Communications System

The Communications System (CS) provides the links between the LM and the Manned Space Flight Network (MSFN), between the LM and the CSM, and between the LM and any extravehicular astronaut. The following information is handled by the Communications System: Tracking and ranging; voice; PCM telemetry (LM status); biomedical data; computer updates; morse code; television; EVA/LM EMU data; and LM/CSM telemetry retransmission. The communications links and their functions are listed in Figure 23. The CS includes all S-band, VHF, and signal processing equipment necessary to transmit and receive voice, tracking, and ranging data, and to transmit telemetry and emergency keying.

LM COMMUNICATIONS LINKS

Link	Mode	Band	Purpose
MSFN-LM-MSFN	Pseudorandom noise	S-band	Ranging and tracking
LM-MSFN	Voice	S-band, VHF (optional)	In flight 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)	Record and retransmit to earth
MSFN-LM	Voice	S-band, VHF (optional)	In-flight communications
MSFN-LM	Uplink data or uplink voice backup	S-band	Update LGC or voice backup for in-flight communications
LM-MSFN	Biomed-PCM telemetry	S-band	In-flight communications
LM-MSFN-CSM	Voice	S-band or VHF	Conference (with earth as relay)
LM-EVA-LM	Voice and data	VHF duplex	EVA direct communication
EVA-LM-MSFN	Voice and data	VHF, S-band	Conference (with LM as relay)
EVA-LM-CSM	Voice and data	VHF duplex	Conference (with LM as relay)
CSM-MSFN-LM-EVA	Voice and data	S-band, VHF	Conference (via MSFN-LM relay)

Fig. 23

The CS antenna equipment consists of: two S-band in-flight antennas; an S-band steerable antenna; two VHF in-flight antennas and di-plexer, and RF selector switches for S-band and VHF. The "line of sight" range of the VHF transmitter is limited to 740 nautical miles. The LM S-band capability covers earth-lunar distances.

Explosive Devices System

The Explosive Devices System (EDS) uses explosives to activate or enable various LM equipment. The system deploys the landing gear, enables pressurization of the descent, ascent, and RCS propellant tanks, venting of descent propellant tanks, and separation of the Ascent and Descent Stages. There are two separate systems in the EDS. The systems are parallel and provide completely redundant circuitry. Each system has a 37.1-volt (no load) battery, relays, time delay circuits, fuse resistors, buses and explosive cartridges.

Two separate cartridges are provided for each EDS function. Each cartridge is sufficient to perform the function without the other. The EDS supports the main propulsion systems by clearing the valves isolating pressurants and propellants. Other pyrotechnic devices guillotine interstage umbilicals in addition to the structural connections. System performance is indicated to the crew by instrumentation and to the MSFN by telemetry. The two EDS batteries use silver-zinc plates and are rated at .75 ampere-hour. Battery output/voltage status is displayed to the crew. One battery is located in the Descent Stage and one is in the Ascent Stage.

Instrumentation System

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

The IS consists of system sensors, a Signal Conditioning Electronics Assembly (SCEA), Pulse-Code-Modulation and Timing Electronics Assembly (PCMTEA), Caution and Warning Electronics Assembly (CWEA), and a Data Storage Electronics Assembly (DSEA). The CWEA provides the astronauts and MSFN with a continuous rapid check of data supplied by the SCEA for malfunction detection. The CWEA provides signals that light caution lights, warning lights, component caution lights, and "Master-Alarm" pushbutton lights.

Lighting

Interior lighting is designed to enhance crew performance by reducing crew fatigue in an environment of interior-exterior glare effects. Exterior lighting includes a radioluminescent docking target, five docking lights, and a high intensity tracking light. The five docking lights are automatically turned on prior to the first CSM docking and are turned off after docking. They indicate gross relative attitude of the vehicle and are color discernable to a distance of 1000 feet. The flashing, high-intensity, tracking light on the LM facilitates CSM tracking of the LM. It has a beam spread of 60 degrees and flashes 60 times per minute.

Crew Provisions

Apparel

The combination of items a crewman wears varies during a mission (Figure 24). There are three basic configurations of dress: unsuited, suited, and extravehicular. A brief description of each item is contained in the latter part of this section.

Unsuited

This mode of dress is worn by crewmen in the CSM under conditions termed "shirt-sleeve environment." The crewman wears a biomedical harness, a Communications Carrier, a Constant Wear Garment, Flight Coveralls, and Booties. This unsuited mode is the most comfortable, convenient, and consequently, the least fatiguing of the modes. When unsuited, the astronaut relies upon the CSM ECS to maintain the proper cabin environment of pressure, temperature, and oxygen.

Suited

This mode enables a crewman to operate in an unpressurized cabin up to the design life of the pressure suit of 115 hours. The intravehicular configuration includes: The Pressure Garment Assembly (PGA) made up of a Torso-Limb Suit, Pressure Helmet, and Pressure Gloves; the Fecal Containment System; Constant Wear Garment; Biomedical Belt; Communications Carrier; Urine Collection and Transfer Assembly, and a PGA integrated with a thermal-micrometeoroid garment.

The Command Module Pilot does not participate in any extravehicular activity, permitting substitution of a lighter, fire-resistant covering over the PGA in lieu of the thermal-micrometeoroid garment. Various suit fittings and hardware required for LM and EVA operations are also omitted from the Command Module Pilot's suit.

APOLLO APPAREL

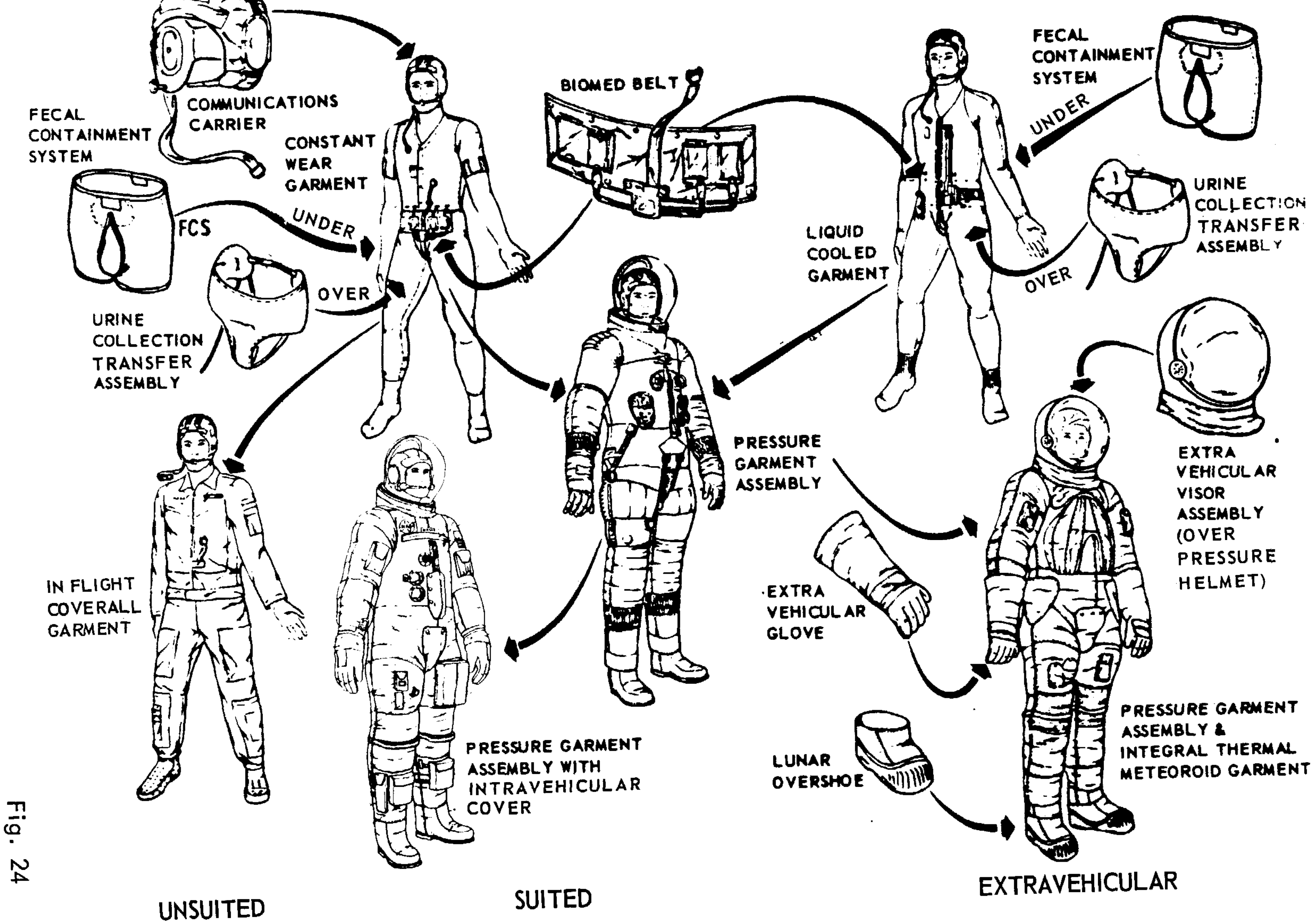


Fig. 24

Extravehicular

In the extravehicular configuration, the Constant Wear Garment is replaced by a Liquid Cooling Garment and four items are added to the Pressure Garment Assembly: Extravehicular Visor Assembly, Extravehicular Gloves, Lunar Overshoes, and a connector cover which fits over umbilical connections on the front of the suit. The addition of the Portable Life Support System (PLSS) and Oxygen Purge System back-pack completes the configuration termed the Extravehicular Mobility Unit (EMU). The EMU protects the astronaut from radiation, micrometeorite impact, and lunar surface temperatures ranging from +250°F to -250°F.

Item Description

Torso Limb Suit Assembly - The Torso Limb Suit is the basic pressure envelope for the astronaut. It contains connectors for oxygen, water (for the Liquid Cooling Garment), communication, biomedical data, and urine transfer.

Pressure Helmet - The Pressure Helmet is basically a polycarbonate plastic shell. It contains a vent manifold and an air-tight feed port for eating, drinking, and purging. The astronaut can turn his head within the fixed helmet.

Pressure Glove - The Pressure Glove is basically made of nylon tricot dipped in Neoprene. A fingerless glove, inner and outer covers, and a restraint system complete the assembly. The Extravehicular Glove is a modified pressure glove with additional layers of thermal and protective material added.

Integrated Thermal Meteoroid Garment - This garment is sewn over the Torso Limb Suit. Construction utilizes multi-layered combinations of Beta cloth, aluminized Kapton film, Beta Marquisette, Neoprene-coated nylon Ripstop, and Chromel-R. Snap-secured covers are located for inner access to some PGA areas and pockets are provided for specified items. LM restraint rings are integrated into the hip area. Boots are attached over the PGA with slide fasteners and loop tape.

Lunar Overshoe - The overshoe is worn over the PGA thermal, meteoroid covered boot. The Lunar Overshoe meets the extensive, additional, thermal and protective requirement for a lunar excursion. Materials used in its construction are: teflon-coated Beta cloth, Kapton film Beta Marquisette, Beta felt, silicon rubber and Chromel-R.

Extravehicular Visor - The Extravehicular Visor consists of two pivoted polycarbonate visors mounted on a polycarbonate shell. The visors furnish protection against micrometeoroids, solar heat and radiation, and protection of the PGA helmet. The outer visor features a vacuum-deposited gold film.

Liquid Cooling Garment - The Liquid Cooling Garment consists of a network of Tygon tubing interwoven in nylon Spandex material. Water from the PLSS circulates through the tubing to maintain the desired suit temperature. An inner liner is fabricated from nylon chiffon. The integral socks do not contain cooling tubes.

Constant Wear Garment - The Constant Wear Garment is an undergarment for the flight coveralls and the non-EVA spacesuit configuration. It is fabricated in one piece, encloses the feet, has short sleeves, a waist to neck zipper, and lower torso openings front and rear.

Flight Coverall - The flight coverall is the outer garment for unsuited operation. It is of two-piece, Beta cloth construction with zipper and pockets.

Booties - Booties worn with the flight coveralls are made of Beta cloth, with Velcro hook material bonded to the soles. During weightlessness, the Velcro hook engages Velcro pile patches attached to the floor to hold the crewman in place.

Communications Carrier and Biomedical Harness - The Communications Carrier is a polyurethane foam headpiece which positions two independent earphones and microphones. The Biomedical Harness carries signal conditioners and converters to transmit heart beat and respiration rates of the astronauts. The wiring of the Biomedical Harness and Communications Carrier connect to a common electrical connector which interfaces with the PGA or an adapter when unsuited.

Urine Collection and Transfer Assembly - The Urine Collection and Transfer Assembly is a truss-like garment which functions by use of a urinal cuff, storage compartment, and tube which connects to the external collection system. It is worn over the Constant Wear Garment or Liquid Cooling Garment.

Fecal Containment System - The Fecal Containment System (FCS) is an elastic underwear with an absorbent liner around the buttock area. This system is worn under the LCG or CWG to allow emergency defecation when the PGA is pressurized. Protective ointment is used on the buttocks and perineal area to lessen skin irritation.

Portable Life Support System

The Portable Life Support System (PLSS) is a portable, self-powered, rechargeable environmental control system with a communications capability. It is carried as a backpack in the extravehicular suited mode. It weighs about 68 pounds. The PLSS supplies pressurized oxygen to the PGA, cleans and cools the suit atmosphere, cools and circulates water through the Liquid Cooling Garment, and provides RF communications with a dual VHF transceiver. The PLSS can operate for up to four hours in a space environment before replenishment of water and oxygen is required. The 17-volt PLSS battery can supply 280 watt-hours of electrical power to meet a nominal usage rate of 50 watts per hour.

Oxygen Purge System

A detachable, non-rechargeable oxygen purge system attaches to the top of the PLSS. The system can supply 30 minutes of regulated flow to the PGA independent of the PLSS for contingency operations. The Oxygen Purge System may be removed from the PLSS and used as an emergency source of oxygen at any time. The Oxygen Purge System also serves as a mount for the PLSS antenna.

Food and Water

Food supplies in the LM and CSM are designed to supply each astronaut with a balanced diet of approximately 2800 calories per day. The food is either freeze-dried or concentrated and is carried in vacuum-packaged plastic bags. Each bag of freeze-dried food has a one-way valve through which water is inserted and a second valve through which food passes. Concentrated food is packaged in bite-size units and needs no reconstitution. Several bags are packaged together to make one meal bag. The meal bags have red, white, and blue dots to identify them for each crewman, as well as labels to identify them by day and meal.

The food is reconstituted by adding hot or cold water through the one-way valve. The astronaut kneads the bag and then cuts the neck of the bag and squeezes the food into his mouth. A "Feed Port" in the Pressure Helmet allows partaking of liquid food and water while suited. Food preparation water is dispensed from a unit which supplies 150°F and 50°F water in the CSM and 90°F and 50°F water in the LM.

