signals between the LM astronauts, and between the LM and MSFN or the CSM. The centers are redundant in that each one can be used by either astronaut, or both astronauts can use either audio center if necessary.

In a transmission mode, the output of the audio centers goes to the VHF transceivers, or to the premodulation processor or to the data storage electronics assembly in the Instrumentation Subsystem (IS). If an audio center output is routed to the VHF transmitter, the transmission is through the diplexer to the selected VHF antenna. If an audio center output is routed to the premodulation processor (PMP) and then to the S-band transceivers, the transmitter output is applied to the diplexer, or to the S-band power amplifier, depending on power output requirements. The output from the transmitter or the power amplifier goes through the diplexer to the selected S-band antenna. If an audio center output is routed to the data storage electronics assembly the voice transmission is recorded.

The inputs to the S-band transceivers are from the premodulation processor or the television camera. The outputs from the premodulation processor (to be transmitted by S-band transmitters) are processed voice, and PCM, EMU and biomed data. For television transmission, the S-band power amplifier is used. In normal flight, the steerable antenna is used. On the lunar surface, the S-band erectable antenna is used for normal communications. The S-band omni antennas are used in any one of a number of backup modes.

External RF inputs to the S-band equipment are MSFN voice, either uplink data or an uplink backup voice signal, and ranging. Received MSFN voice is routed through the premodulation processor to the audio centers. Received uplink data signals are routed to the digital uplink assembly to be decoded and sent to the LM guidance computer. MSFN backup voice is routed to the digital uplink assembly where it is decoded and then sent to the Commander's mic amplifier input.

EQUIPMENT

S-BAND TRANSCEIVER

The S-band transceiver assembly provides deep-space communications between the LM and MSFN. S-band communications consist of voice and pseudorandom noise ranging transmission from MSFN to the LM and voice, pseudorandom noise ranging turnaround, biomed, and subsystem data transmission from the LM to MSFN. The assembly consists of two identical phase-locked receivers, two phase modulators with driver and multiplier chains, and a frequency modulator. The receivers and phase modulators provide the ranging, voice, emergency-keying, and telemetry transmit-receive functions. The frequency modulator is primarily provided for video transmission, but accommodates pulse-code-modulation telemetry (subsystem data), biomed, and voice transmission. The frequency modulator provides limited backup for both phase modulators. The operating frequencies of the S-band equipment are 2282.5 mHz (transmit) and 2101.8 mHz (receive).

S-BAND POWER AMPLIFIER

The S-band power amplifier amplifies the S-band transmitter output when additional transmitted power is required. This assembly consists of two amplitrons, an input and an output isolator (ferrite circulators), and two power supplies, all mounted on a common chassis. The RF circuit is a series interconnection of the isolators and amplitrons. The amplitrons (which are characteristic of saturated, rather than linear, amplifiers) have broad bandwidth, high efficiency, high peak and average power output, but relatively low gain. The isolators protect both amplitrons and both S-band transmitter driver and multiplier chains. The isolators exhibit a minimum isolation of 20 db and a maximum insertion loss of 0.6 db. Each amplitron has its own power supply, One amplitron is designated primary; the other, secondary. Only one amplitron can be activated at a time. When neither amplitron is selected, a feedthrough path through the power amplifier exists with maximum insertion loss of 3.2 db (feedthrough mode).

VHF TRANSCEIVER

The VHF transceiver assembly provides voice communications between the LM and the CSM and, during blackout of transmission to MSFN, low-bit-rate telemetry transmission from the LM to the CSM, and ranging on the LM by the CSM. When the LM mission profile includes extravehicular activity, this equipment also provides EVA-LM voice communications, and reception of EVA biomed and suit data for transmission to MSFN over the S-band. The assembly consists of two solid-state superheterodyne receivers and two transmitters. One transmitter-receiver combination provides a 296.8-mHz channel (channel A); the other, a 259.7-mHz channel (channel B), for simplex or duplex voice communications. Channel B may also be used to transmit pulse-code-modulation data from the IS at the low bit rate and to receive biomed and suit data from the EVA during EVA-programmed missions.

