control for opening the PLV valves and turning on the fan in case the attitude sensor is locked up and cannot be reset; or when the CM is inverted and egress must be made through the tunnel hatch. In either case the POST LANDING VENT switch must be in the LOW or HIGH position.

Water management.- In preparing the spacecraft for the mission, the potable and waste water tanks are partially filled to insure an adequate supply for the early stages of the mission. From the time the fuel cells are placed in operation until CSM separation, the fuel cells replenish the potable water supply. A portion of the water is chilled and made available to the crew through the drinking fixture and the food preparation unit. The remainder is heated, and is delivered through a separate valve on the food preparation unit.

From the time the crew connects into the suit circuit until entry, the water accumulator pumps are extracting water from the suit heat exchanger and pumping it into the waste water system. The water is delivered to the glycol evaporators through individual water control valves. Provision is made for dumping excess waste water manually when the tank is full.

A syringe injection system is incorporated to provide for periodic injection of bactericide to kill bacteria in the potable water system.

Thermal control.- Thermal control is provided by two water-glycol coolant loops (primary and secondary). During prelaunch operations ground servicing equipment cools the water-glycol and pumps it through the primary loop, providing cooling for the electrical and electronic equipment, and the suit and cabin heat exchangers. The cold water-glycol is also circulated through the reservoir to make available a larger quantity of coolant for use as a heat sink during the ascent. Additional heat sink capability is obtained by selecting maximum cooling on the CABIN TEMP selector, and placing both cabin fans in operation. This cold soaks the CM interior structure and equipment. Shortly before launch, one of the primary pumps is placed in operation, the pump in the ground servicing unit is stopped, and the unit is isolated from the spacecraft system.

During the ascent, the radiators will be heated by aerodynamic friction. To prevent this heat from being added to the CM thermal load, the PRIMARY GLYCOL TO RADIATORS valve is placed in the PULL TO BYPASS position at approximately 75 seconds before launch. The coolant then circulates within the CM portion of the loop.

The heat that is generated in the CM, from the time that the ground servicing unit is isolated until the spacecraft reaches 110K feet, is absorbed by the coolant and the prechilled structure. Above 110K feet it is possible to reject the excess heat by evaporating water in the primary glycol evaporator.

After attaining orbit the reservoir is isolated from the loop to maintain a reserve quantity of coolant for refilling the primary loop in case of loss of fluid by leakage. The PRIMARY GLYCOL TO RADIATORS valve is placed in the position (control pushed in) to allow circulation through the radiators and the radiator outlet temperature sensors. If the radiators have cooled sufficiently (radiator outlet temperature is less than the inlet) they will be kept on-stream; if not, they will be bypassed until sufficient cooling has taken place. After the radiators have been placed on-stream, the glycol temperature control is activated (GLYCOL EVAP TEMP IN switch in AUTO); and the CABIN TEMP selector is positioned as desired.

The primary loop provides thermal control throughout the mission unless a degradation of system performance requires the use of the secondary loop.

Several hours before CM-SM separation the system valves are positioned so that the primary loop provides cooling for the cabin heat exchanger, the entire cold plate network, and the suit heat exchanger. The CABIN TEMP control valve is placed in the MAX COOL position, and both cabin fans are turned on to cold-soak in the CM interior structure.

Prior to separation the PRIMARY GLYCOL TO RADIATORS, and the GLYCOL TO RADIATORS SEC valves are placed in the BYPASS position to prevent loss of coolant when the CSM umbilical is cut. From that time (until approximately 110K feet spacecraft altitude) cooling is provided by water evaporation.

Oxygen Subsystem

The oxygen subsystem shares the oxygen supply with the electrical power system. Approximately 640 pounds of oxygen is stored in two cryogenic tanks located in the service module. Heaters within the tanks pressurize the oxygen to 900 psig for distribution to the using equipment.

Oxygen is delivered to the command module through two separate supply lines, each of which is connected to an oxygen inlet restrictor assembly. Each assembly contains a filter, a capillary line, and a spring-loaded check valve. The filters provide final filtration of gas entering the CM. The capillaries which are wound around the hot glycol line serve two purposes; they restrict the total O_2 flow rate to a maximum of 9.0 pounds per hour, and they heat the oxygen entering the CM. The check valves serve to isolate the two supply lines.

Downstream of the inlet check valves the two lines tee together and a single line is routed to the OXYGEN-S/M SUPPLY valve on panel 326. This valve is used in flight as a shutoff valve to back up the inlet check valves during entry. It is closed prior to CM-SM separation.

PART A2.8

TELECOMMUNICATIONS SYSTEM

Introduction

The communications subsystem is the only link between the spacecraft and the manned space flight network (MSFN). In this capacity, the communications subsystem provides the MSFN flight controllers with data through the pulse code modulated (PCM) telemetry system for monitoring spacecraft parameters, subsystem status, crew biomedical data, event occurrence, and scientific data. As a voice link, the communications subsystem gives the crew the added capability of comparing and evaluating data with MSFN computations. The communications subsystem, through its MSFN link, serves as a primary means for the determination of spacecraft position in space and rate of change in position. CM-LM rendezvous is facilitated by a ranging transponder and an active ranging system. Through the use of television camera, crew observations and public information can be transmitted in real time to MSFN. A means by which CM and LM telemetry and voice can be stored in the spacecraft for later playback, to avoid loss because of an interrupted communications link, is provided by the communications subsystem in the form of the data storage equipment (DSE). Direction-finding aids are provided for postlanding location and rescue by ground personnel.

The following list summarizes the general telecomm functions:

a. Provide voice communication between:

(1) Astronauts via the intercom

(2) CSM and MSFN via the unified S-band equipment (USBE) and in orbital and recovery phases via the VHF/AM

(3) CSM and extravehicular astronaut (EVA) via VHF/AM

(4) CSM and LM via VHF/AM

(5) CSM and launch control center (LCC) via PAD COMM

(6) CSM and recovery force swimmers via swimmers umbilical

(7) Astronauts and the voice log via intercomm to the data storage equipment

b. Provide data to the MSFN of:

(1) CSM system status

(2) Astronaut biomedical status

(3) Astronaut activity via television

(4) EVA personal life support system (PLSS) and biomed status

(5) LM system status recorded on CSM data storage equipment

c. Provide update reception and processing of:

(1) Digital information for the command module computer (CMC)

(2) Digital time-referencing data for the central timing equipment (CTE)

(3) Real-time commands to remotely perform switching functions in three CM systems

d. Facilitate ranging between:

(1) MSFN and CSM via the USBE transponder

(2) LM and CSM via the rendezvous radar transponder (RRT)

(3) CSM and LM via the VHF/AM ranging system

e. Provide a recovery aid VHF for spacecraft location.

f. Provide a time reference for all time-dependent spacecraft subsystems except the guidance and navigation subsystem.

Functional Description

The functional description of the telecommunications system is divided into four parts: intercommunications equipment, data equipment, radio frequency equipment, and antenna equipment. All of these functional groups of equipment interface with each other to perform the system tasks. In the functional descriptions of these parts, such interfaces will be apparent.

PART A2.9

SEQUENTIAL SYSTEMS

Introduction

Sequential systems include certain detection and control subsystems of the launch vechicle (LV) and the Apollo spacecraft (SC). They are utilized during launch preparations, ascent, and entry portions of a mission, preorbital aborts, early mission terminations, docking maneuvers, and SC separation sequences. Requirements of the sequential systems are achieved by integrating several subsystems. Figure A2.9-1 illustrates the sequential events control subsystem (SECS), which is the nucleus of sequential systems, and its interface with the following subsystems and structures:

a. Displays and controls

b. Emergency detection (EDS)

c. Electrical power (EPS)

d. Stabilization and control (SCS)

e. Reaction control (RCS)

f. Docking (DS)

g. Telecommunications (T/C)

h. Earth landing (ELS)

i. Launch escape (LES)

j. Structural

Sequential Events Control Subsystem

The SECS is an integrated subsystem consisting of 12 controllers which may be categorized in seven classifications listed as follows:

a. Two master events sequence controllers (MESC)

b. Two service module jettison controllers (SMJC)

c. One reaction control system controller (RCSC)

d. Two lunar module (LM) separation sequence controllers (LSSC)

e. Two lunar docking events controllers (LDEC)

f. Two earth landing sequence controllers (ELSC)

g. One pyro continuity verification box (PCVB)

Five batteries and three fuel cells are the source of electrical power. The SMJC is powered by fuel cells; however, battery power is used for the start signal. The RCSC is powered by the fuel cells and batteries. The remaining controllers of the SECS are powered by batteries exclusively.