Drinking water comes from the water chiller to two outlets: the water meter dispenser, and the food preparation unit. The dispenser has an aluminum mounting bracket, a 72-inch coiled hose, and a dispensing valve unit in the form of a button-actuated pistol. The pistol barrel is placed in the mouth and the button is pushed for each half-ounce of water. The meter records the amount of water drunk. A valve is provided to shut off the system in case the dispenser develops a leak or malfunction.

Couches and Restraints

Command/Service Module

The astronaut couches are individually adjustable units made of hollow steel tubing and covered with a heavy, fireproof, fiberglass cloth. The couches rest on a head beam and two side-stabilizer beams supported by eight attenuator strust (two each for the Y and Z axes and four for the X axis) which absorb the impact of landing. These couches support the crewmen during acceleration and deceleration, position the crewmen at their duty stations, and provide support for translation and rotation hand controls, lights, and other equipment.

The couches can be folded or adjusted into a number of seat positions. The one used most is the 85-degree position assumed for launch, orbit entry, and landing. The 170-degree (flat-out) position is used primarily for the center couch, so that crewmen can move into the lower equipment bay. The armrests on either side of the center couch can be folded footward so the astronauts from the two outside couches can slide over easily. The hip pan of the center couch can be disconnected and the couch can be pivoted around the head beam and laid on the aft bulkhead floor of the CM. This provides both room for the astronauts to stand and easier access to the side hatch for extravehicular activity.

Two armrests are attached to the back pan of the left couch and two armrests are attached to the right couch. The center couch has no armrests. The translation and rotation controls can be mounted to any of the four armrests. A support at the end of each armrest rotates 100 degrees to provide proper tilt for the controls. The couch seat pan and leg pan are formed of framing and cloth, and the foot pan is all steel. The foot pan contains a restraint device which holds the foot in place.

The couch restraint harness consists of a lap belt and two shoulder straps which connect to the lap belt at the buckle. The shoulder straps connect to the shoulder beam of the couch. Other restraints in the CM include handholds, a hand bar, hand straps, and patches of Velcro which hold the crewmen when they wear booties.

The astronauts may sleep in bags under the left and right couches with heads toward the hatch or in their couches. The two sleeping bags are made of lightweight Beta fabric 64 inches long, with zipper openings for the torso and a 7-inch diameter opening for the neck. They are supported by two longitudinal straps that attach to storage boxes in the lower equipment bay and to the CM inner structure. The astronauts sleep in the bags when unsuited and restrained on top of the bags when suited.

Lunar Module

The crew support and restraint equipment in the LM includes armrests, hand holds, Velcro on the floor to interface with the PGA Boots, and a restraint assembly operated by a rope-and-pully arrangement that holds the LM crewmen in a standing position. The restraint assembly attaches to "D" rings located at the hips of the astronaut's suit and holds him to the cabin floor with a force of about 30 pounds (Figure 25). The armrests restrain the crewmen laterally. LM crew members rest positions are shown in Figure 26.

LM CREWMAN AT FLIGHT STATION

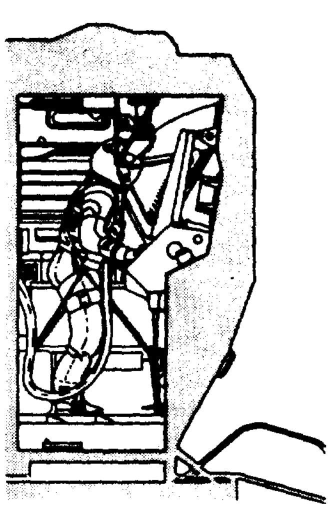


Fig. 25

LM CREWMEN REST POSITIONS

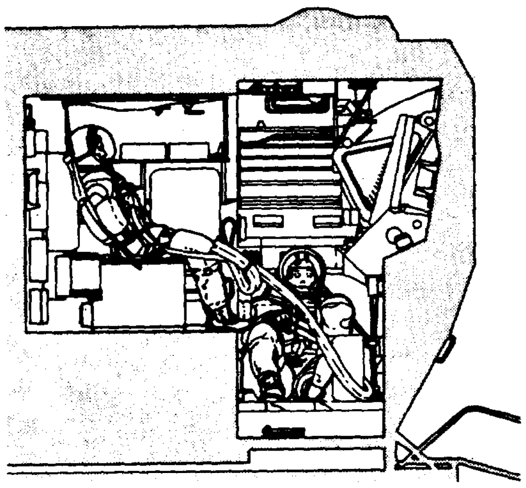


Fig. 26

Hygiene Equipment

Hygiene equipment includes wet and dry cloths for cleaning, towels, a toothbrush, and the waste management system. The waste management system controls and disposes of waste solids, liquids, and gases. The major portion of the system is in the right-hand equipment bay. The system stores feces, removes odors, dumps urine overboard, and removes urine from the space suit. Waste management in the LM differs in that urine is stored and not dumped overboard.

Operational Aids

Operational aids include data files, tools, workshelf, cameras, fire extinguishers, oxygen masks, medical supplies, and waste bags. The CM has one fire extinguisher, located adjacent to the left-hand and lower equipment bays. The extinguisher weighs about eight pounds. The extinguishing agent is an aqueous gel expelled in two cubic feet of foam for approximately 30 seconds at high pressure. Fire ports are located at various panels so that the extinguisher's nozzle can be inserted to put out a fire behind the panel.

Oxygen masks are provided for each astronaut in case of smoke, toxic gas, or other hostile atmosphere in the cabin while the astronauts are out of their suits in the CM. Oxygen is supplied through a flexible hose from the emergency oxygen/repressurization unit in the upper equipment bay.

Medical supplies are contained in an emergency medical kit, about 7 x 5 x 5 inches, which is stored in the lower equipment bay. It contains oral drugs and pills (pain capsules, stimulant, antibiotic, motion sickness, diarrhea, decongestant, and aspirin), injectable drugs (for pain and motion sickness), bandages, topical agents (first-aid cream, sun cream, and an antibiotic ointment), and eye drops.

Survival Equipment

Survival equipment, intended for use in an emergency after earth landing, is stowed in two rucksacks in the right-hand forward equipment bay. One of the rucksacks contains a three-man rubber life raft with an inflation assembly, a carbon-dioxide cylinder, a sea anchor, dye marker, and a sunbonnet for each crewman. The other rucksack contains a beacon transceiver, survival lights, desalter kits, a machete, sun glasses, water cans, and a medical kit. The survival medical kit contains the same type of supplies as the emergency medical kit: six bandages, six injectors, 30 tablets, and one tube of all-purpose ointment.

Miscellaneous Equipment

Each crewman is provided a toothbrush, wet and dry cleansing cloths, ingestible toothpaste, a 64-cubic inch container for personal items, and a two-compartment temporary storage bag. A special tool kit is provided which also contains three jack screws for contingency hatch closure.

LAUNCH COMPLEX

GENERAL

Launch Complex 39 (LC 39), located at Kennedy Space Center, Florida, is the facility provided for the assembly, checkout, and launch of the Apollo Saturn V Space Vehicle. Assembly and checkout of the vehicle is accomplished on a Mobile Launcher in the controlled environment of the Vehicle Assembly Building. The Space Vehicle and the Mobile Launcher are then moved as a unit by the Crawler-Transporter to the launch site. The major elements of the launch complex shown in Figure 27 are the Vehicle Assembly Building (VAB), the Launch Control Center (LCC), the Mobile Launcher (ML), the Crawler-Transporter (C/T), the crawlerway, the Mobile Service Structure (MSS), and the launch pad.

LC 39 FACILITIES AND EQUIPMENT

Vehicle Assembly Building

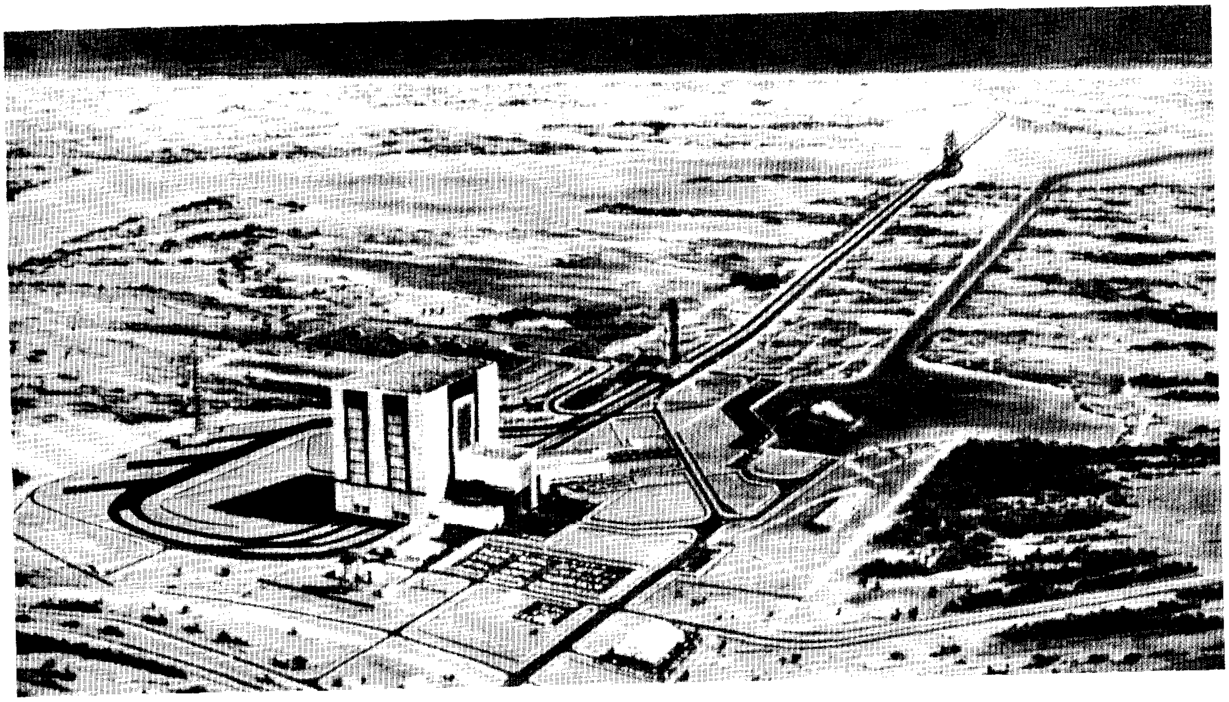
The VAB provides a protected environment for receipt and checkout of the propulsion stages and IU, erection of the vehicle stages and spacecraft in a vertical position on the ML, and integrated checkout of the assembled space vehicle. The VAB, as shown in Figure 28, is a totally-enclosed structure covering eight acres of ground. It is a structural steel building approximately 525 feet high, 518 feet wide, and 716 feet long. The principal operational elements of the VAB are the low bay and high bay areas. A 92-foot wide transfer aisle extends through the length of the VAB and divides the low and high bay areas into equal segments. The low bay area provides the facilities for receiving, uncrating, checkout, and preparation of the S-II stage, S-IVB stage, and the IU. The high bay area provides the facilities for erection and checkout of the S-IC stage; mating and erection operations of the S-II stage, S-IVB stage, IU, and Spacecraft; and integrated checkout of the assembled Space Vehicle. The high bay area contains four checkout bays, each capable of accommodating a fully-assembled Apollo Saturn V Space Vehicle.

Launch Control Center

The LCC, Figure 28, serves as the focal point for overall direction, control, and monitoring of space vehicle checkout and launch. The LCC is located adjacent to the VAB and at a sufficient distance from the launch pad (three miles) to permit the safe viewing of lift-off without requiring site hardening.

The LCC is a four-story structure. The ground floor is devoted to service and support functions. The second floor houses telemetry and tracking equipment, in addition to instrumentation and data reduction facilities. The third floor is divided into four separate but similar control areas, each containing a firing room, a computer room,

LAUNCH COMPLEX 39



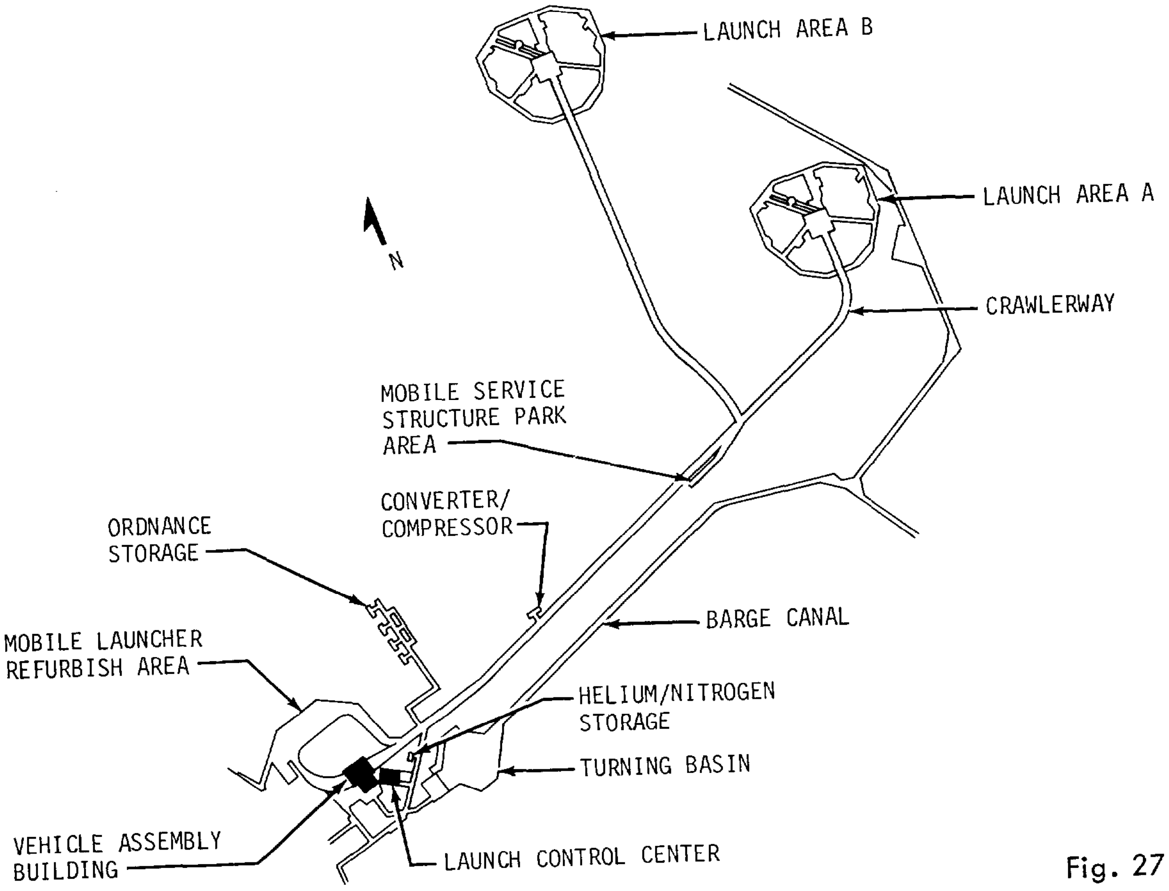
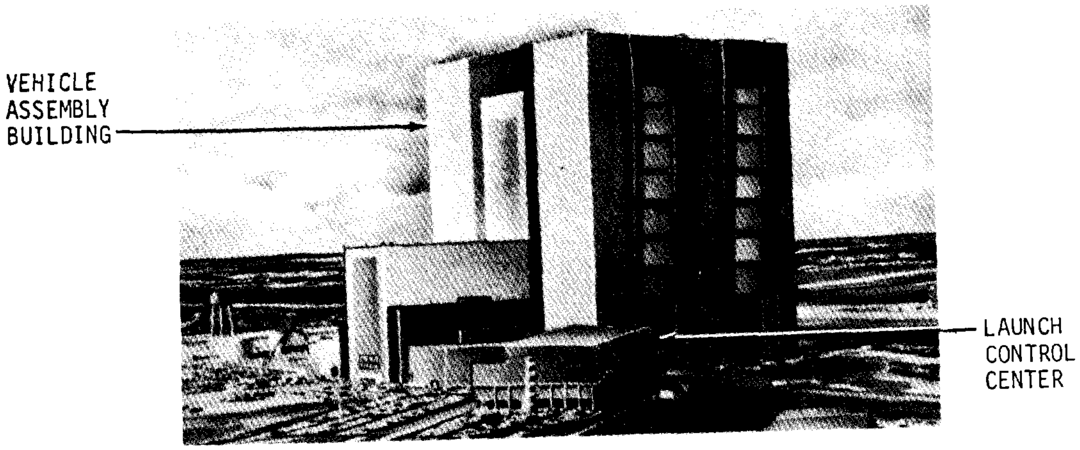