SIGNAL PROCESSOR ASSEMBLY

The signal processor assembly is the common acquisition and distribution point for most CS received and transmitted data, except that low-bit-rate, split-phase data are directly coupled to VHF channel B and TV signals are directly coupled to the S-band transmitter. The signal processor assembly processes voice and biomed signals and provides the interface between the RF electronics, data storage electronics assembly, and pulse-code-modulation and timing electronics assembly of the IS. The signal processor assembly consists of an audio center for each astronaut and a premodulation processor. The signal processor assembly does not handle ranging and uplink data signals. The premodulation processor provides signal modulation, mixing, and switching in accordance with the selected mode of operation. It also permits the LM to be used as a relay station between the CSM and MSFN, and, for EVA-programmed missions, between the EVA and MSFN. The audio centers are identical. They provide individual selection, isolation, and amplification of audio signals received by the CS receivers and which are to be transmitted by the CS transmitters. Each audio center contains a microphone amplifier, headset amplifier, voice operated relay (VOX) circuit, diode switches, volume control circuits, and isolation pads. The VOX circuit controls the microphone amplifier by activating it only when required for voice transmission. Audio signals are routed to and from the VHF A, VHF B, and S-band equipments and the intercom bus via the audio centers. The intercom bus, common to both audio centers, provides hardline communications between the astronauts. Voice signals to be recorded by the data storage electronics assembly are taken from the intercom bus.

DIGITAL UPLINK ASSEMBLY

The digital uplink assembly decodes S-band uplink commands from MSFN and routes the data to the LM guidance computer. The digital uplink assembly provides a verification signal to the IS for transmission to MSFN, to indicate that the uplink messages have been received and properly decoded by the digital uplink assembly. The LM guidance computer also routes a no-go signal to the IS for transmission to MSFN whenever the computer receives an incorrect message. The uplink commands addressed to the LM parallel those inputs available to the LM guidance computer via the display and keyboard assembly. The digital uplink assembly also provides a voice backup capability if the received S-band audio circuits in the premodulation processor fail.

RANGING TONE TRANSFER ASSEMBLY

The ranging tone transfer assembly operates with VHF receiver B and VHF transmitter A to provide a transponder function for CSM-LM VHF ranging. The ranging tone transfer assembly receives VHF ranging tone inputs from VHF receiver B and produces ranging tone outputs to key VHF transmitter A.

The VHF ranging tone input consists of two acquisition tone signals and one track tone signal. Accurate ranging is accomplished when the track tone signal from the CSM is received and retransmitted from the LM.

S-BAND STEERABLE ANTENNA

The S-band steerable antenna is a 26-inch-diameter parabolic reflector with a point source feed that consists of a pair of cross-sleeved dipoles over a ground plane. The prime purpose of this antenna is to provide deep-space voice and telemetry communications and deep-space tracking and ranging. This antenna provides 174° azimuth coverage and 330° elevation coverage. The antenna can be operated manually or automatically. The manual mode is used for initial positioning of the antenna to orient it within ±12.5° (capture angle) of the line-of-sight signal received from the MSFN station. Once the antenna is positioned within the capture angle, it can operate in the automatic mode.

S-BAND IN-FLIGHT ANTENNAS

The two S-band in-flight antennas are omnidirectional; one is forward and one is aft on the LM. The antennas are right-hand circularly polarized radiators that collectively cover 90% of the sphere at -3 db or better. They operate at 2282.5 mHz (transmit) and 2101.8 mHz (receive). These antennas are the primary S-band antennas for the LM when in flight.

S-BAND ERECTABLE ANTENNAS

The S-band erectable antenna is stowed in the descent stage. When erected on the lunar surface, it is a 10-foot-diameter parabolic reflector which is used as a reflector with a telescopic feed system.

VHF IN-FLIGHT ANTENNAS

The two VHF in-flight antennas are omnidirectional, right-hand circularly polarized antennas that operate in the 259.7- to 296.8-mHz range.