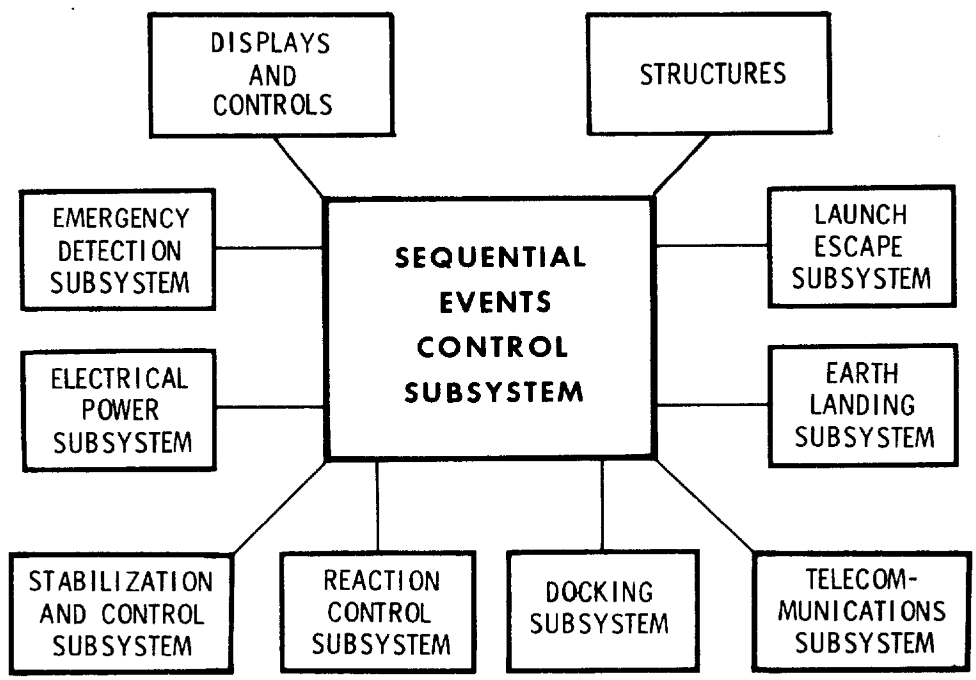

Figure A2.9-1.- SECS interface.

Origin of Signals

The SECS receives manual and/or automatic signals and performs control functions for normal mission events or aborts. The manual signals are the result of manipulating switches on the main display console (MDC) or rotating the Commander's translation hand control counterclockwise, which is the prime control for a manual abort. Automatic abort signals are relayed by the emergency system (EDS).

PART A2.10

CAUTION AND WARNING SYSTEM

Introduction

The caution and warning system (C&WS) monitors critical parameters of most of the systems in the CM and SM. When a malfunction or out-of-tolerance condition occurs in any of these systems, the crew is immediately alerted in order that corrective action may be taken.

Functional Description

Upon receipt of malfunction or out-of-tolerance signals, the C&WS simultaneously identifies the abnormal condition and alerts the crew to its existence. Each signal will activate the appropriate systems status indicator and a master alarm circuit. The master alarm circuit visually and aurally attracts the crew's attention by alarm indicators on the MDC and by an audio tone in the headsets. Crew acknowledgment of an abnormal condition consists of resetting the master alarm circuit, while retaining the particular systems status malfunction indication. The capability exists for the crew to select several modes of observing systems status and master alarm indicators and of monitoring CM or SM systems.

Major Component Subsystem Description

The C&WS consists of one major component, the detection unit. It is located behind MDC-3, and therefore is neither visible nor accessible to the crew during the mission. The balance of the system is made up of visual indicators, aural alerting and associated circuits, and those switches required to control the various system functions. Visual indicators include the two uppermost fuel cell electromechanical event devices on MDC-3, as well as all systems status and master alarm lights.

The detection unit circuits consist of comparators, logic, lamp drivers, and a master alarm and tone generator. Also incorporated are two redundant power supplies, a regulated +12 and a -12 V dc for the electronics.

Inputs to the detection unit consist of both analog and event-type signals. The analog signals are in the 0 to 5 V dc range. Alarm limits for these signals trigger voltage comparators, which, in turn, activate logic and lamp-driver circuits, thus causing activation of the master alarm circuit and tone generator, illumination of applicable systems status lights on MDC-2, and for certain measurements, activation of applicable electromechanical event indicators on MDC-3. Several event inputs are monitored by the C&WS detection unit. These signals originate from solid state and mechanical switch closures in malfunction sensing devices. These signals will directly illuminate applicable system status lights and, through logic circuitry, activate the master alarm lights and tone generator. One event signal, originating within the detection unit, directly illuminates the C/W light, but activates only the MASTER ALARM switch lights of the master alarm circuit. One event signal, "CREW ALERT," originates from MSFN stations through the UDL portion of the communications system. This system status light can only be extinguished by a second signal originating from the MSFN.

The master alarm circuit alerts crewmembers whenever abnormal conditions are detected. This is accomplished visually by illumination of remote MASTER ALARM switch-lights on MDC-1, MDC-3, and LEB-122. An audio alarm tone, sent to the three headsets, aurally alerts the crew. The output signal of the tone generator is a square wave that is alternately 750 and 2000 cps, modulated at 2.5 times per second. Although the tone is audible above the conversation level, it does not render normal conversation indistinct or garbled. When the crew has noted the abnormal condition, the master alarm lights and the tone generator are deactivated and reset by depressing any one of the three MASTER ALARM switch-lights. This action leaves the systems status lights illuminated and resets the master alarm circuit for alerting the crew if another abnormal condition should occur. The individual systems status lights will remain illuminated until the malfunction or out-of-tolerance condition is corrected, or the NORMAL-BOOST-ACK switch (MDC-3) is positioned to ACK.

The C&WS power supplies include sensing and switching circuitry that insure unit self-protection should high-input current, or high- or low-output voltage occur. Any of these fault conditions will cause the illumination of the master alarm lights and the C/W system status light. The tone generator, however, will not be activated because it requires the 12 V dc output from the malfunctioned power supply for its operation. The crew must manually select the redundant power supply to return the C&WS to operation. This is accomplished by repositioning the CAUTION/WARNING-POWER switch on MDC-2. In so doing, the C/W status light is extinguished, but the master alarm circuit remains activated, requiring it to be reset.

Incorporated into the C&WS is the capability to test the lamps of systems status and master alarm lights. Position 1 of the CAUTION/WARNING-LAMP TEST switch tests the illumination of the left-hand group of status lights on MDC-2 and the MASTER ALARM switch-light on MDC-1.

Position 2 tests the MASTER ALARM switch-light on MDC-3 and the right-hand group of status lights on MDC-2. The third MASTER ALARM light, located on LEB-122, is tested by placing the CONDITION LAMPS switch on LEB-122 to TEST.

The position of the CAUTION/WARNING - CSM-CM switch (MDC-2) establishes the systems to be monitored. Before CM-SM separation, systems in both the CM and SM are monitored for malfunction or out-of-tolerance conditions with this switch in the CSM position. Positioning the switch to CM deactivates systems status lights and event indicators associated with SM systems.

The CAUTION/WARNING - NORMAL-BOOST-ACK switch (MDC-2) permits variable modes of status and alarm light illumination. For most of the mission, the switch is set to the NORMAL position to give normal C&WS operation; that is, upon receipt of abnormal condition signals, all systems status lights and master alarm lights are capable of illumination. During the ascent phase, the switch is set to the BOOST position, which prevents the MASTER ALARM switch-light on MDC-1 from illuminating. This prevents possible confusion on MDC-1 between the red MASTER ALARM light and the adjacent red ABORT light. The ACK switch position is selected when the crew desires to adapt their eyes to darkness, or if a continuously illuminated systems status light is undesirable. While in this mode, incoming signals will activate only the master alarm lights and the tone generator. To determine the abnormal condition, the crew must depress either MASTER ALARM switch-light on MDC-1 or -3. This illuminates the applicable systems status light, and deactivates and resets the master alarm circuit. The systems status light will remain illuminated as long as the switch-light is depressed. However, it may be recalled as long as the abnormal condition exists by again pressing either switch-light.