Fig. 27

VEHICLE ASSEMBLY BUILDING



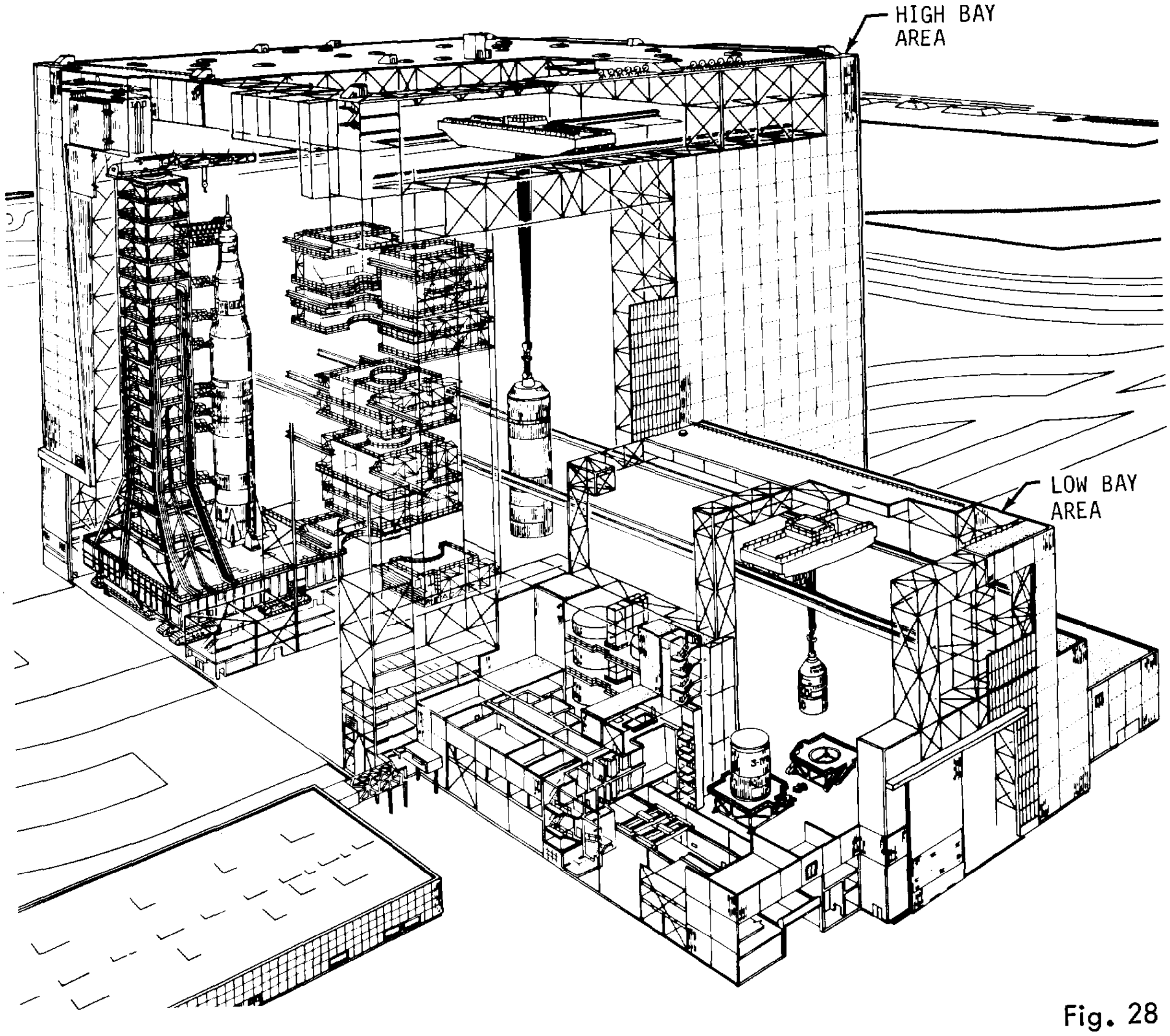


Fig. 28

a mission control room, a test conductor platform area, a visitor gallery, and offices. The four firing rooms, one for each high bay in the VAB, contain control, monitoring and display equipment for automatic vehicle checkout and launch. The display rooms, offices, Launch Information Exchange Facility (LIEF) rooms, and mechanical equipment are located on the fourth floor.

The power demands in this area are large and are supplied by two separate systems, industrial and instrumentation. This division between power systems is designed to protect the instrumentation power system from the adverse effects of switching transients, large cycling loads and intermittent motor starting loads. Communication and signal cable troughs extend from the LCC via the enclosed bridge to each ML location in the VAB high bay area. Cableways also connect to the ML refurbishing area and to the Pad Terminal Connection Room (PTCR) at the launch pad. Antennas on the roof provide an RF link to the launch pads and other facilities at KSC.

Mobile Launcher

The ML (Figure 29) is a transportable steel structure which, with the C/T, provides the capability to move the erected vehicle to the launch pad. The ML is divided into two functional areas, the launcher base and the umbilical tower. The launcher base is the platform on which a Saturn V vehicle is assembled in the vertical position, transported to a launch site, and launched. The umbilical tower provides access to all important levels of the vehicle during assembly, checkout, and servicing. The equipment used in the servicing, checkout, and launch is installed throughout both the base and tower sections of the ML.

The launcher base is a steel structure 25 feet high, 160 feet long, and 135 feet wide. The upper deck, designated level 0, contains, in addition to the umbilical tower, the four hold-down arms and the three tail service masts. There is a 45-foot square opening through the ML base for first stage exhaust.

The base has provisions for attachment to the C/T, six launcher-to-ground mount mechanisms, and four extensible support columns. All electrical/mechanical interfaces between vehicle systems and the VAB or the launch site are located through or adjacent to the base structure. The base houses such items as the computer systems test sets, digital propellant loading equipment, hydraulic test sets, propellant and pneumatic lines, air conditioning and ventilating systems, electrical power systems, and water systems. Fueling operations at the launch area require that the compartments within the structure be pressurized with a supply of uncontaminated air.

MOBILE LAUNCHER

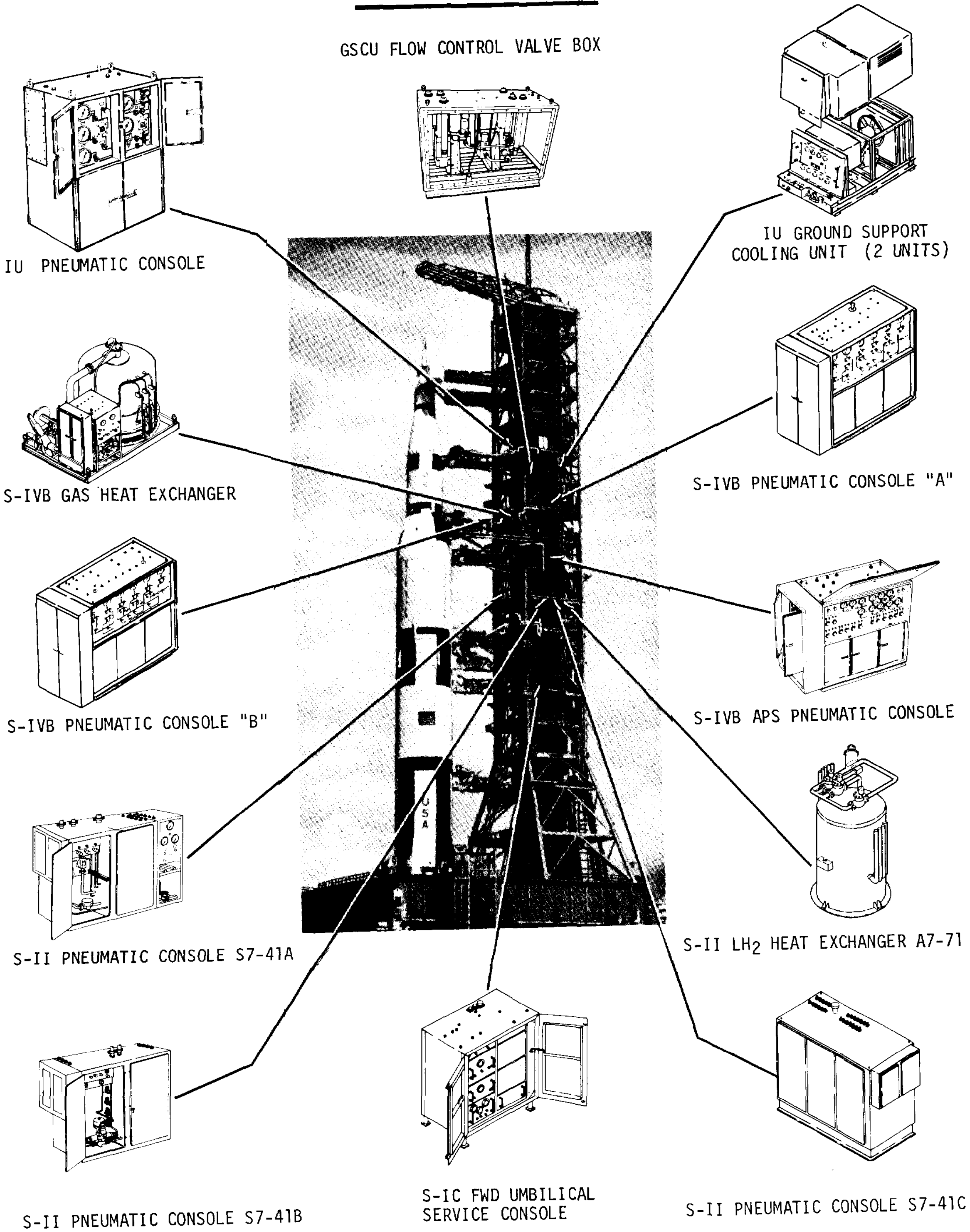


Fig. 29

The primary electrical power supplied to the ML is divided into four separate services: instrumentation, industrial, in-transit, and emergency. Emergency power is supplied by a diesel-driven generator located in the ground facilities. It is used for obstruction lights, emergency lighting, and for one tower elevator. Water is supplied to the ML for fire, industrial, and domestic purposes.

The umbilical tower is a 380-foot high open steel structure which provides the support for eight umbilical service arms, Apollo Spacecraft access arm, 18 work and access platforms, distribution equipment for the propellant, pneumatic, electrical, and instrumentation subsystems, and other ground support equipment. Two high-speed elevators service 18 landings from level A of the base to the 340-foot tower level. The structure is topped by a 25-ton hammerhead crane. Remote control of the crane is possible from numerous locations on the ML.

The four holddown arms (Figure 30) are mounted on the ML deck, 90 apart around the vehicle base. They position and hold the vehicle on the ML during the VAB checkout, movement to the pad, and pad checkout. The vehicle base is held with a pre-loaded force of 700,000 pounds at each arm. At engine ignition, the vehicle is restrained until proper engine thrust is achieved. The unlatching interval for the four arms should not exceed 0.050 second. If any of the separators fail to operate in 0.180 second, release is effected by detonating an explosive nut link. At launch, the holddown arms quickly release, but the vehicle is prevented from accelerating too rapidly by the controlled-release mechanisms (Figure 30). Each controlled-release mechanism basically consists of a tapered pin inserted in a die which is coupled to the vehicle. Upon vehicle release, the tapered pin is drawn through the die during the first six inches of vehicle travel. There are provisions for as many as 16 mechanisms per vehicle. The precise number is determined on a mission basis.

The three Tail Service Mast (TSM) assemblies (Figure 30) support service lines to the S-IC stage and provide a means for rapid retraction at vehicle lift-off. The TSM assemblies are located on level 0 of the ML base. Each TSM is a counterbalanced structure which is pneumatically/electrically controlled and hydraulically operated. Retraction of the umbilical carrier and vertical rotation of the mast is accomplished simultaneously to ensure no physical contact between the vehicle and mast. The carrier is protected by a hood which is closed by a separate hydraulic system after the mast rotates.

The nine service arms provide access to the space vehicle and support the service lines that are required to sustain the vehicle, as described in Figure 31. The service arms are designated as either pre-flight or in-flight arms. The pre-flight arms are retracted and locked against the umbilical tower prior to lift-off. The in-flight arms retract at vehicle lift-off. Carrier withdrawal and arm retraction is accomplished by pneumatic and/or hydraulic systems.