VHF EVA ANTENNA

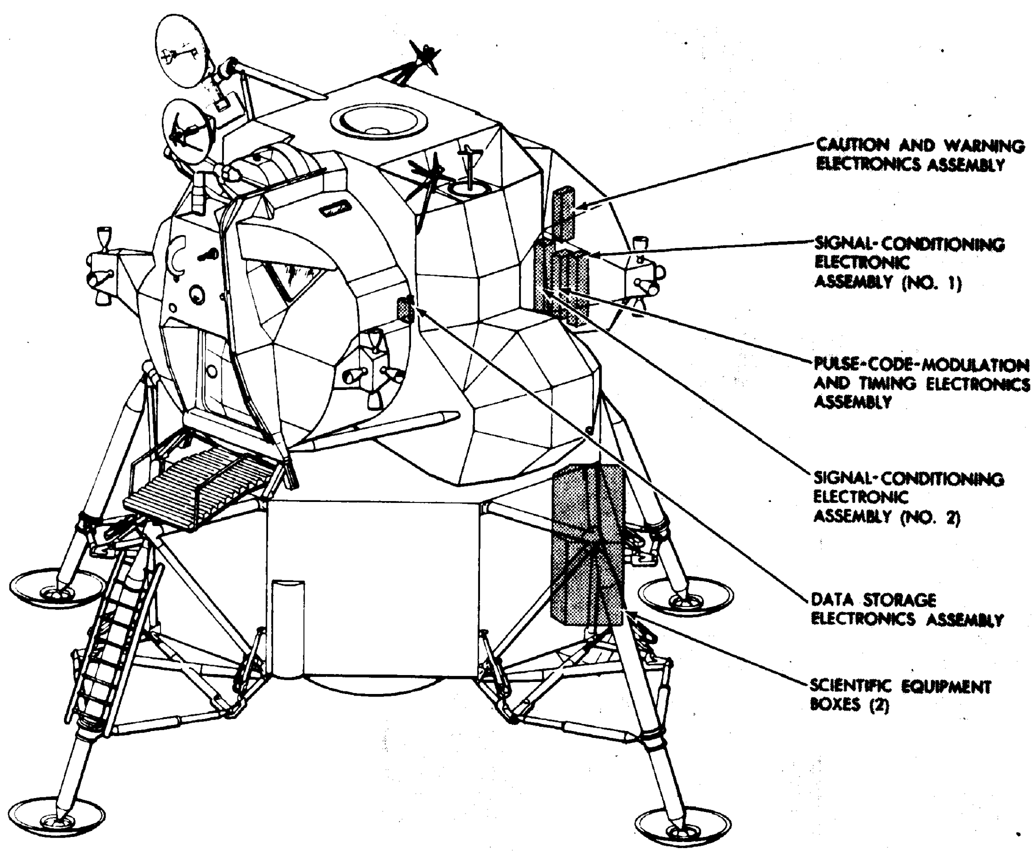
The VHF EVA antenna is an omnidirectional conical antenna, which is used for LM-EVA communications when the LM is on the lunar surface. It is mounted on the LM and unstowed by an astronaut in the LM after landing.

INSTRUMENTATION

QUICK REFERENCE DATA

Signal-conditioning electronics assembly	
Height	8.0 inches
Width	5.25 inches
Length	23.90 inches
Weight	
Assembly 1	35.44 pounds
Assembly 2	35.25 pounds
Power requirements	
Excitation	28 volts dc
Consumption	
Assembly 1	16.04 watts
Assembly 2	14.23 watts
Temperature	
Operating	$+30^{o}$ to $+130^{o}$ F
Nonoperating	-65^{o} to $+160^{o}$ F
Pulse-code-modulation and timing electronics assembly	
Height	6.72 inches
Width	5.12 inches
Length	19.75 inches
Weight	23.0 pounds (approximate)
Power requirements	
Excitation	28 volts dc
Consumption	11 watts
Operating temperature (ambient)	$+30^{o}$ to $+130^{o}$ F
Number of analog channels	277
Normal bit rate (51.2 kilobits per second)	200 channels externally programmed, 77 channels internally redundant
Reduced bit rate (1.6 kilobits per second)	113 channels externally programmed, 41 channels internally redundant
Parallel digital signals	
Number of channels	75
Normal bit rate	1, 10, 50, 100, or 200 samples per second
Reduced bit rate	1 sample per second
Serial digital signals	
Number of channels	2 channels, serial by bit
Normal bit rate	50 samples per second
Reduced bit rate	None
Data storage electronics assembly	
Height	2.05 inches
Width	4.0 inches
Length	6.22 inches
Weight	38 ounces
Power supply input	115 ± 2.5 volts rms, 400 Hz, single phase
Magnetic heads	Two record/reproduce heads to provide four tracks
Voice record amplifier	
Input level	-3 to +7 dbm
Frequency response	$\pm$ 3 db from 300 Hz to 3 kHz