A stowable tone booster is added to the caution and warning system to allow all three astronauts to sleep simultaneously with the headsets removed. Stowage of this unit during non-use periods is under locker A3.

The unit consists of a power plug, tone booster, and a photo-sensitive device which can be used on the left or right side of the command module. The power connection is made to the UTILITY receptacle on MDC-15 or 16. The tone booster, which provides an audible signal, is mounted by velcro pad to the left-hand or right-hand girth shelf. The photo-sensitive device is mounted by velcro over the MDC-1 or MDC-3 MASTER ALARM lamp.

Since the MASTER ALARM is triggered by any caution/warning monitored symptom, it will activate the tone booster until the

MASTER ALARM is extinguished by a manual reset. In the event of a caution/warning system power supply failure, this unit will provide the audio alarm.

Electrical power distribution.- The C&WS receives power from the MNA & MNB buses (see fig. A2.10-1). Two circuit breakers, located on MDC-5, provide circuit protection. Closure of either circuit breaker will allow normal system operation.

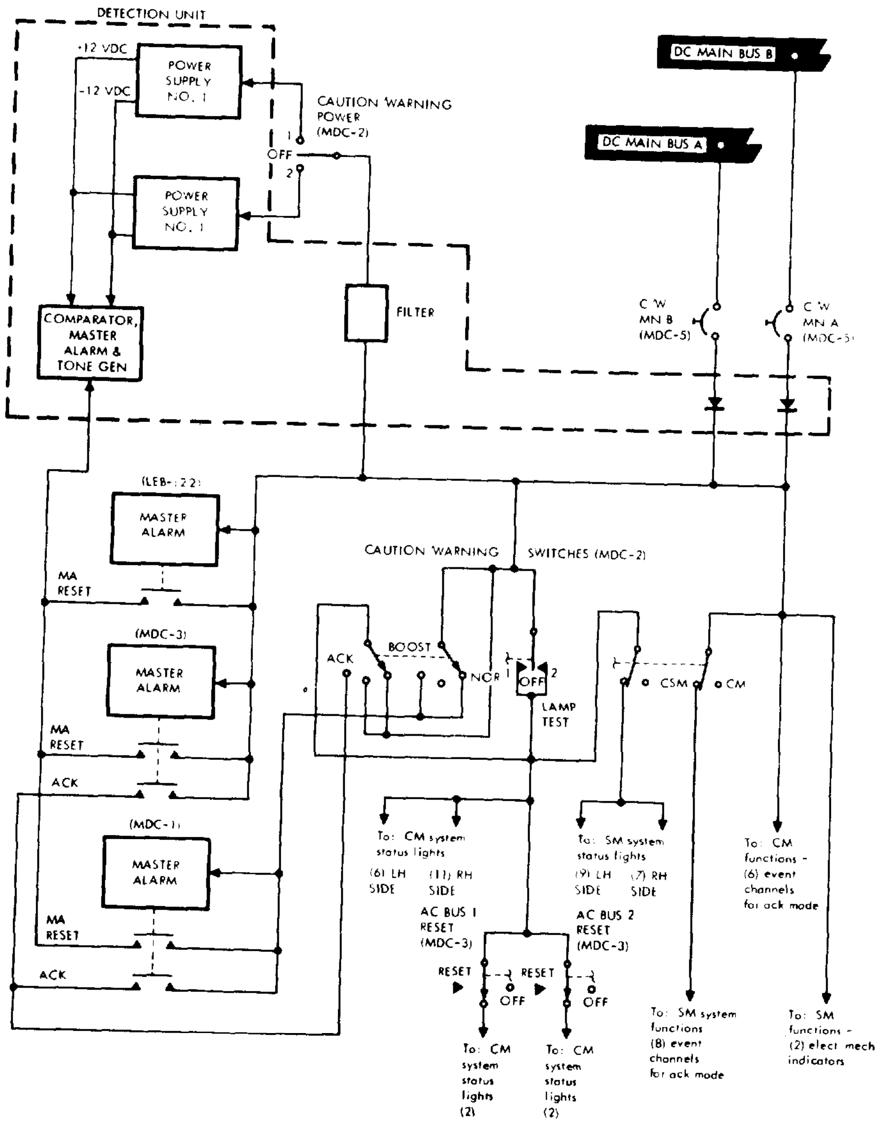

Figure A2.10-1.- C&WS power distribution diagram.

Operational Limitations and Restrictions

With the CAUTION/WARNING - NORMAL-BOOST-ACK switch in the BOOST position during ascent, the MASTER ALARM switch-light on MDC-1 will not illuminate should a malfunction occur. The master alarm circuit reset capability of the light is also disabled during this time. This requires the MASTER ALARM switch-light on MDC-3 to be used exclusively for monitoring and resetting functions during boost. Several peculiarities should be noted in regard to the CAUTION/WARNING - POWER switch. Whenever this switch is moved from or through the OFF position to either power supply position, the master alarm circuit is activated, requiring it be reset. Also, switching from one power supply to another (when there is no power supply failure) may cause the C/W system status light to flicker as the switch passes through the OFF position.

Should both power supplies fail, the C&WS is degraded to the extent that the complete master alarm circuit, as well as those system status lights that illuminate as the result of analog-type input signals, are rendered inoperative. This leaves only those status lights operative that require event-type input signals. They include the following SM and CM lights: CMC, ISS, BMAG 1 TEMP, BMAG 2 TEMP, SPS ROUGH ECO, PITCH GMBL 1, PITCH GMBL 2, YAW CMBL 1, YAW GMBL 2, O_2 FLOW HI, FC BUS DISCONNECT, AC BUS 1, AC BUS 1 OVERLOAD, AC BUS 2, AC BUS 2 OVERLOAD, MN BUS A UNDERVOLT, MN BUS B UNDERVOLT, and CREW ALERT. The C/W light will be operative only while the CAUTION/WARNING - POWER switch is in position 1 or 2.

The CAUTION/WARNING - CSM-CM switch must be in the CSM position in order to conduct a lamp test of those system status lights associated with SM systems. The status lights of CM systems may be tested with the switch in either position. Circuit design permits a complete lamp test to be conducted with the CAUTION/WARNING switch in the NORMAL or ACK position only. In the BOOST position, all lamps except the MASTER ALARM light on MDC-1 may be tested.

Normally, each abnormal condition signal will activate the C&WS master alarm circuit and tone generator, and illuminate the applicable systems status light. However, after initial activation of any status light that monitors several parameters, and reset of the MASTER ALARM, any additional out-of-tolerance condition or malfunction associated with the same system status light will not activate the MASTER ALARM until the first condition has been corrected, thus extinguishing the status light.

Each crewmember's audio control panel has a power switch which will allow or inhibit the tone signal from entering his headset. The AUDIO-TONE position allows the signal to pass on to the headset, while the AUDIO position inhibits the signal.

PART A2.11

MISCELLANEOUS SYSTEMS DATA

Introduction

Miscellaneous systems data pertain to items that are not covered in other systems. These items consist of timers, accelerometers (G-meter), and uprighting system.

Timers

Two mission timers (electrical) and two event timers (electrical/mechanical) are provided for the crew in the command module. One mission timer is located on panel 2 of the MDC and the other on panel 306 in the left-hand forward equipment bay. Each mission timer has provisions for manually setting the readout (hours, minutes, and seconds), and the capability of starting, stopping, and resetting to zero. The numerical elements are electroluminescent lamps and the intensity is controlled by the NUMERICS light control on panels MDC-8 and LEB-100. The event timers are located on MDC-1 and -306 in the left-hand forward equipment bay, and provide the crew with a means of monitoring and timing events. All timers reset and start automatically when lift-off occurs, and the timer located on MDC-1 will be automatically reset and restarted if an abort occurs. The event timers are integrally illuminated by an internal electroluminescent lamp and controlled by the INTEGRAL light controls located on MDC-8 and LEB-100.

Accelerometer (G-meter)

The accelerometer or G-meter (MDC-1) provides the crew with a visual indication of spacecraft positive and negative G-loads. This meter is illuminated by an internal electroluminescent lamp and controlled by the INTEGRAL light control on MDC-8.