HOLDDOWN ARMS/TAIL SERVICE MAST

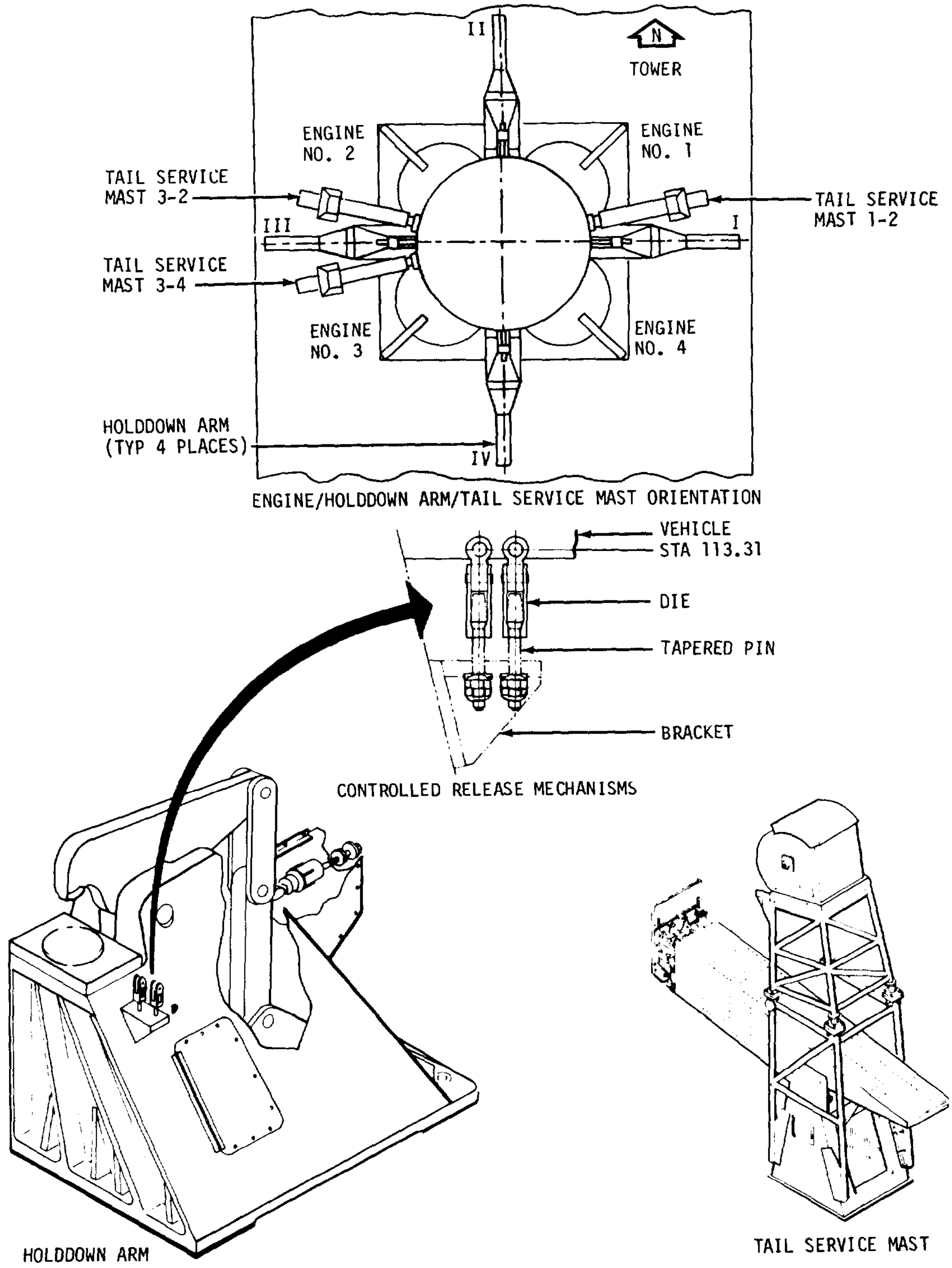


Fig. 30

MOBILE LAUNCHER SERVICE ARMS

1 S-IC Intertank (preflight). Provides lox fill and drain interfaces. Umbilical withdrawal by pneumatically driven compound parallel linkage device. Arm may be reconnected to vehicle from LCC. Retract time is 8 seconds. Reconnect time is approximately 5 minutes.

2 S-IC Forward (preflight). Provides pneumatic, electrical, and air-conditioning interfaces. Umbilical withdrawal by pneumatic disconnect in conjunction with pneumatically driven block and tackle/lanyard device. Secondary mechanical system. Retracted at T-20 seconds. Retract time is 8 seconds.

3 S-II Aft (preflight). Provides access to vehicle. Arm retracted prior to liftoff as required.

4 S-II Intermediate (inflight). Provides LH_2 and lox transfer, vent line, pneumatic, instrument cooling, electrical, and air-conditioning interfaces. Umbilical withdrawal systems same as S-IVB Forward with addition of a pneumatic cylinder actuated lanyard system. This system operates if primary withdrawal system fails. Retract time is 6.4 seconds (max).

5 S-II Forward (inflight). Provides GH_2 vent, electrical, and pneumatic interfaces. Umbilical withdrawal systems same as S-IVB Forward. Retract time is 7.4 seconds (max).

6 S-IVB Aft (inflight). Provides LH_2 and lox transfer, electrical, pneumatic, and air-conditioning interfaces. Umbilical withdrawal systems same as S-IVB Forward. Also equipped with line handling device. Retract time is 7.7 seconds (max).

7 S-IVB Forward (inflight). Provides fuel tank vent, electrical, pneumatic, air-conditioning, and preflight conditioning interfaces. Umbilical withdrawal by pneumatic disconnect in conjunction with pneumatic/hydraulic redundant dual cylinder system. Secondary mechanical system. Arm also equipped with line handling device to protect lines during withdrawal. Retract time is 8.4 seconds (max).

8 Service Module (inflight). Provides air-conditioning, vent line, coolant, electrical, and pneumatic interfaces. Umbilical withdrawal by pneumatic/mechanical lanyard system with secondary mechanical system. Retract time is 9.0 seconds (max).

9 Command Module Access Arm (preflight). Provides access to spacecraft through environmental chamber. Arm may be retracted or extended from LCC. Retracted 12° park position until T-4 minutes. Extend time is 12 seconds from this position.

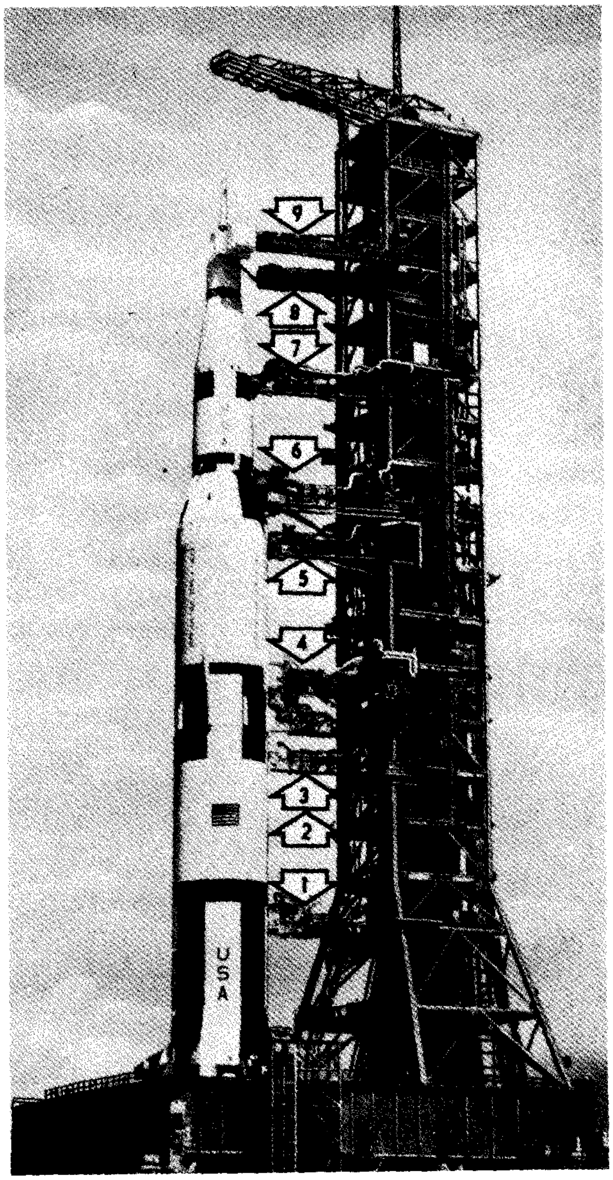


Fig. 31

Launch Pad

The launch pad (Figure 32) provides a stable foundation for the ML during Apollo Saturn V launch and pre-launch operations and an interface to the ML for ML and vehicle systems. There are presently two pads at LC 39 located approximately three miles from the VAB area. Each launch site is approximately 3000 feet across.

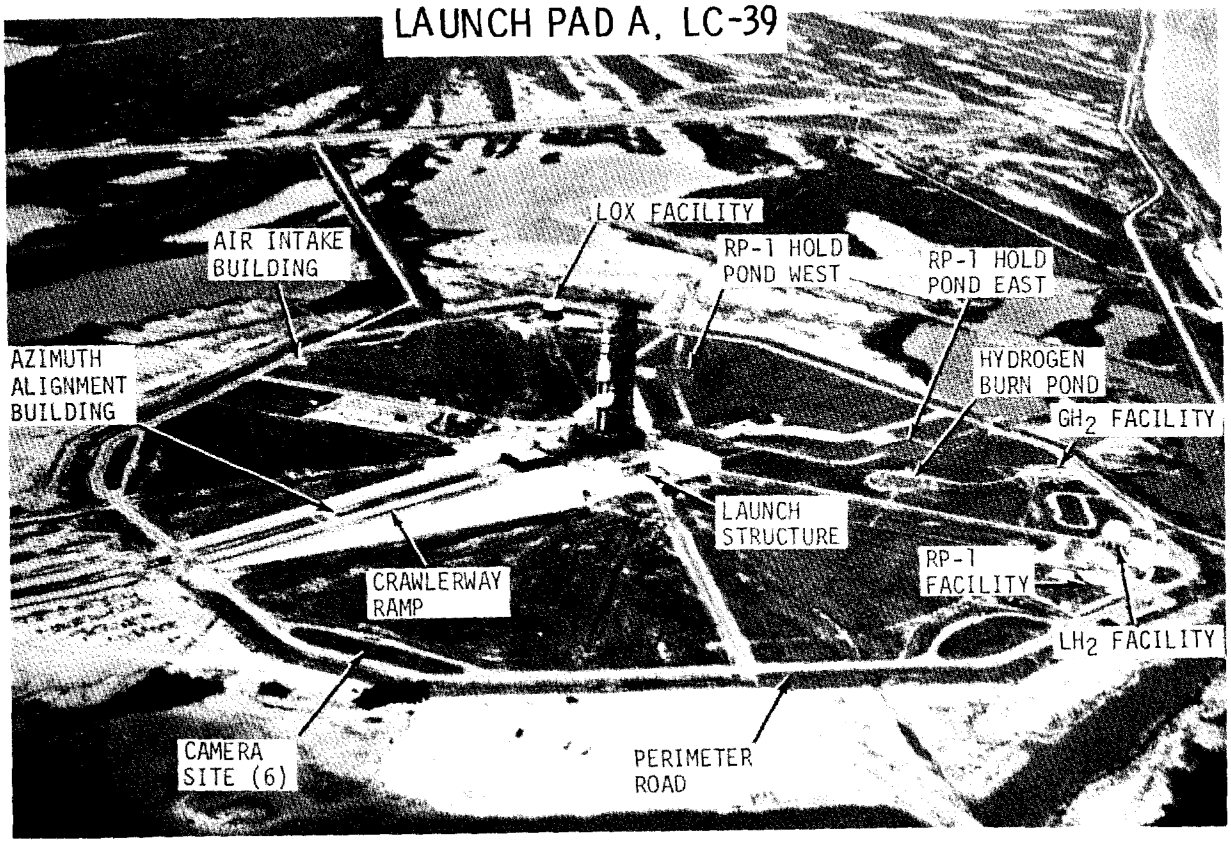


Fig. 32

The launch pad is a cellular, reinforced concrete structure with a top elevation of 42 feet above grade elevation. Located within the fill under the west side of the structure (Figure 33) is a two-story concrete building to house environmental control and pad terminal connection equipment. On the east side of the structure within the fill, is a one-story concrete building to house the high-pressure gas storage battery. On the pad surface are elevators, staircase, and interface structures to provide service to the ML and the MSS. A ramp with a five percent grade provides access from the crawlerway. This is used by the C/T to position the ML/Saturn V and the MSS on the support pedestals. The azimuth alignment building is located on the approach ramp in the crawlerway median strip. A flame trench 58 feet wide by 450 feet long bisects the pad. This trench opens to grade at the north end. The 700,000 pound, mobile, wedge-type flame deflector is mounted on rails in the trench.

LAUNCH STRUCTURE EXPLODED VIEW

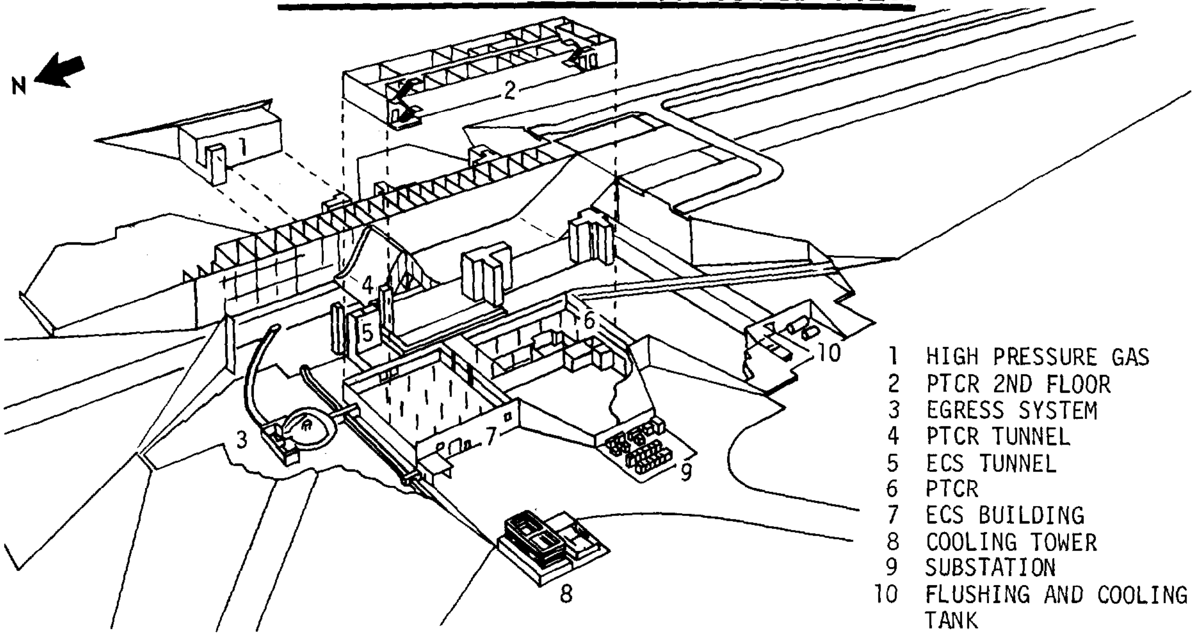


Fig. 33

The Pad Terminal Connection Room (PTCR) (Figure 33) provides the terminals for communication and data link transmission connections between the ML or MSS and the launch area facilities and between the ML or MSS and the LCC. This facility also accommodates the electronic equipment that simulates functions for checkout of the facilities during the absence of the launcher and vehicle.