Tape	
Speed	0.6 inch per second
Total recording time	10 hours (maximum)
Length of tape between sensor strips	450 feet (minimum)
Transport	
Speed error	0.05 of input power frequency deviation
Record time	Total of 10 hours
Caution and warning electronics assembly	
Height	7.0 inches
Width	6.750 inches
Depth	11.750 inches
Weight	18.20 pounds
Power requirements	
Excitation	28 volts dc
Consumption	13 watts
Temperature	
Operating	+35° to +135° F
Nonoperating	-65° to +160° F



R-102

Major Instrumentation Equipment Location

The Instrumentation Subsystem (IS) monitors the LM subsystems, performs in-flight checkout, prepares LM status data for transmission, provides timing frequencies and correlated data for LM subsystems, stores voice and time-correlation data, performs lunar surface checkout, and provides scientific instrumentation for lunar experiments.

The IS monitors various parameters (status) of LM subsystems and structure and prepares the status data for telemetering via the Communications Subsystem (CS), to MSFN. In a high-bit-rate mode of operation, MSFN receives 51,200 bits of information from 279 subsystem sensors every second. This, along with Guidance, Navigation, and Control Subsystem data, enables mission controllers to participate in major decisions, assist in spacecraft management during complicated astronaut activity, and maintain a detail subsystem performance history.

Caution and warning lights and two master alarm lights alert the astronauts to out-of-tolerance conditions (malfunctions) that affect the mission or their safety. In addition a 3-kHz alarm tone is routed to the astronaut headsets to advise the astronauts that a malfunction exists. The tone is especially helpful in alerting the astronauts when they are preoccupied or asleep. The master alarm lights can be turned off by pushing either illuminated lens; this also stops the tone. When a warning light (red) goes on, it indicates a malfunction that affects the mission, but could affect astronaut safety if not corrected.

FUNCTIONAL DESCRIPTION

The IS consists of subsystem sensors, a signal-conditioning electronics assembly, a pulse-code-modulation and timing electronics assembly, a caution and warning electronics assembly, and a data storage electronics assembly.

The sensors continuously monitor the status of LM subsystems and provide outputs indicative of temperature, pressure, frequency, gas and liquid quantity, stage-separation distance, valve and switch positions, voltage, and current. These outputs are in analog and digital form; some are routed to the signal-conditioning electronics assembly for voltage-level conditioning. If conditioning is not required, the outputs are routed directly to the pulse-code-modulation and timing electronics assembly. The signal-conditioning electronics assembly conditions its sensor-derived inputs and routes high-level analog or digital data to the pulse-code-modulation and timing electronics assembly, caution and warning electronics assembly, and crew displays.

The pulse-code-modulation and timing electronics assembly converts the conditioned and unconditioned signals to several forms for telemetering. This assembly also provides subcarrier frequencies, time reference signals, and sync pulses.

The sensed subsystem data, routed in analog and digital form to the caution and warning electronics assembly, are constantly compared with internally generated references. When an out-of-tolerance condition is detected, this assembly provides a signal to light the appropriate warning or caution light and both master alarm lights and to provide the 3-kHz alarm tone to the headsets.

Basically, all caution and warning lights operate in the same manner. The following is a typical example. Signals are routed from Reaction Control Subsystem (RCS) helium tank pressure sensors to comparators in the caution and warning electronics assembly. If comparison indicates a low-pressure condition, solid-state electronic circuits are enabled, causing the RCS caution light to go on. The astronauts then monitor helium tank pressure on indicators to determine actual pressure levels.