Command Module Uprighting System

The CM uprighting system is manually controlled and operated after the CM has assumed a stable, inverted floating attitude. The system consists of three inflatable air bags, two relays, three solenoid-control valves, two air compressors, control switches, and air lines. The inflatable bags are located in the CM forward compartment and the air compressors in the aft compartment. The control switches and circuit breakers are located in the crew compartment. The switches control relays which are powered by the postlanding bus and the relays control power to the compressors which are powered by battery buses A and B. (See figure A2.11-1.)

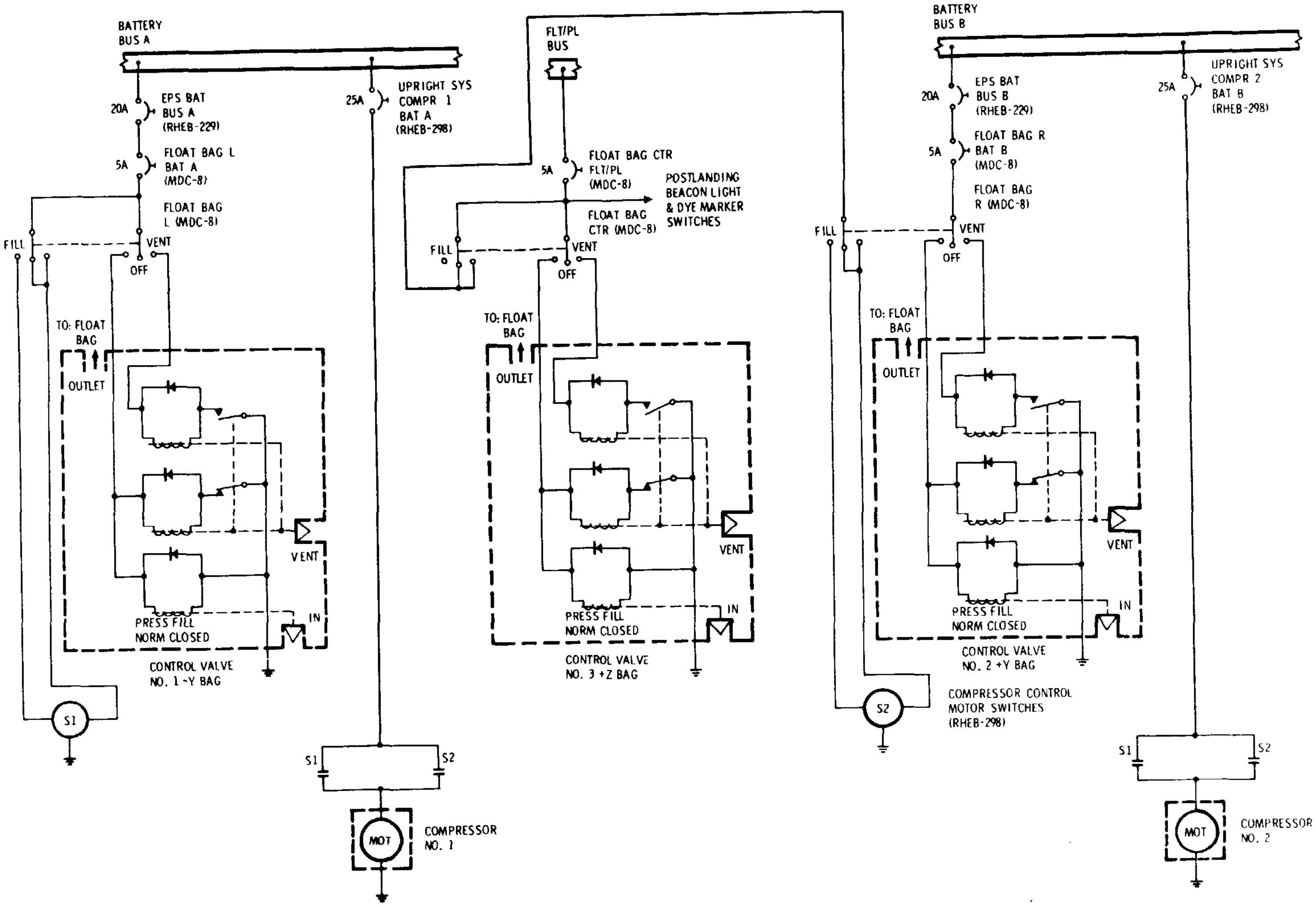

Figure A2.11-1.- Sequential systems operational/functional diagram.

Functional description.- FLOAT BAG 1L switch controls inflation of the air bag on -Y axis, switch 2R controls inflation of the air bag on the +Y axis, and switch 3 CTR controls inflation of the air bag on the +Z axis of the CM (see fig. A2.11-1). Two of the bags are 45 inches in diameter; the other bag is 24 inches in diameter. If the CM becomes inverted after landing, the crewmember at station 1 initiates filling of the three bags by setting the FLOAT BAG 1L, 2R, and 3 CTR switches to FILL. When the CM is uprighted, the three FLOAT BAG switches will be set to OFF. A 4.25±0.25-psi relief valve is located in the inlet of each bag. Backup relief valves set at 13.5 psi are located in the outlet of each compressor.

PART A2.12

CREW PERSONAL EQUIPMENT

This section contains the description and operation of Contractor- and NASA-furnished crew personal equipment and miscellaneous stowed equipment that is not described in other sections of the handbook. All major items are identified as Contractor-furnished equipment (CFE) or Government-furnished (NASA) property (GFP - synonymous with GFE).

The crew equipment is presented in the general order of operational usage in SM2A-03-BLOCK. A brief outline is as follows:

a. Spacesuits

(1) Intravehicular Spacesuit Assembly

(a) Biomedical Harness and Belt
(b) Constant Wear Garment (CWG)
(c) Flight Coveralls
(d) Pressure Garment Assembly (PGA)
(e) Associated Umbilicals, Adapters, and Equipment

(2) Extravehicular Spacesuit Assembly

(a) Liquid-Cooled Garment (LCG)
(b) PGA with Integrated Thermal Meteroid Garment (ITMG)
(c) Associated Equipment

b. G-Load Restraints

(1) Crewman Restraint Harness

(2) Interior Handhold and Straps

(3) Hand Bar

c. Zero-g Restraints

(1) Rest Stations

(2) Velcro and Snap Restraint Areas

(3) Straps

d. Internal Sighting and Illumination Aids

(1) Window Shades

(2) Mirrors

(3) Crewman Optical Alignment Sight (COAS)

(4) LM Active Docking Target

(5) Window Markings

(6) Miscellaneous Aids

e. External Sighting and Illumination Aids

(1) Exterior Spotlight

(2) Running Lights

(3) EVA Floodlight

(4) EVA Handles with RL Disks

(5) Rendezvous Beacon

f. Mission Operational Aids

(1) Flight Data File

(2) Inflight Toolset

(3) Cameras

(4) Accessories & Miscellaneous

(a) Waste Bags
(b) Pilot's Preference Kits (PPKs)
(c) Fire Extinguishers
(d) Oxygen Masks
(e) Utility Outlets
(f) Scientific Instrumentation Outlets

g. Crew Life Support

(1) Water

(2) Food

(3) The Galley System

(4) Waste Management System

(5) Personal Hygiene

h. Medical Supplies and Equipment

i. Radiation Monitoring and Measuring Equipment

j. Postlanding Recovery Aids

(1) Postlanding Ventilation Ducts

(2) Swimmer Umbilical and Dye Marker

(3) Recovery Beacon

(4) Snagging Line

(5) Seawater Pump

(6) Survival Kit

k. Equipment Stowage

PART A2.13

DOCKING AND TRANSFER

Introduction

This section identifies the physical characteristics of the docking system and the operations associated with docking and separation.

Docking operational sequence.- The following sequence of illustrations and text describe the general functions that are performed during docking. These activities will vary with the different docking modes.

After the spacecraft and third stage have orbited the earth, possibly up to three revolutions, the third stage is reignited to place the spacecraft on a translunar flight.

Shortly after translunar injection, the spacecraft transposition and docking phase takes place (fig. A2.13-1). When the CSM is separated from the third stage, docking is achieved by maneuvering the CSM close enough so that the extended probe (accomplished during earth orbit) engages with the drogue in the LM. When the probe engages the drogue with the use of the capture latches, the probe retract system is activated to pull the LM and CSM together.