The Environmental Control System (ECS) room, located in the pad fill west of the pad structure and north of the PTCR (Figure 33), houses the equipment which furnishes temperature and/or humidity-controlled air or nitrogen for space vehicle cooling at the pad. The ECS room is 96 feet wide by 112 feet long and houses air and nitrogen handling units, liquid chillers, air compressors, a 3000-gallon water-glycol storage tank, and other auxiliary electrical and mechanical equipment. The high-pressure gas storage facility at the pad provides the launch vehicle with high-pressure helium and nitrogen.

The launch pad interface system (Figure 34) provides mounting support pedestals for the ML and MSS, an engine access platform, and support structures for fueling, pneumatic, electric power, and environmental control interfaces.

LAUNCH PAD INTERFACE SYSTEM

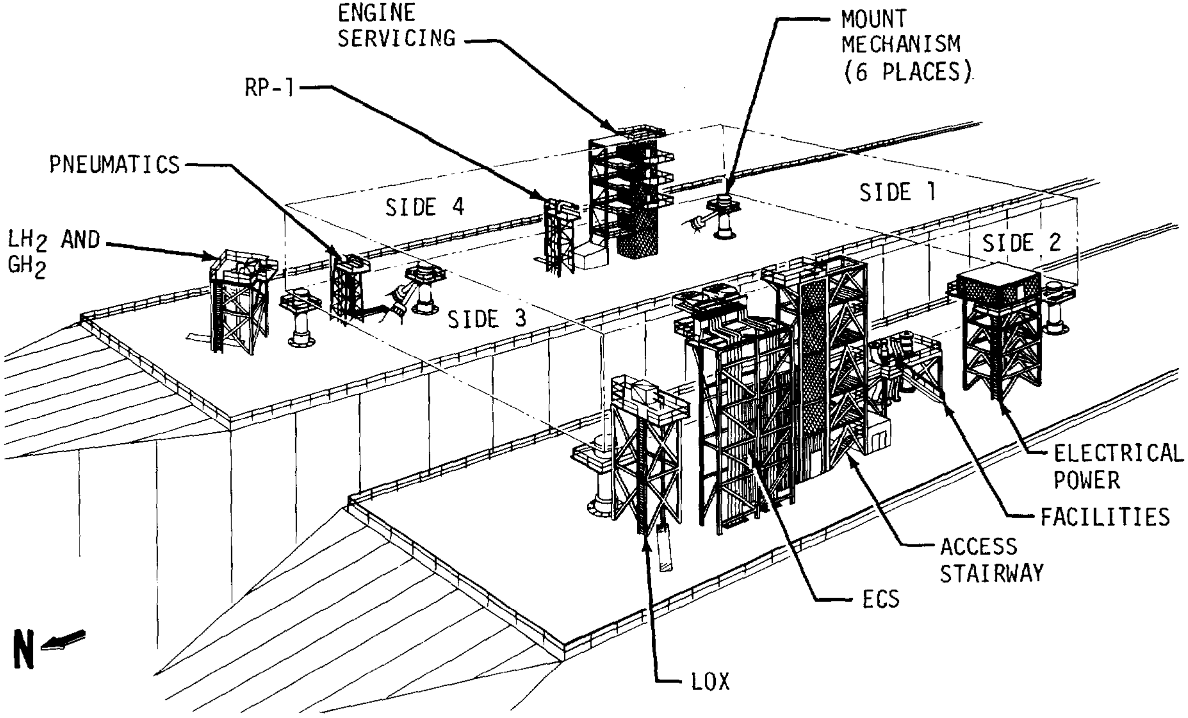


Fig. 34

Apollo Emergency Ingress/Egress and Escape System

The Apollo emergency ingress/egress and escape system provides access to and from the Command Module (CM) plus an escape route and safe quarters for the astronauts and service personnel in the event of a serious malfunction prior to launch. The system includes the CM Access Arm, two 600-feet per minute elevators from the 340-foot level to level A of the ML, pad elevator No. 2, personnel carriers located adjacent to the exit of pad elevator No. 2, the escape tube, and the blast room.

The CM Access Arm provides a passage for the astronauts and service personnel from the spacecraft to the 320-foot level of the tower. Egressing personnel take the high-speed elevators to level A of the ML, proceed through the elevator vestibule and corridor to pad elevator No. 2, move down this elevator to the bottom of the pad, and enter armored personnel carriers which remove them from the pad area.

When the state of the emergency allows no time for retreat by motor vehicle, egressing personnel, upon reaching level A of the ML, slide down the escape tube into the blast room vestibule, commonly called the "rubber room" (Figure 35). Entrance to the blast room is gained through blast-proof doors controllable from either side. The blast room floor is mounted on coil springs to reduce outside acceleration forces to between 3 and 5 g's. Twenty people may be accommodated for 24 hours. Communication facilities

ELEVATOR /TUBE EGRESS SYSTEM

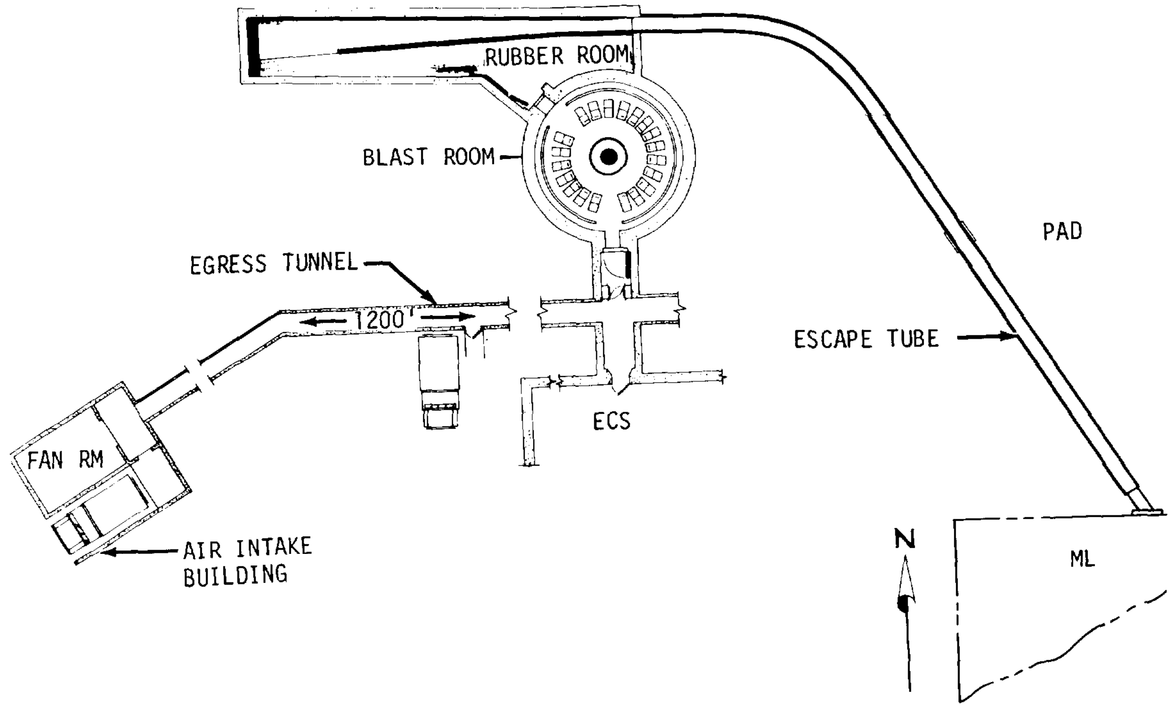


Fig. 35

are provided in the room, including an emergency RF link. An underground air duct from the vicinity of the blast room to the remote air intake facility permits egress from the pad structure to the pad perimeter. Provision is made to decrease air velocity in the duct to allow personnel movement through the duct.

An alternate emergency egress system (Figure 36) is referred to as the "Slide Wire." The system consists of a winch-tensioned cable extending from above the 320-foot level of the ML to a 30-foot tail tower on the ground approximately 2200 feet (horizontal projection) from the launcher. A nine-man, tubular-frame cab is suspended from the cable by two brake-equipped trolleys. The unmanned weight of the cab is 1200 pounds and it traverses the distance to the "landing area" in 40 seconds. The cab is decelerated by the increasing drag of a chain attached to a picked-up arresting cable. The occupants of the cab then take refuge in a bunker constructed adjacent to the landing area. The cable has a minimum breaking strength of 53.2 tons and is varied in tension between 18,000 and 32,000 pounds by the winch located beyond the tail tower. The lateral force exerted by the tensioned cable on the ML is negligible relative to the mass of the launcher and the rigidity of the ML tower precludes any effect on tolerances or reliability of tower mechanisms.

SLIDE WIRE/CAB EGRESS SYSTEM

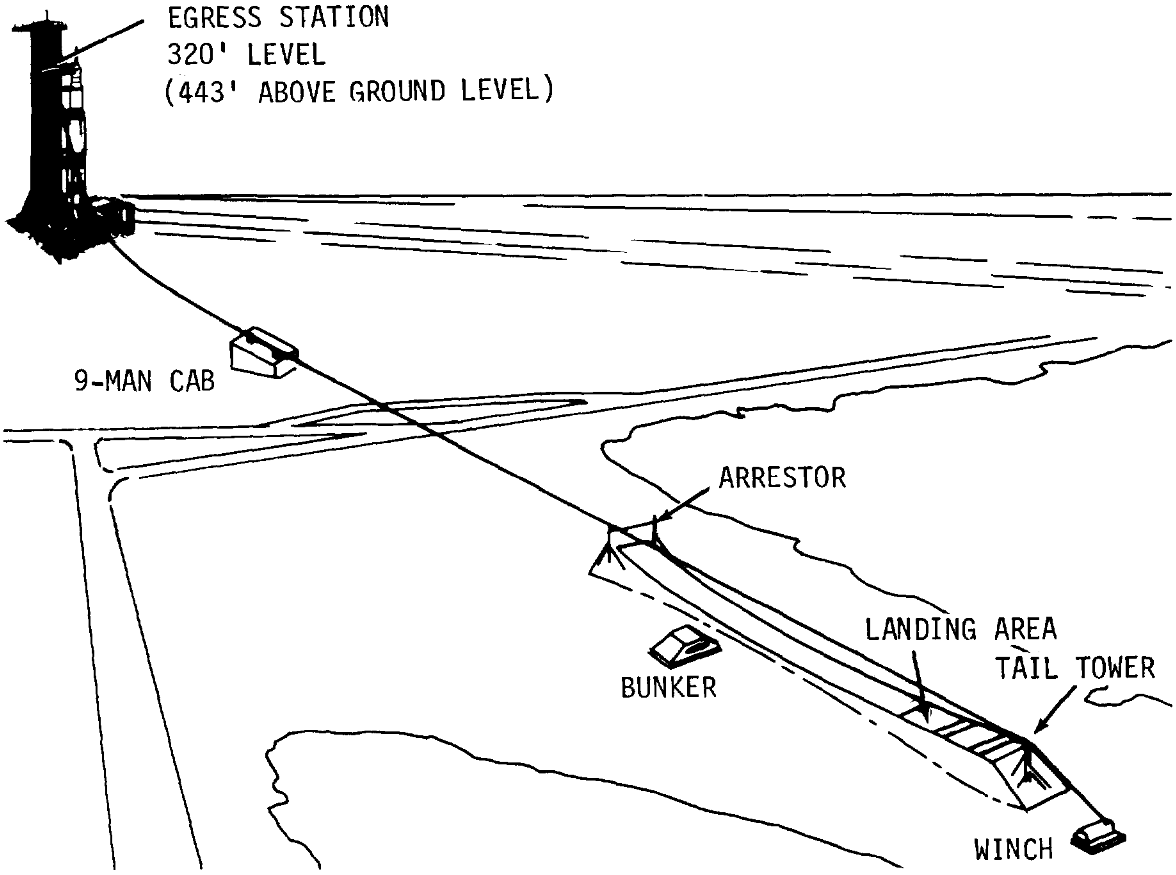


Fig. 36

Fuel System Facilities

The RP-1 facility consists of three 86,000-gallon steel storage tanks, a pump house, a circulating pump, a transfer pump, two filter-separators, an 8-inch stainless steel transfer line, RP-1 foam generating building, and necessary valves, piping, and controls. Two RP-1 holding ponds (Figure 32), 150 feet by 250 feet, with a water depth of two feet, are located north of the launch pad, one on each side of the north-south axis. The ponds retain spilled RP-1 and discharge water to drainage ditches.

The LH_2 facility (Figure 32) consists of one 850,000-gallon spherical storage tank, a vaporizer/heat exchanger which is used to pressurize the storage tank to 65 psi, a vacuum-jacketed, 10-inch invar transfer line and a burn pond venting system. Internal tank pressure provides the proper flow of LH_2 from the storage tank to the vehicle without using a transfer pump. Liquid hydrogen boil-off from the storage and ML areas is directed through vent-piping to bubble-capped headers submerged in the burn pond where a hot wire ignition system maintains the burning process.

LOX System Facility

The LOX facility (Figure 32) consists of one 900,000-gallon spherical storage tank, a LOX vaporizer to pressurize the storage tank, main fill and replenish pumps, a drain basin for venting and dumping of LOX, and two transfer lines.

Azimuth Alignment Building

The azimuth alignment building (Figure 32) houses the auto-collimator theodolite which senses, by a light source, the rotational output of the stable platform in the Instrument Unit of the launch vehicle. This instrument monitors the critical inertial reference system prior to launch.

Photography Facilities

These facilities support photographic camera and closed circuit television equipment to provide real-time viewing and photographic documentation coverage. There are six camera sites in the launch pad area. These sites cover pre-launch activities and launch operations from six different angles at a radial distance of approximately 1300 feet from the launch vehicle. Each site has four engineering, sequential cameras and one fixed, high-speed metric camera.

Pad Water System Facilities

The pad water system facilities furnish water to the launch pad area for fire protection, cooling, and quenching. Specifically, the system furnishes water for the industrial water system, flame deflector cooling and quench, ML deck cooling and quench, ML tower fogging and service arm quench, sewage treatment plant, Firex water system, liquid propellant facilities, ML and MSS fire protection, and all fire hydrants in the pad area.

Mobile Service Structure

The MSS (Figure 37) provides access to those portions of the space vehicle which cannot be serviced from the ML while at the launch pad. The MSS is transported to the launch site by the C/T where it is used during launch pad operations. It is removed from the pad a few hours prior to launch and returned to its parking area 7000 feet from the nearest launch pad. The MSS is approximately 402 feet high and weighs 12 million pounds. The tower structure rests on a base 135 feet by 135 feet. At the top, the tower is 87 feet by 113 feet.

The structure contains five work platforms which provide access to the space vehicle. The outboard sections of the platforms open to accept the vehicle and close around it to provide access to the launch vehicle and spacecraft. The lower two platforms are vertically adjustable to serve different parts of the launch vehicle. The upper three platforms are fixed but can be disconnected from the tower and relocated as a unit to serve different vehicle configurations. The second and third platforms from the top are enclosed and provide environmental control for the spacecraft.

The MSS is equipped with the following systems: air conditioning, electrical power, various communication networks, fire protection, compressed air, nitrogen pressurization, hydraulic pressure, potable water, and spacecraft fueling.

MOBILE SERVICE STRUCTURE

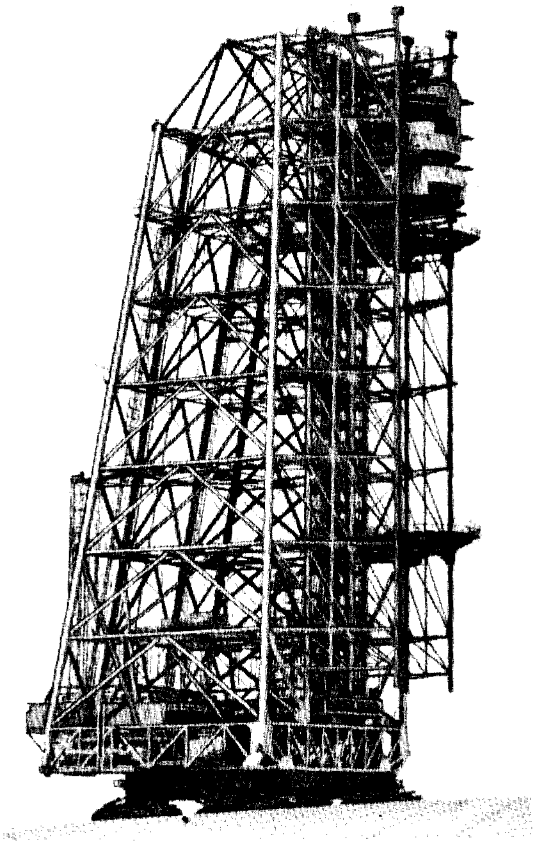


Fig. 37

Crawler-Transporter

The C/T (Figure 38) is used to transport the ML, including the space vehicle, and the MSS to and from the launch pad. The C/T is capable of lifting, transporting, and lowering the ML or the MSS, as required, without the aid of auxiliary equipment. The C/T supplies limited electric power to the ML and the MSS during transit.

The C/T consists of a rectangular chassis which is supported through a suspension system by four dual-tread, crawler-trucks. The overall length is 131 feet and the overall width is 114 feet. The unit weighs approximately six million pounds. The C/T is powered by self-contained, diesel-electric generator units. Electric motor-driven pumps provide hydraulic power for steering and suspension control. Air conditioning and ventilation are provided where required.

CRAWLER TRANSPORTER

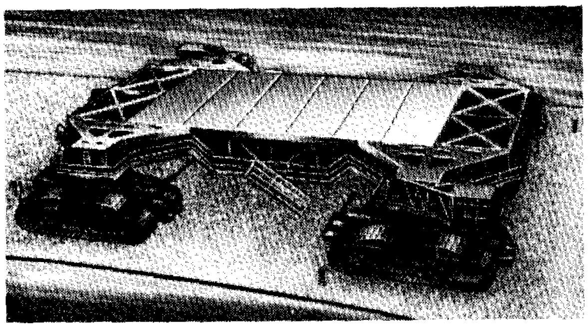


Fig. 38

The C/T can be operated with equal facility in either direction. Control cabs are located at each end. The leading cab, in the direction of travel, has complete control of the vehicle. The rear cab, however, has override controls for the rear trucks only. Maximum C/T speed is 2 mph unloaded, 1 mph with full load on level grade, and 0.5 mph with full load on a five percent grade. It has a 500-foot minimum turning radius and can position the ML or the MSS on the facility support pedestals within ±2 inches.

VEHICLE ASSEMBLY AND CHECKOUT

The Saturn V Launch Vehicle propulsive stages and the IU are, upon arrival at KSC, transported to the VAB by special carriers. The S-IC stage is erected on an ML in one of the checkout bays in the high bay area. The S-II and S-IVB stages and the IU are delivered to preparation and checkout cells in the low bay area for inspection, checkout, and pre-erection preparations. All components of the space vehicle, including the Apollo Spacecraft and Launch Escape System, are then assembled vertically on the ML in the high bay area. Following assembly, the space vehicle is connected to the LCC via a high-speed data link for integrated checkout and a simulated flight test. When checkout is completed, the C/T picks up the ML with the assembled space vehicle and moves it to the launch site via the crawlerway.

At the launch site, the ML is emplaced and connected to system interfaces for final vehicle checkout and launch monitoring. The MSS is transported from its parking area by the C/T and positioned on the side of the vehicle opposite the ML. A flame deflector is moved on its track to its position beneath the blast opening of the ML to deflect the blast from the S-IC stage engines. During the pre-launch checkout, the final system checks are completed, the MSS is removed to the parking area, propellants are loaded, various items of support equipment are removed from the ML, and the vehicle is readied for launch. After vehicle launch, the C/T transports the ML to the parking area near the VAB for refurbishment.

MISSION MONITORING, SUPPORT, AND CONTROL

GENERAL

Mission execution involves the following functions: pre-launch checkout and launch operations; tracking the space vehicle to determine its present and future positions; securing information on the status of the flight crew and space vehicle systems (via telemetry); evaluation of telemetry information; commanding the space vehicle by transmitting real-time and updata commands to the onboard computer; voice communication between flight and ground crews; and recovery operations.

These functions require the use of a facility to assemble and launch the space vehicle (see Launch Complex); a central flight control facility; a network of remote stations located strategically around the world; a method of rapidly transmitting and receiving information between the space vehicle and the central flight control facility; a real-time data display system in which the data is made available and presented in usable form at essentially the same time that the data event occurred; and ships/aircraft to recover the spacecraft on return to earth.

The flight crew and the following organizations and facilities participate in mission control operations:

1. Mission Control Center (MCC), Manned Spacecraft Center (MSC), Houston, Texas. The MCC contains the communication, computer, display, and command systems to enable the flight controllers to effectively monitor and control the space vehicle.

2. Kennedy Space Center (KSC), Cape Kennedy, Florida. The space vehicle is launched from KSC and controlled from the Launch Control Center (LCC), as described previously. Pre-launch, launch, and powered flight data are collected at the Central Instrumentation Facility (CIF) at KSC from the launch pads, CIF receivers, Merritt Island Launch Area (MILA), and the down-range Air Force Eastern Test Range (AFETR) stations. This data is transmitted to MCC via the Apollo Launch Data System (ALDS). Also located at KSC (ETR) is the Impact Predictor (IP), for range safety purposes.

3. Goddard Space Flight Center (GSFC), Greenbelt, Maryland. GSFC manages and operates the Manned Space Flight Network (MSFN) and the NASA communications (NASCOM) networks. During flight, the MSFN is under operational control of the MCC.

4. George C. Marshall Space Flight Center (MSFC), Huntsville, Alabama. MSFC, by means of the Launch Information Exchange Facility (LIEF) and the Huntsville Operations Support Center (HOSC) provides

launch vehicle systems real-time support to KSC and MCC for pre-flight, launch, and flight operations.

A block diagram of the basic flight control interfaces is shown in Figure 39.

BASIC TELEMETRY, COMMAND, AND COMMUNICATION INTERFACES FOR FLIGHT CONTROL

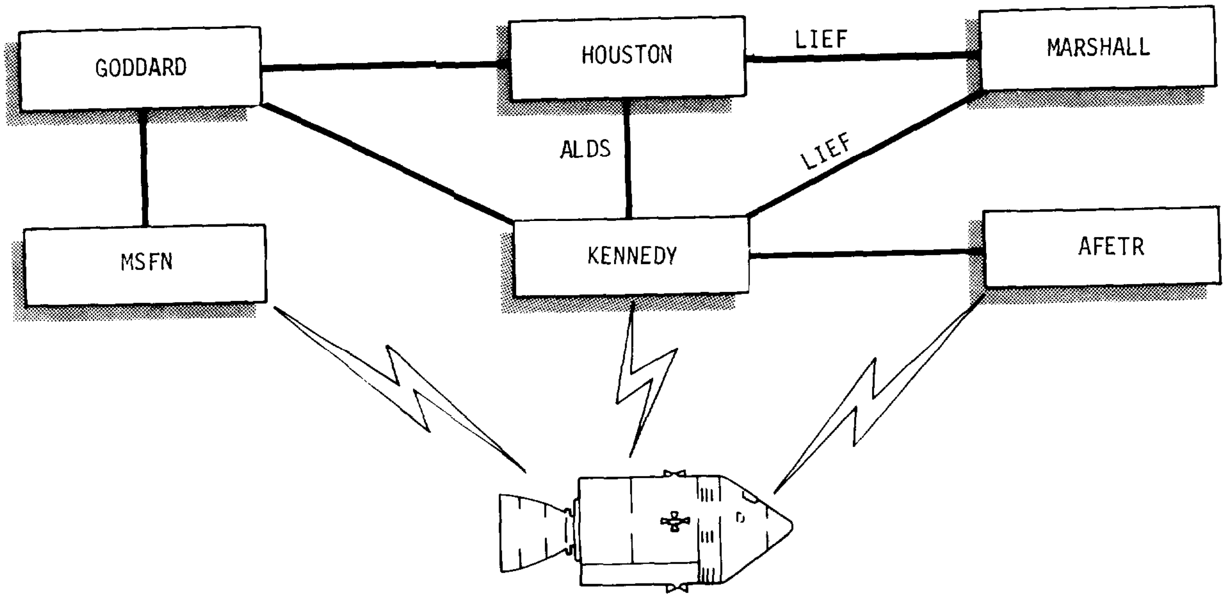


Fig. 39

VEHICLE FLIGHT CONTROL CAPABILITY

Flight operations are controlled from the MCC. The MCC has two flight control rooms. Each control room, called a Mission Operations Control Room (MOCR), is used independently of the other and is capable of controlling individual Staff Support Rooms (SSR's) located adjacent to the MOCR. The SSR's are manned by flight control specialists who provide detailed support to the MOCR. Figure 40 outlines the organization of the MCC for flight control and briefly describes key responsibilities. Information flow within the MOCR is shown in Figure 41.