Upon retraction, the LM tunnel ring will activate the 12 automatic docking ring latches on the CM and effect a pressure seal between the modules through the two seals in the CM docking ring face. After the two vehicles are docked, the pressure in the tunnel is equalized from the CM through a pressure equalization valve. The CM forward hatch is removed and the actuation of all 12 latches is verified. Any latches not automatically actuated will be cocked and latched manually by the crewman. The LM to CM electrical umbilicals are retrieved from their stowage position in the LM tunnel and connected to their respective connectors in the CM docking ring.

The vehicle umbilicals supply the power to release the LM from the SLA. Once the hold-down straps are severed, four large springs located at each attachment point push the two vehicles apart, and the combined CSM/LM continues towards the moon.

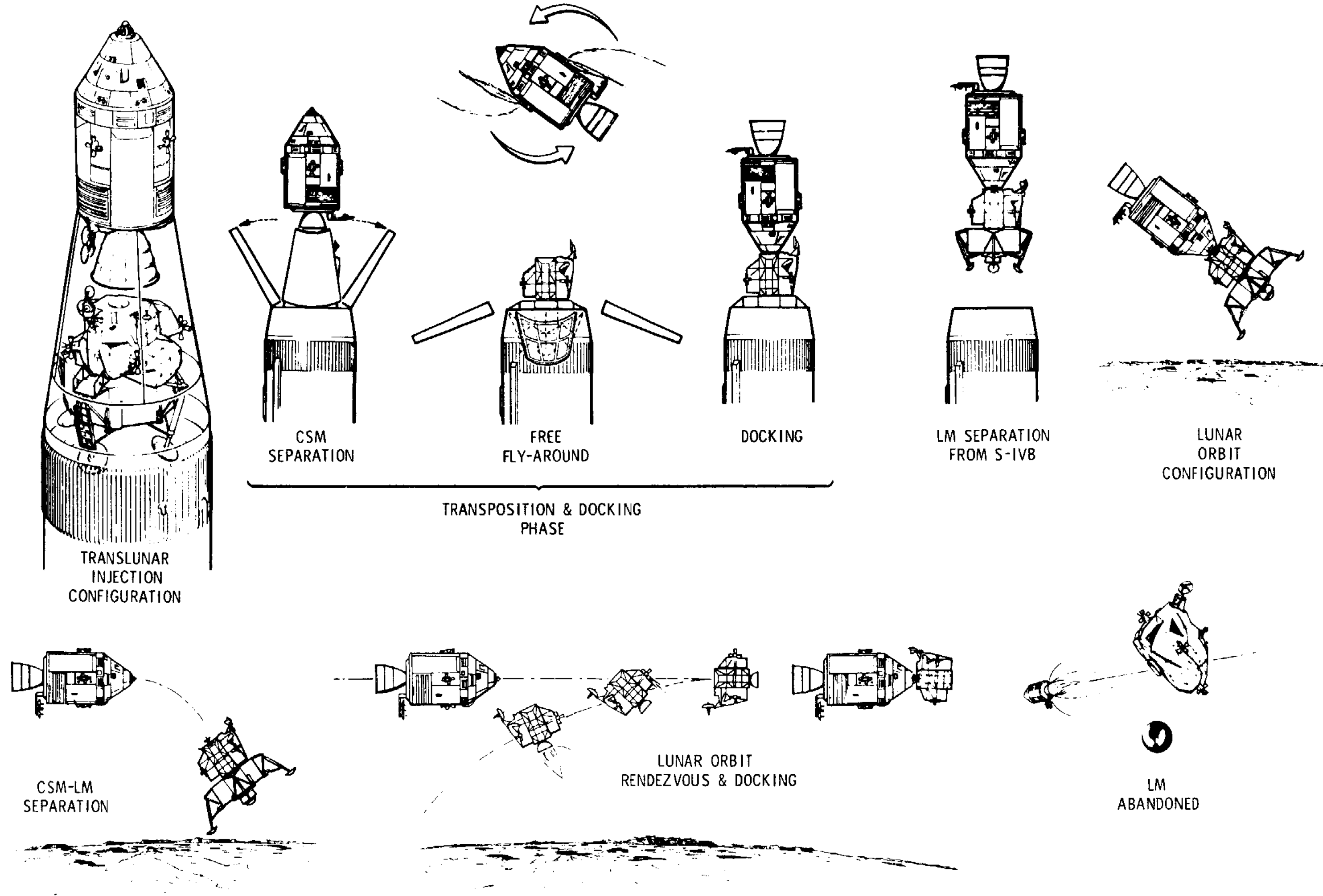

Figure A2.13-1.- CSM/LM docking operational phases.

Once in lunar orbit, the tunnel is repressurized. The probe assembly and drogue assembly are removed from the tunnel and stowed in the CM. The pressure in the LM is equalized through the LM hatch valve. With the pressure equalized, the LM hatch is opened and locked in the open position to provide a passageway between the two modules.

After two crewmen transfer to the LM, the CM crewman retrieves the drogue from its stowage location in the CM, passes it through the tunnel, and helps to install and lock it in the tunnel. The drogue may be installed and locked by the LM crewmen, if they choose. The probe assembly is then retrieved from its stowage location in the CM and installed and preloaded to take all the load between the modules. This accomplished, the LM hatch is closed by the LM crewmen. The 12 docking latches are released and cocked by the crewman in the CM so that the latches are ready for the next docking operation. The CM forward hatch is reinstalled and checked to assure a tight seal. The modules are now prepared for separation.

The probe EXTEND RELEASE/RETRACT switch in the CM (MDC-2) is placed in the EXTEND position, energizing the probe extend latch. The probe extends and during extension will activate a switch energizing an enternal electrical motor to unlock the capture latches. After the probe extends, the LM pulls away from the CM and descends to the lunar surface. If the switch is not held until the probe reaches full extension, the capture latches will reengage to hold the two vehicles together. The switch would then have to be reactivated and separation performed with the RCS.

After landing, it will be several hours before the first man steps foot on the moon. The first few hours are spent checking the LM ascent stage and resting. This completed, the cabin is depressurized and one of the crewmen descends to the lunar surface. Following a short period, the second crewman descends to the surface. Lunar surface activities will vary for each mission.

Following completion of the lunar surface exploration the ascent engine is fired using the depleted descent stage as a launch platform.

After rendezvous and docking in lunar orbit, the LM crewmen transfer back to the CM. After the CSM and LM pressures have equalized, the LM crew opens the LM hatch while the CM pilot removes the tunnel hatch. The drogue and probe are removed and stowed in the LM. Lunar samples, film, and equipment to be returned to earth are transferred from the LM to the CM. Equipment in the CM that is no longer needed is put into the LM, and the LM hatch is closed, the CM hatch is replaced, and the seal checked.

The LM is then released by firing the separation system (detonating cord) located around the circumference of the docking ring, thus serving the ring and abandoning the LM (fig. A2.13-1). This completed, the CM SPS engine is fired, placing the spacecraft in a return trajectory toward the earth.

Functional Description

The docking system is a means of connecting and disconnecting the LM/CSM during a mission and is removable to provide for intravehiclular transfer between the CSM and LM of the flight crew and transferrable equipment.

The crew transfer tunnel, or CSM/LM interlock area, is a passageway between the CM forward bulkhead and the LM upper hatch. The hatch relationship with the docking hardware is shown in fig. A2.13-2. (The figure does not show the installed positions.) For descriptive purposes that portion of the interlock area above the CM forward bulkhead to the docking interface surface is referred to as the CM tunnel. That portion of the interlock outboard of the LM upper hatch extending to the docking interface surface is referred to as the LM tunnel. The CM tunnel incorporates the CM forward hatch, probe assembly, docking ring and seals, and the docking automatic latches. The LM tunnel contains a hinged pressure hatch, drogue support fittings, drogue assembly, drogue locking mechanism, and LM/CM electrical umbilicals.