MCC ORGANIZATION

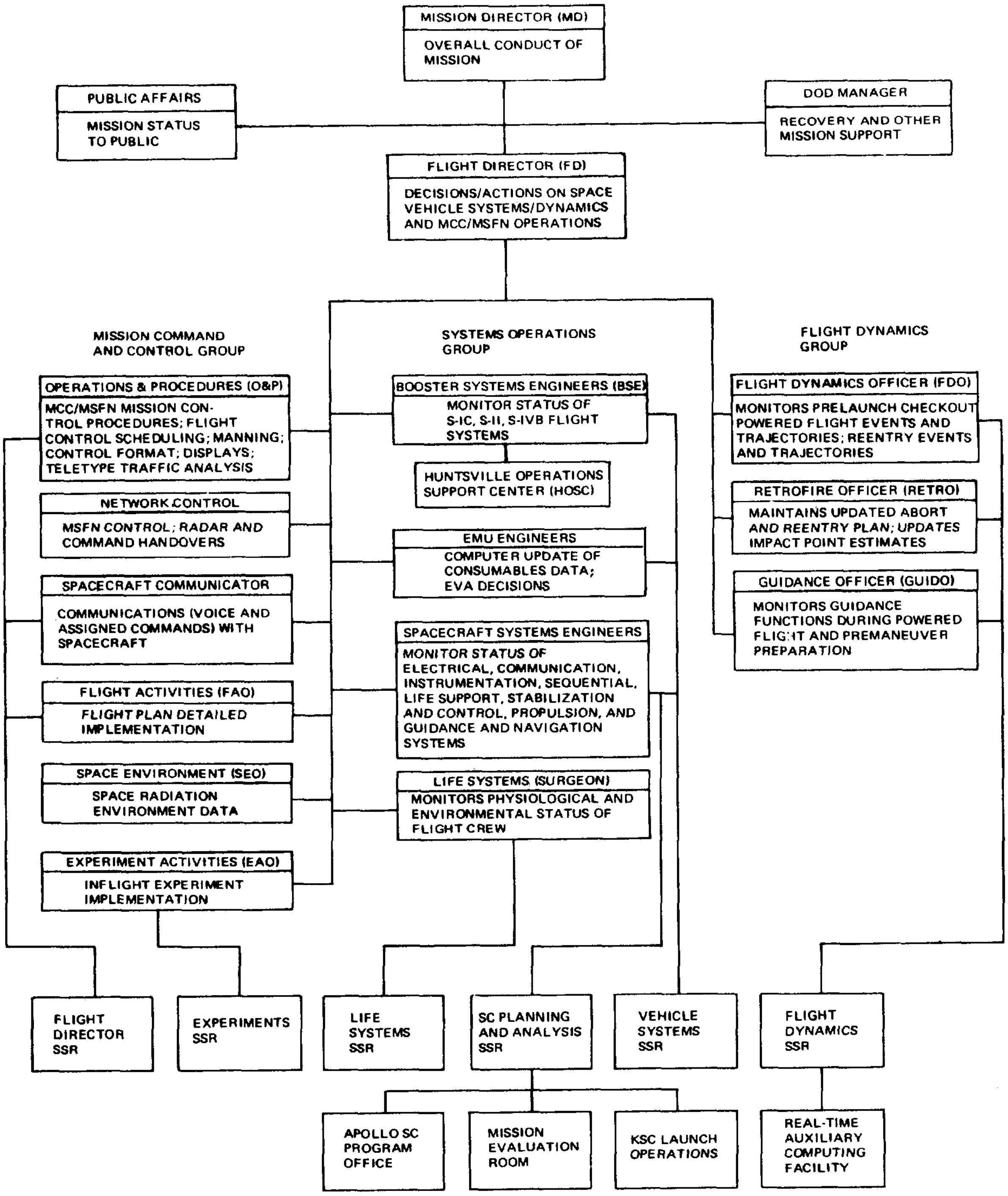


Fig. 40

INFORMATION FLOW MISSION OPERATIONS CONTROL ROOM

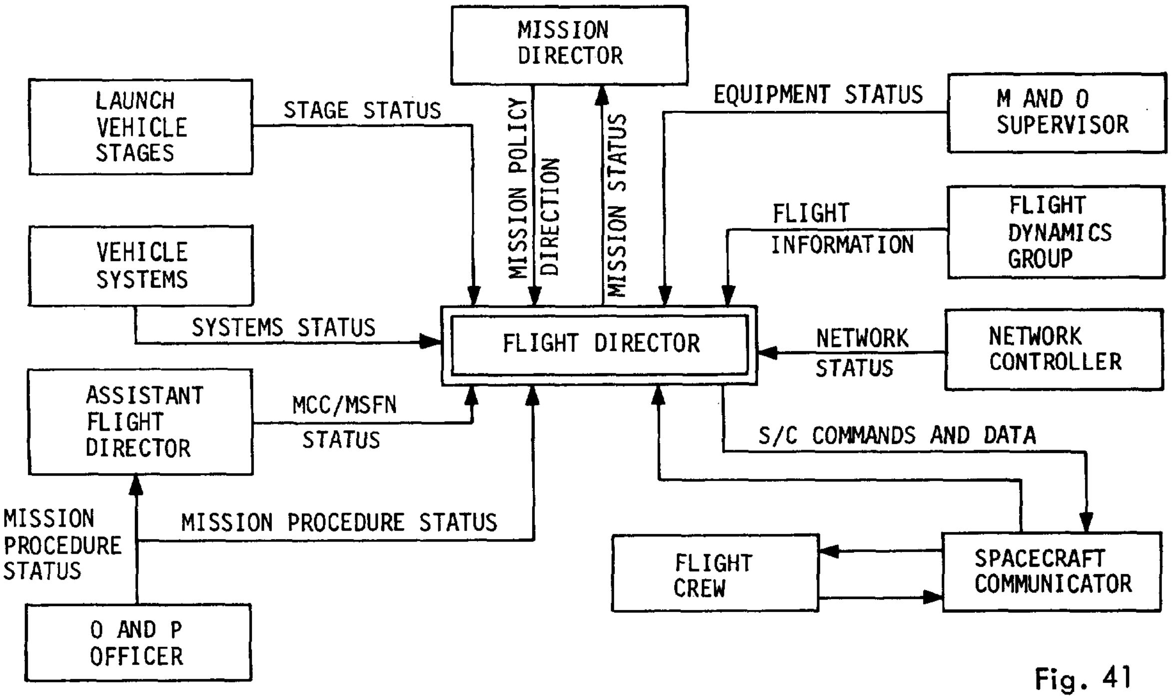


Fig. 41

The consoles within the MOCR and SSR's permit the necessary interface between the flight controllers and the spacecraft. The displays and controls on these consoles and other group displays provide the capability to monitor and evaluate data concerning the mission and, based on these evaluations, to recommend or take appropriate action on matters concerning the flight crew and spacecraft.

Problems concerning crew safety and mission success are identified to flight control personnel in the following ways:

1. Flight crew observations;
2. Flight controller real-time observations;
3. Review of telemetry data received from tape recorder playback;
4. Trend analysis of actual and predicted values;
5. Review of collected data by systems specialists;
6. Correlation and comparison with previous mission data;
7. Analysis of recorded data from launch complex testing.

The facilities at the MCC include an input/output processor designated as the Command, Communications, and Telemetry System (CCATS) and a computational facility, the Real-Time Computer Complex (RTCC). Figure 42 shows the MCC functional configuration.

MCC FUNCTIONAL CONFIGURATION

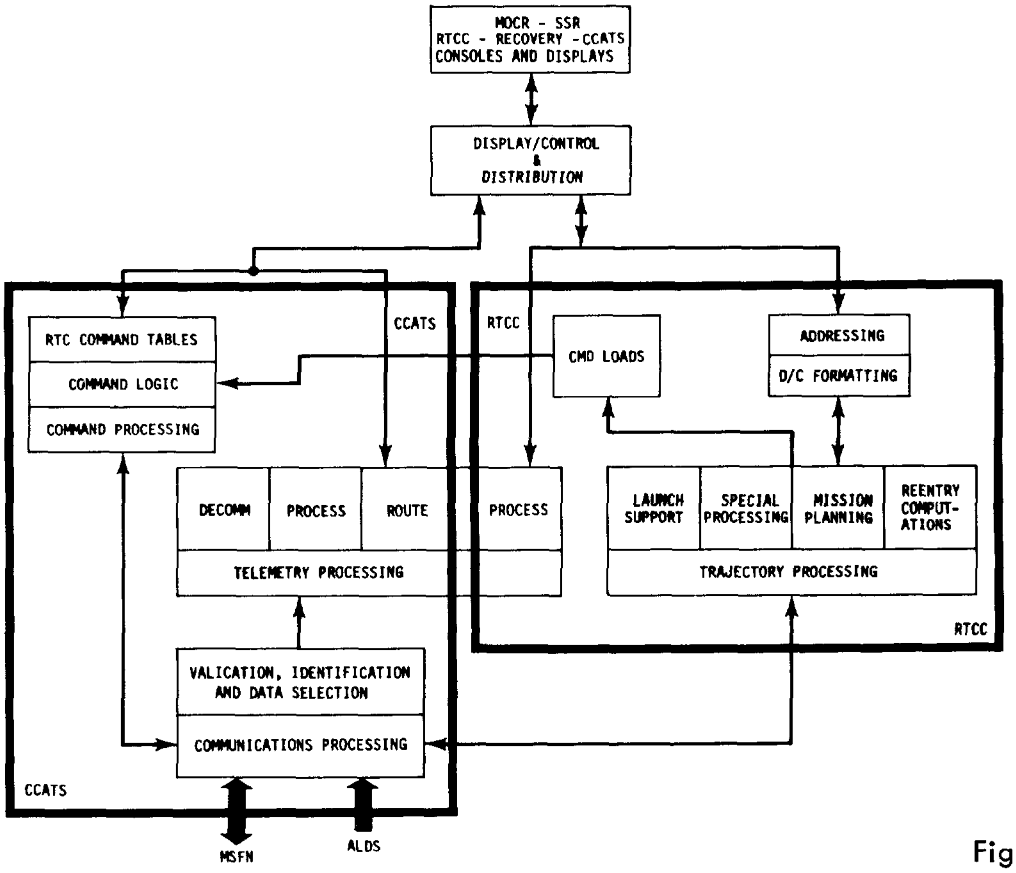


Fig. 42

The CCATS consists of three Univac 494 general purpose computers. Two of the computers are configured so that either may handle all of the input/output communications for two complete missions. One of the computers acts as a dynamic standby. The third computer is used for nonmission activities.

The RTCC is a group of five IBM 360 large-scale, general purpose computers. Any of the five computers may be designated as the Mission Operations Computer (MOC). The MOC performs all the required computations and display formatting for a mission. One of the remaining computers will be a dynamic standby. Another pair of computers may be used for a second mission or simulation.

Space Vehicle Tracking

From lift-off of the launch vehicle to insertion into orbit, accurate position data are required to allow the Impact Predictor (IP) to function effectively as a Range Safety device, and the RTCC to compute a trajectory and an orbit. These computations are required by the flight controllers to evaluate the trajectory, the orbit, and/or any abnormal situations to ensure safe recovery of the astronauts. The launch tracking data are transmitted from the AFETR site to the IP and thence to the RTCC via high-speed data communications circuits. The IP also generates spacecraft inertial positions and inertial rates of motion in real-time.

During boost the trajectory is calculated and displayed on consoles and plotboards in the MOCR and SSR's. Also displayed are telemetry data concerning status of launch vehicle and spacecraft systems. If the space vehicle deviates excessively from the nominal flight path, or if any critical vehicle condition exceeds tolerance limits, or if the safety of the astronauts or range personnel is endangered, a decision is made to abort the mission.

During the orbit phase of a mission, all stations that are actively tracking the spacecraft will transmit the tracking data through GSFC to the RTCC by teletype. If a thrusting maneuver is performed by the spacecraft, high-speed tracking data is also transmitted.

Command System

The Apollo ground command systems have been designed to work closely with the telemetry and trajectory systems to provide flight controllers with a method of "closed-loop" command. The astronauts and flight controllers act as links in this operation.

To prevent spurious commands from reaching the space vehicle, switches on the Command Module console block uplink data from the onboard computers. At the appropriate times, the flight crew will move the switches from the "BLOCK" to the "ACCEPT" positions and thus permit the flow of uplink data.

With a few exceptions, commands to the space vehicle fall into two categories: real-time commands, and command loads (also called computer loads, computer update, loads, or update).

Real-time commands are used to control space vehicle systems or subsystems from the ground. The execution of a real-time command results in immediate reaction by the affected system. Real-time commands are stored prior to the mission in the Command Data Processor (CDP) at the applicable command site. The CDP, a Univac 642B, general-purpose digital computer, is programmed to format, encode, and output commands when a request for uplink is generated.

Command loads are generated by the real-time computer complex on request of flight controllers. Command loads are based on the latest available telemetry and/or trajectory data. Flight controllers typically required to generate a command load include the Booster Systems Engineer (BSE), the Flight Dynamics Officer (FDO), the Guidance Officer (GUIDO), and the Retrofire Officer (RETRO).

Display and Control System

The MCC is equipped with facilities which provide for the input of data from the MSFN and KSC over a combination of high-speed data, low-speed data, wide-band data, teletype, and television channels. These data are computer processed for display to the flight controllers.

Several methods of displaying data are used including television (projection TV, group displays, closed circuit TV, and TV monitors), console digital readouts, and event lights. The display and control system interfaces with the RTCC and includes computer request, encoder multiplexer, plotting display, slide file, digital-to-TV converter, and telemetry event driver equipments.

A control system is provided for flight controllers to exercise their respective functions for mission control and technical management. This system is comprised of different groups of consoles with television monitors, request keyboards, communications equipment, and assorted modules added as required to provide each operational position in the MOCR with the control and display capabilities required for the particular mission.

CONTINGENCY PLANNING AND EXECUTION

Planning for a mission begins with the receipt of mission requirements and objectives. The planning activity results in specific plans for pre-launch and launch operations, pre-flight training and simulation, flight control procedures, flight crew activities, MSFN and MCC support, recovery operations, data acquisition and flow, and other mission-related operations. Numerous simulations are planned and performed to test procedures and train flight control and flight crew teams in normal and contingency operations.

MCC Role in Aborts

After launch and from the time the space vehicle clears the ML, the detection of slowly-deteriorating conditions which could result in an abort is the prime responsibility of MCC; prior to this time, it is the prime responsibility of LCC. In the event such conditions are discovered, MCC requests abort of the mission or, circumstances permitting, sends corrective commands to the vehicle or requests corrective flight crew actions. In the event of a noncatastrophic contingency, MCC recommends alternate flight procedures, and mission events are rescheduled to derive maximum benefit from the modified mission.

VEHICLE FLIGHT CONTROL PARAMETERS

In order to perform flight control monitoring functions, essential data must be collected, transmitted, processed, displayed, and evaluated to determine the space vehicle's capability to start or continue the mission.

Parameters Monitored by LCC

The launch vehicle checkout and pre-launch operations monitored by the Launch Control Center (LCC) determine the state of readiness of the launch vehicle, ground support, telemetry, range safety, and other operational support systems. During the final countdown, hundreds of parameters are monitored to ascertain vehicle, system, and component performance capabilities. Among these parameters are the "redlines." The redline values must be within the predetermined limits or the countdown will be halted. In addition to the redlines, there are a number of operational support elements such as ALDS, range instrumentation, ground tracking and telemetry stations, and ground support facilities which must be operational at specified times in the countdown.

Parameters Monitored by Booster Systems Group

The Booster Systems Group (BSG) monitors launch vehicle systems (S-IC, S-II, S-IVB, and IU) and advises the flight director and flight crew of any system anomalies. It is responsible for confirming in-flight power, stage ignition, holddown release, all engines go, engine cutoffs, etc. BSG also monitors attitude control, stage separations, and digital commanding of LV systems.

Parameters Monitored by Flight Dynamics Group

The Flight Dynamics Group monitors and evaluates the powered flight trajectory and makes the abort decisions based on trajectory violations. It is responsible for abort planning, entry time and orbital maneuver determinations, rendezvous planning, inertial alignment correlation, landing point prediction, and digital commanding of the guidance systems.

The MOCR positions of the Flight Dynamics Group include the Flight Dynamics Officer (FDO), the Guidance Officer (GUIDO), and the Retrofire Officer (RETRO). The MOCR positions are given detailed, specialized support by the Flight Dynamics SSR.

The surveillance parameters measured by the ground tracking stations and transmitted to the MCC are computer processed into plotboard and digital displays. The Flight Dynamics Group compares the actual data with pre-mission, calculated, nominal data and is able to determine mission status.

Parameters Monitored by Spacecraft Systems Group

The Spacecraft Systems Group monitors and evaluates the performance of spacecraft electrical, optical, mechanical, and life support systems; maintains and analyzes consumables status; prepares the mission log; coordinates telemetry playback; determines spacecraft weight and center of gravity; and executes digital commanding of spacecraft systems.

The MOCR positions of this group include the Command and Service Module Electrical, Environmental, and Communications Engineer (CSM EECOM), the CSM Guidance, Navigation, and Control Engineer (CSM GNC), the Lunar Module Electrical, Environmental, and Communications Engineer (LM EECOM), and the LM Guidance, Navigation, and Control Engineer (LM GNC). These positions are backed up with detailed support from the Vehicle Systems SSR.

Parameters Monitored by Life Systems Group

The Life Systems Group is responsible for the well-being of the flight crew. The group is headed by the Flight Surgeon in the MOCR. Aeromedical and environmental control specialists in the Life Systems SSR provide detailed support to the Flight Surgeon. The group monitors the flight crew health status and environmental/biomedical parameters.