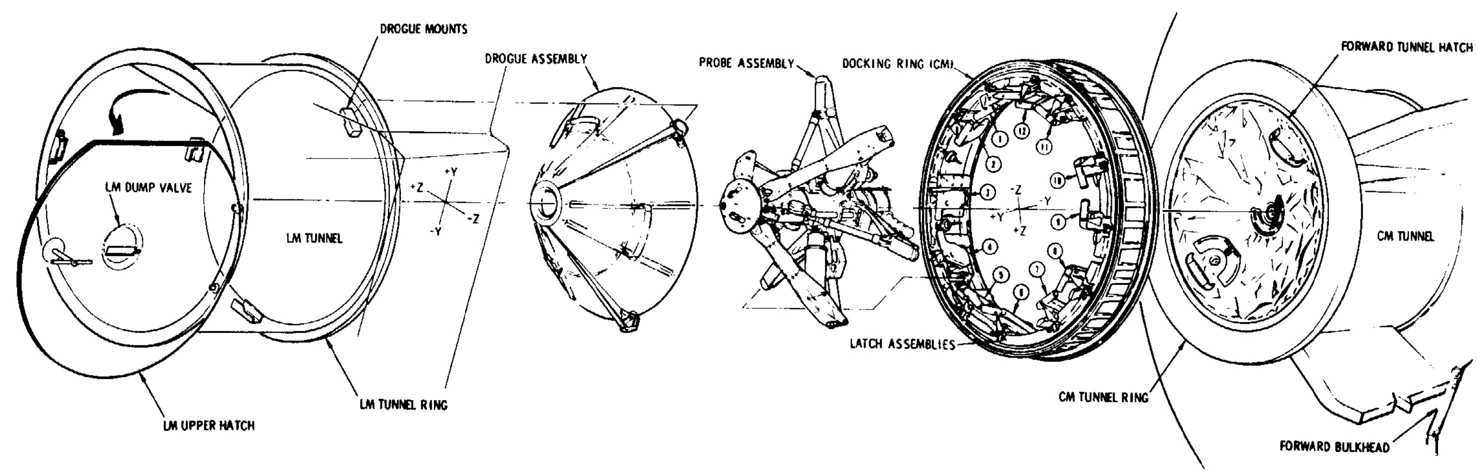

Figure A2.13-2.- Docking system.

PART A3

LUNAR MODULE SYSTEMS DESCRIPTION

INTRODUCTION

This part includes descriptions of the LM, the LM - spacecraft-to-lunar module adapter (SLA) - S-IVB connections, the LM-CSM interfaces, and LM stowage provisions are included in this chapter. These data were extracted from the technical manual LMA 790-3-LM, Apollo Operations Handbook, Lunar Module, Volume 1, dated February 1, 1970.

LM CONFIGURATION

The LM (fig. A3-1) is designed for manned lunar landing missions. It consists of an ascent stage and a descent stage; the stages are joined together at four interstage fittings by explosive nuts and bolts. Subsystem continuity between the stages is accomplished by separable interstage umbilicals and hardline connections.

Both stages function as a single unit during lunar orbit, until separation is required. Stage separation is accomplished by explosively severing the four interstage nuts and bolts, the interstage umbilicals, and the water lines. All other hardlines are disconnected automatically at stage separation. The ascent stage can function as a single unit to accomplish rendezvous and docking with the CSM. The overall dimensions of the LM are given in figure A3-2. Station reference measurements (fig. A1-1) are established as follows:

a. The Z- and Y-axis station reference measurements (inches) start at a point where both axes intersect the X-axis at the vehicle vertical centerline: the Z-axis extends forward and aft of the intersection; the Y-axis, left and right. The point of intersection is established as zero.

b. The +Y-axis measurements increase to the right from zero; the -Y-axis measurements increase to the left. Similarly, the +Z- and -Z-axis measurements increase forward (+Z) and aft (-Z) from zero.

c. The X-axis station reference measurements (inches) start at a design reference point identified as station +X200.000. This reference point is approximately 128 inches above the bottom surface of the footpads (with the landing gear extended); therefore, all X-axis station reference measurements are +X-measurements.

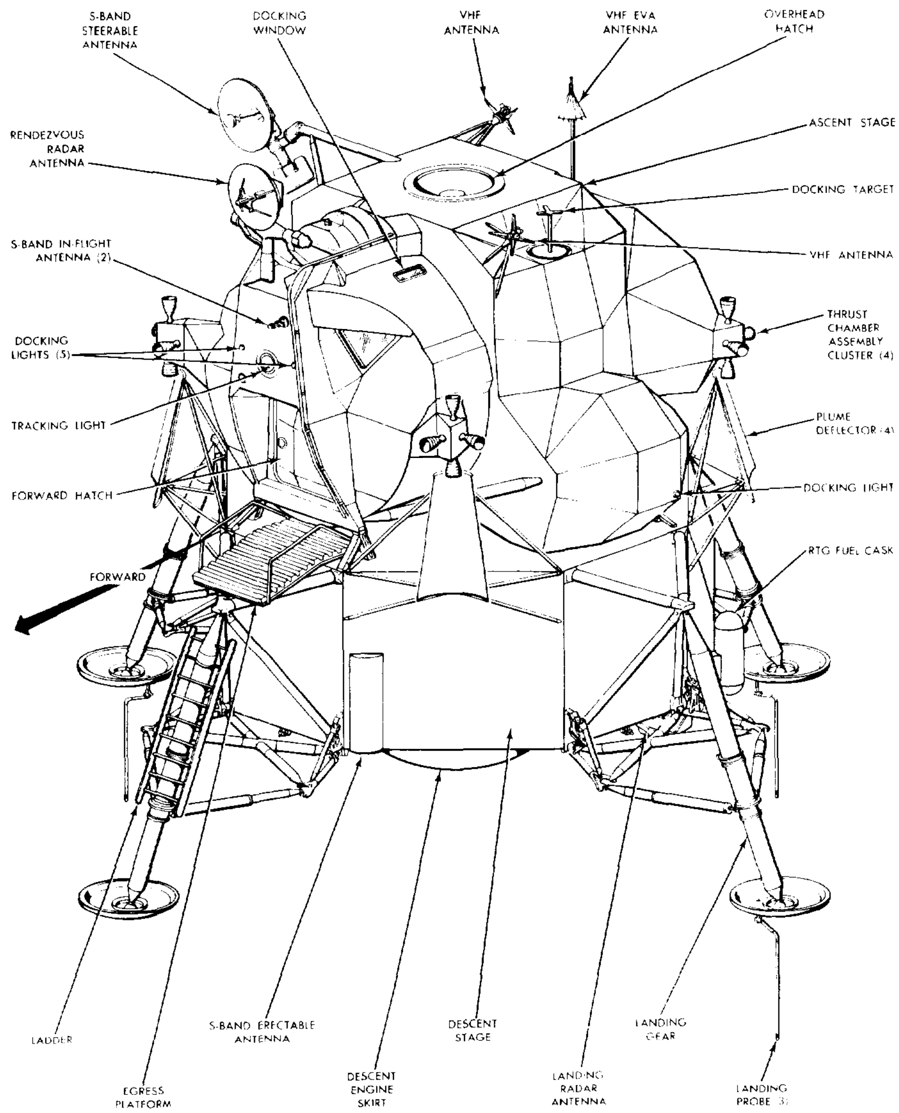

Figure A3-1.- LM configuration.

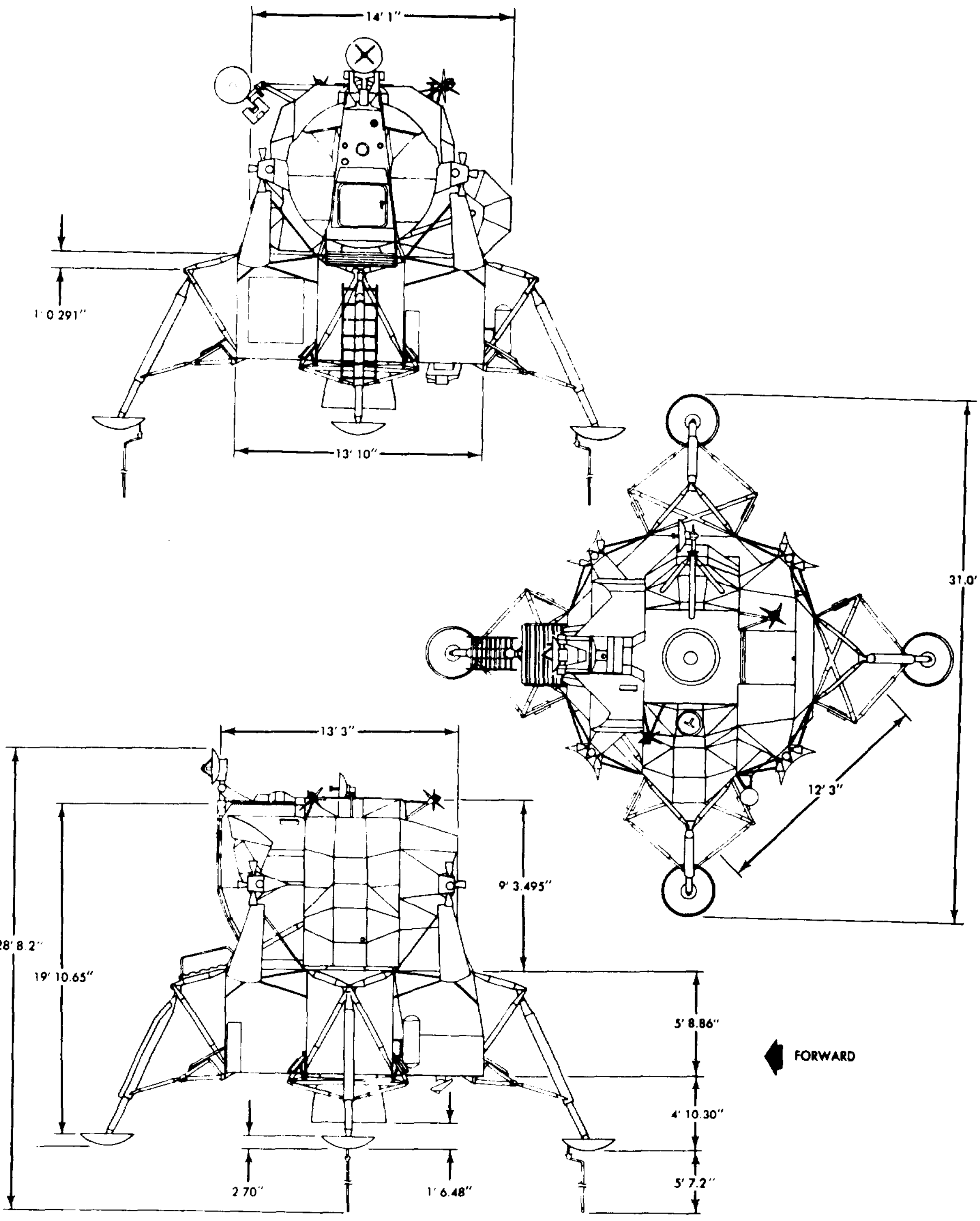

Figure A3-2.- LM overall dimensions.

Ascent Stage

The ascent stage, the control center and manned portion of the LM, accommodates two astronauts. It comprises three main sections: the crew compartment, midsection, and aft equipment bay. The crew compartment and midsection make up the cabin, which has an approximate overall volume of 235 cubic feet. The cabin is climate-controlled, and pressurized to 4.8 ± 0.2 psig. Areas other than the cabin are unpressurized.

Crew Compartment. - The crew compartment is the frontal area of the ascent stage; it is 92 inches in diameter and 42 inches deep. This is the flight station area; it has control and display panels, armrests, body restraints, landing aids, two front windows, a docking window, and an alignment optical telescope (AOT). Flight station centerlines are 44 inches apart; each astronaut has a set of controllers and armrests. Circuit breaker, control, and display panels are along the upper sides of the compartment. Crew provision storage space is beneath these panels. The main control and display panels are canted and centered between the astronauts to permit sharing and easy scanning. An optical alignment station, between the flight stations, is used in conjunction with the AOT. A portable life support system (PLSS) donning station is also in the center aisle, slightly aft of the optical alignment station.

Control and display panels: The crew compartment has 12 control and display panels (fig. A3-3): two main display panels (1 and 2) that are canted forward 10 degrees, two center panels (3 and 4) that slope down and aft 45 degrees towards the horizontal, two bottom side panels (5 and 6), two lower side panels (8 and 12), one center side panel (14), two upper side panels (11 and 16), and the orbital rate display - earth and lunar (ORDEAL) panel aft of panel 8.

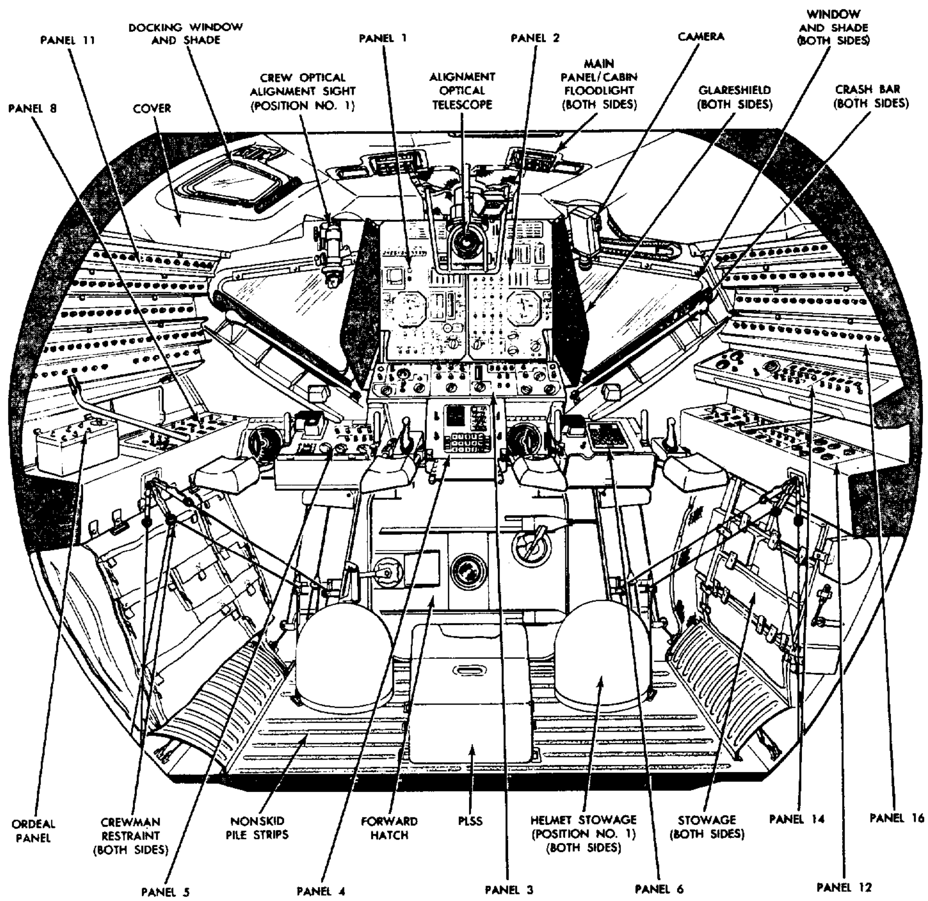

Figure A3-3.- Cabin interior (looking forward).

Panels 1 and 2 are located on each side of the front face assembly centerline, at eye level. Each panel is constructed of two 0.015-inch-thick aluminum-alloy face sheets, spaced 2 inches apart by formed channels. The spacer channels are located along the sheet edges; additional channels, inboard of the edge channels, reinforce the sheets. This forms a rigid box-like construction with a favorable strength-to-weight ration and a relatively high natural frequency. Four shock mounts support each panel on the structure. Panel instruments are mounted to the back surface of the bottom and/or to the top sheet of the panel. The instruments protrude through the top sheet of the panel. All dial faces are nearly flush with the forward face of the panel. Panel 1 contains warning lights, flight indicators and controls, and propellant quantity indicators. Panel 2 contains caution lights, flight indicators and controls, and Reaction Control Subsystem (RCS) and Environmental Control Subsystem (ECS) indicators and controls.

Panel 3 is immediately below panels 1 and 2 and spans the width of these two panels. Panel 3 contains the radar antenna temperature indicators and engine, radar, spacecraft stability, event timer, RCS and lighting controls.

Panel 4 is centered between the flight stations and below panel 3. Panel 4 contains attitude controller assembly (ACA) and thrust translation controller assembly (TTCA) controls, navigation system indicators, and LM guidance computer (LGC) indicators and controls. Panels 1 through 4 are within easy reach and scan of both astronauts.

Panels 5 and 6 are in front of the flight stations at astronaut waist height. Panel 5 contains lighting and mission timer controls, engine start and stop pushbuttons, and the X-translation pushbutton. Panel 6 contains abort guidance controls.

Panel 8 is at the left of the Commander's station. The panel is canted up 15 degrees from the horizontal; it contains controls and displays for explosive devices, audio controls, and the TV camera connection.

Panel 11, directly above panel 8, has five angled surfaces that contain circuit breakers. Each row of circuit breakers is canted 15 degrees to the line of sight so that the white band on the circuit breakers can be seen when they open.

Panel 12 is at the right of the LM Pilot's station. The panel is canted up 15 degrees from the horizontal; it contains audio, communications, and communications antennas controls and displays.

Panel 14, directly above panel 12, is canted up 36.5 degrees from the horizontal. It contains controls and displays for electrical power distribution and monitoring.

Panel 16, directly above panel 14, has four angled surfaces that contain circuit breakers. Each row of circuit breakers is canted 15 degrees to the line of sight so that the white band on the circuit breakers can be seen when they open.

The orbital rate display - earth and lunar (ORDEAL) panel is immediately aft of the panel 8. It contains the controls for obtaining LM attitude, with respect to a local horizontal, from the LGC.

Windows: Two triangular windows in the front face assembly provide visibility during descent, ascent, and rendezvous and docking phases of the mission. Both windows have approximately 2 square feet of viewing area; they are canted down to the side to permit adequate peripheral and downward visibility. A third (docking) window is in the curved overhead portion of the crew compartment shell, directly above the Commander's flight station. This window provides visibility for docking maneuvers. All three windows consist of two separated panes, vented to space environment. The outer pane is made of Vycor glass with a thermal (multilayer blue-red) coating on the outboard surface and an antireflective coating on the inboard surface. The inner pane is made of structural glass. It is sealed with a Raco seal (the docking window inner pane has a dual seal) and has a defog coating on the outboard surface and an antireflective coating on the inboard surface. Both panes are bolted to the window frame through retainers.

All three windows are electrically heated to prevent fogging. The heaters for the Commander's front window and the docking window receive their power from 115-volt ac bus A and the Commander's 28-volt dc bus, respectively. The heater for the LM Pilot's front window receives power from 115-volt ac bus B. The heater power for the Commander's front window and the docking window is routed through the AC BUS A: CDR WIND HTR and HEATERS: DOCK WINDOW circuit breakers, respectively; for the LM Pilot's front window, through the AC BUS B: SE WIND HTR circuit breaker. These are 2-ampere circuit breakers on panel 11. The temperature of the windows is not monitored with an indicator; proper heater operation directly affects crew visibility and is, therefore, visually determined by the astronauts. When condensation or frost appears on a window, that window heater is turned on. It is turned off when the abnormal condition disappears. When a window shade is closed, that window heater must be off.

Midsection.- The midsection structure (fig. A3-4) is a ring-stiffened semimonocoque shell. The bulkheads consist of aluminum-alloy, chemically milled skin with fusion-welded longerons and machined stiffeners. The midsection shell is mechanically fastened to flanges on the major structural bulkheads at stations +Z27.00 and -Z27.00. The crew compartment shell is mechanically secured to an outboard flange of the +Z27.00 bulkhead. The upper and lower decks, at stations +X294.643 and +X233.500, respectively, are made of aluminum-alloy, integrally stiffened and machined. The lower deck provides structural support for the ascent stage engine. The upper deck provides structural support for the docking tunnel and the overhead hatch.

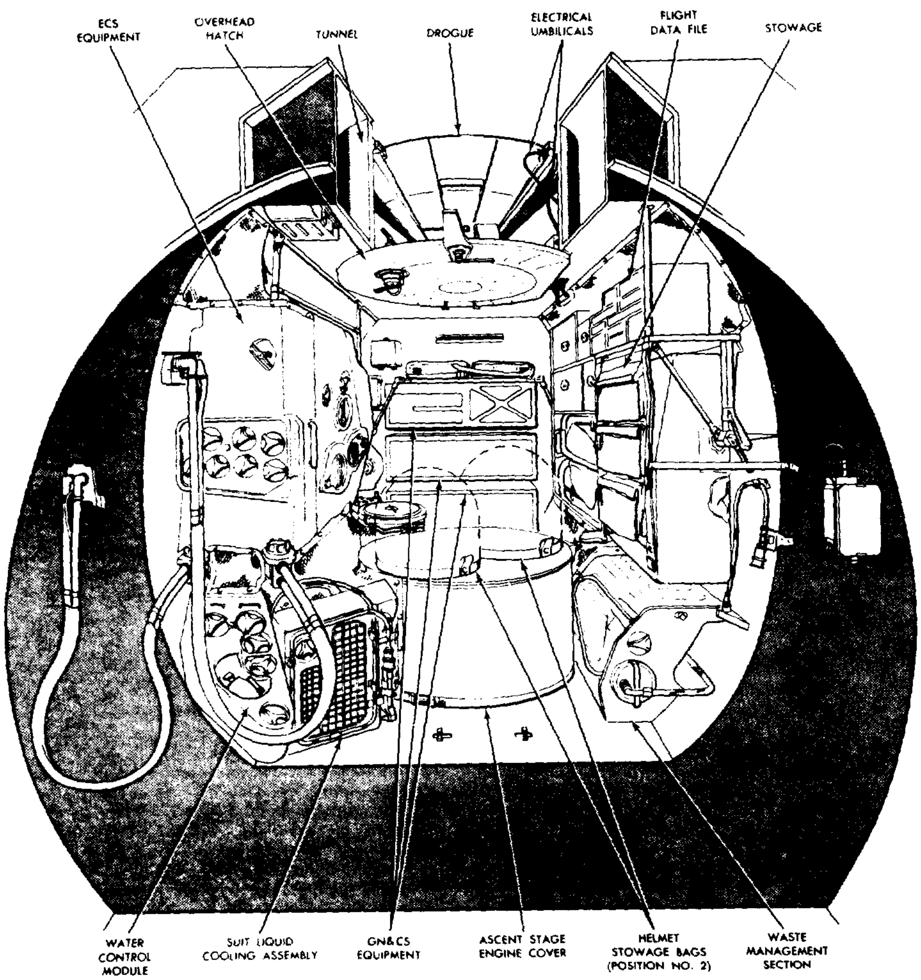

Figure A3-4.- Cabin interior (looking aft).

Two main beams running fore and aft, integral with those above the crew compartment, are secured to the upper deck of the midsection; they support the deck at the outboard end of the docking tunnel. The aft ends of the beams are fastened to the aft bulkhead (-Z27.000), which has provisions for bolting the tubular truss members that support both aft interstage fittings. Ascent stage stress loads applied to the front beam are transmitted through the two beams on the upper deck to the aft bulkhead.

Descent Stage

The descent stage is the unmanned portion of the LM. It contains the descent engine propellant system, auxiliary equipment for the astronauts, and scientific experiment packages to be placed on the lunar surface. The descent stage structure provides attachment and support points for securing the LM within the spacecraft-lunar module adapter (SLA).

LM - SLA - S-IVB Connections

At earth launch, the LM is within the SLA, which is connected to the S-IVB booster. The SLA has an upper section and a lower section. The outriggers, to which the landing gear is attached, provide attachment points for securing the LM to the SLA lower section. The LM is mounted to the SLA support structure on adjustable spherical seats at the apex of each of the four outriggers; it is held in place by a tension holddown strap at each mounting point. Before the LM is removed, the upper section of the SLA is explosively separated into four segments. These segments, which are hinged to the lower section, fold back and are then forced away from the SLA by spring thrusters. The LM is then explosively released from the lower section.

LM-CSM Interfaces

A ring at the top of the ascent stage provides a structural interface for joining the LM to the CSM. The ring, which is compatible with the clamping mechanisms in the CM, provides structural continuity. The drogue portion of the docking mechanism is secured below this ring. The drogue is required during docking operations to mate with the CM-mounted probe. See figure A3-5 for orientation of the LM to the CSM.

Crew transfer tunnel.- The crew transfer tunnel (LM-CM interlock area) is the passageway created between the LM overhead hatch and the CM forward pressure hatch when the LM and the CSM are docked. The