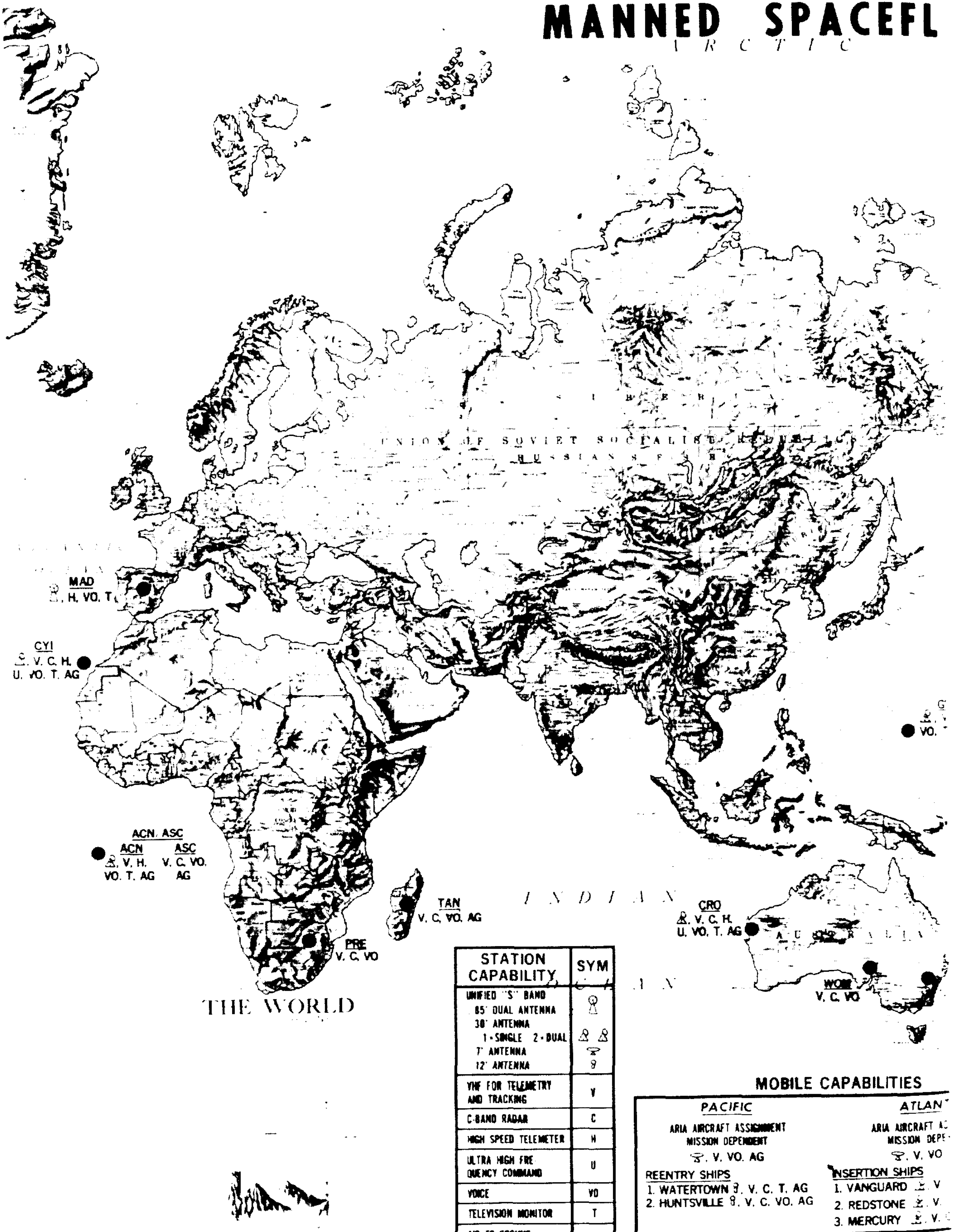
MANNED SPACE FLIGHT NETWORK

The Manned Space Flight Network (MSFN) (Figure 43) is a global network of ground stations, ships, and aircraft designed to support manned and unmanned space flights. The network provides tracking, telemetry, voice and teletype communications, command, recording, and television capabilities. The network is specifically configured to meet the requirements of each mission.

MSFN stations are categorized as lunar support stations (deep-space tracking in excess of 15,000 miles), near-space support stations with Unified S-Band (USB) equipment, and near-space support stations without USB equipment. The deep-space S-band capability is attained with 85-foot antennas located at: Honeysuckle Creek, Australia; Goldstone, California; and Madrid, Spain. MSFN stations include facilities operated by NASA, the United States Department of Defense (DOD), and the Australian Department of Supply (DOS). The DOD facilities include the Eastern Test Range (ETR), Western Test Range (WTR), White Sands Missile Range (WSMR), Range Instrumentation Ships (RIS), and Apollo Range Instrumentation Aircraft (ARIA).

The MSFN coverage by ground stations is supplemented by the five Range Instrumentation Ships. The number and position of the ships is determined for each mission. The Vanguard, Redstone, and Mercury support earth-orbital insertion and translunar injection phases of a mission. The Huntsville and Watertown support reentry phases of a mission. The ships

MANNED SPACEFL



STATION CAPABILITY	SYM
UNIFIED "S" BAND 85' DUAL ANTENNA 30' ANTENNA 1 - SINGLE 2 - DUAL 7' ANTENNA 12' ANTENNA	
VHF FOR TELEMETRY AND TRACKING	V
C-BAND RADAR	C
HIGH SPEED TELEMETER	H
ULTRA HIGH FREQUENCY COMMAND	U
VOICE	VO
TELEVISION MONITOR	T
AIR TO GROUND COMMUNICATIONS	AG

MOBILE CAPABILITIES

PACIFIC

ARIA AIRCRAFT ASSIGNMENT
MISSION DEPENDENT
. V. VO. AG

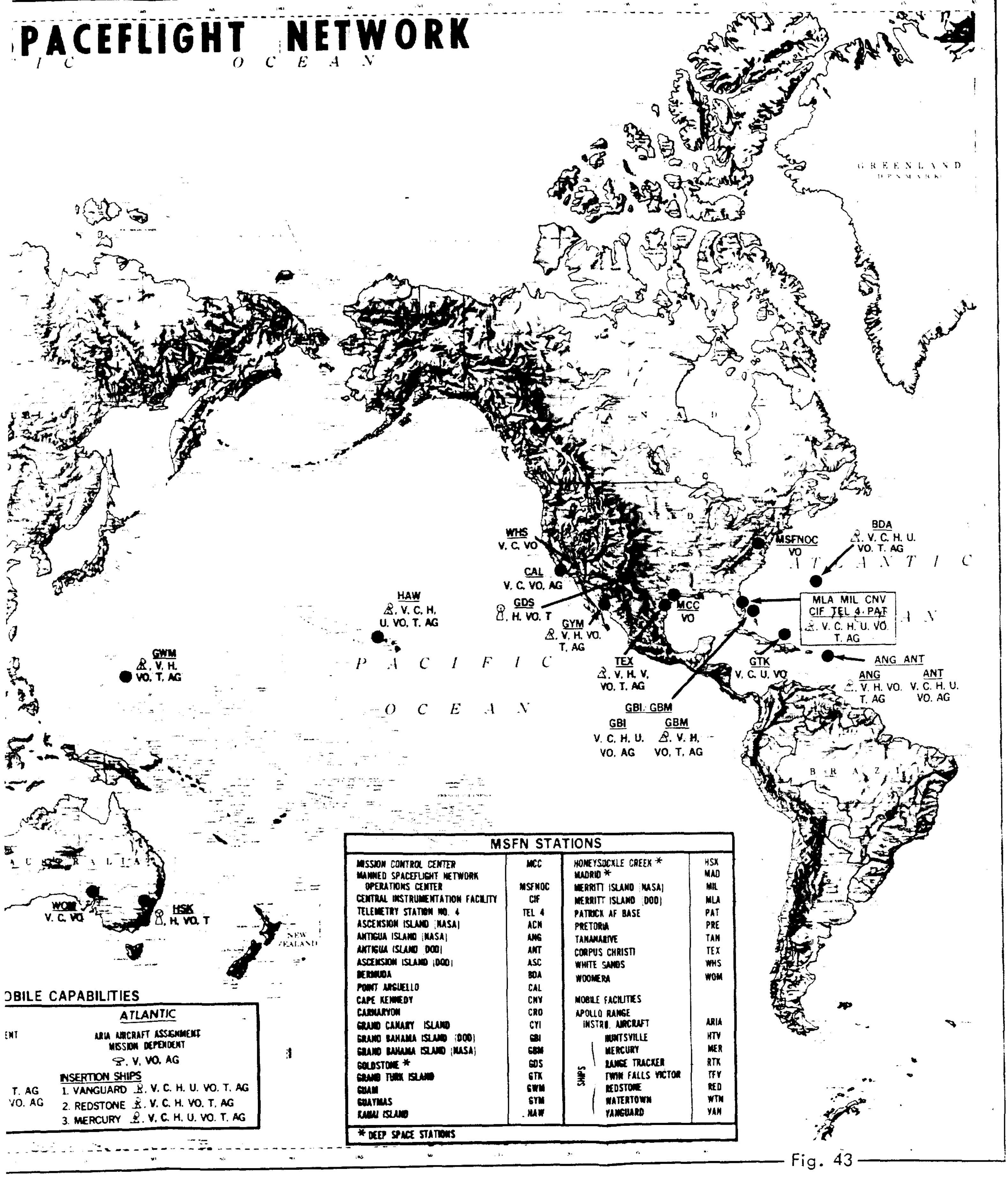
REENTRY SHIPS
1. WATERTOWN . V. C. T. AG
2. HUNTSVILLE . V. C. VO. AG

ATLAN

ARIA AIRCRAFT A
MISSION DEPE
. V. VO

INSERTION SHIPS
1. VANGUARD . V
2. REDSTONE . V.
3. MERCURY . V.

PACEFLIGHT NETWORK



MSFN STATIONS

MISSION CONTROL CENTER	MCC	HONEYSUCKLE CREEK *	HSK
MANNED SPACEFLIGHT NETWORK OPERATIONS CENTER	MSFNOC	MADRID *	MAD
CENTRAL INSTRUMENTATION FACILITY	CIF	MERRITT ISLAND (NASA)	MIL
TELEMETRY STATION NO. 4	TEL 4	MERRITT ISLAND (DOD)	MLA
ASCENSION ISLAND (NASA)	ACN	PATRICK AF BASE	PAT
ANTIGUA ISLAND (NASA)	ANG	PRETORIA	PRE
ANTIGUA ISLAND (DOD)	ANT	TANANARIVE	TAN
ASCENSION ISLAND (DOD)	ASC	CORPUS CHRISTI	TEX
BERMUDA	BDA	WHITE SANDS	WHS
POINT ARGUELLO	CAL	WOOMERA	WOM
CAPE KENNEDY	CNV		
CARNARVON	CRO	MOBILE FACILITIES	
GRAND CANARY ISLAND	CYI	APOLLO RANGE INSTRU. AIRCRAFT	ARIA
GRAND BAHAMA ISLAND (DOD)	GBI	SHIPS	
GRAND BAHAMA ISLAND (NASA)	GBM	HUNTSVILLE	HTV
GOLDSTONE *	GDS	MERCURY	MER
GRAND TURK ISLAND	GTK	RANGE TRACKER	RTK
GUAM	GWM	TWIN FALLS VICTOR	TFV
GUAYMAS	GYM	REDSTONE	RED
KAUAI ISLAND	HAW	WATERTOWN	WTN
		VANGUARD	VAN

* DEEP SPACE STATIONS

OBILE CAPABILITIES

ATLANTIC

ENT

ARIA AIRCRAFT ASSIGNMENT
MISSION DEPENDENT
V, VO, AG

T. AG
VO. AG

INSERTION SHIPS
1. VANGUARD V, C, H, U, VO, T, AG
2. REDSTONE V, C, H, VO, T, AG
3. MERCURY V, C, H, U, VO, T, AG

Fig. 43

operate as integral stations of the MSFN, meeting target acquisition, tracking, telemetry, communications, and command and control requirements. The reentry ships have no telemetry computer, command control system, mission control center, or satellite communications terminal. The DOD operates the ships in support of NASA/DOD missions with an Apollo priority. The Military Sea Transport Service provides the maritime crew and the WTR provides the instrumentation crews by contract. The WTR also has the operational management responsibility for the ships. The ships may contribute to the recovery phase as necessary for contingency landings.

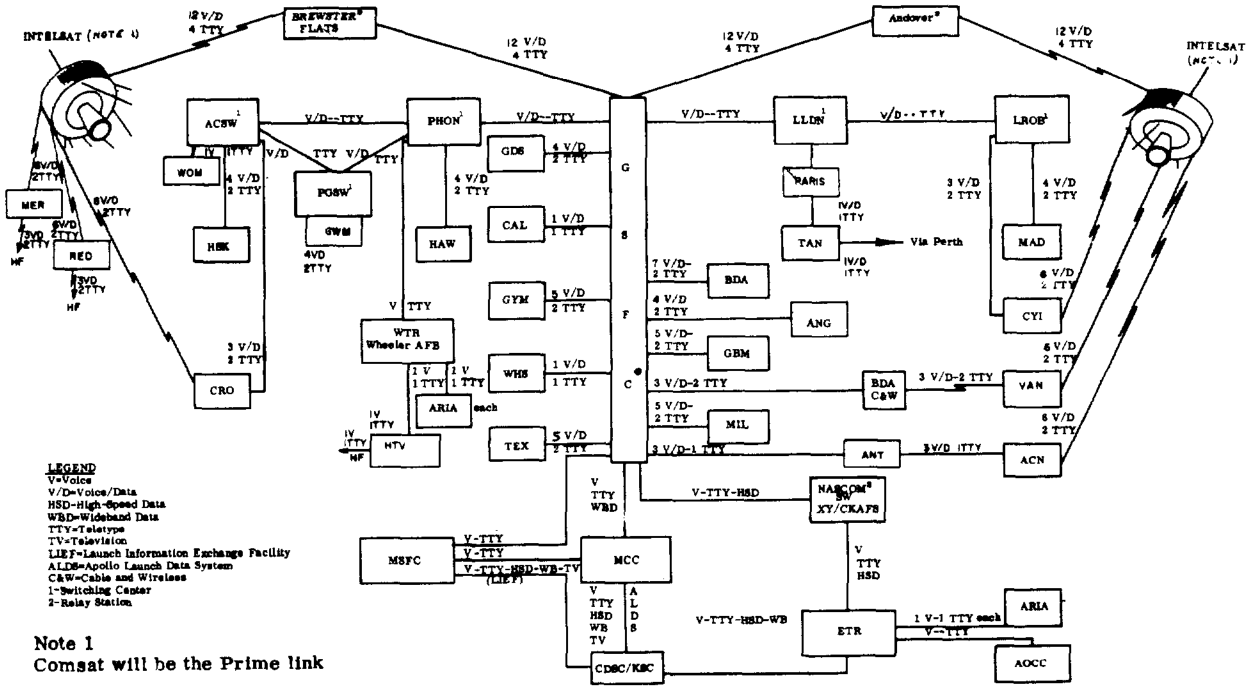
Eight modified C-135 aircraft supplement the ground stations and instrumentation ships as highly mobile "gap fillers." The ARIA support other space and missile projects when not engaged in their primary mission of Apollo support. The ARIA provide two-way relay of; voice communications between the spacecraft and surface stations; reception, recording, and retransmission of telemetry signals from the spacecraft to the ground (postpass). The aircraft are used: shortly before, during, and shortly after injection burn; from initial communications blackout to final landing; for coverage of a selected abort area in the event of a "no-go" decision after injection or for any irregular reentry. The ARIA have an endurance of about 10 hours and a cruise airspeed of about 450 knots.

NASA COMMUNICATIONS NETWORK

The NASA Communications (NASCOM) network (Figure 44) is a point-to-point communications system connecting the MSFN stations to the MCC. NASCOM is managed by the Goddard Space Flight Center, where the primary communications switching center is located. Three smaller NASCOM switching centers are located at London, Honolulu, and Canberra. Patrick AFB, Florida and Wheeler AFB, Hawaii serve as switching centers for the DOD eastern and western test ranges, respectively. The MSFN stations throughout the world are interconnected by landline, undersea cable, radio, and communications satellite circuits. These circuits carry teletype, voice, and data in real-time support of the missions.

Each MSFN USB land station has a minimum of five voice/data circuits and two teletype circuits. The Apollo insertion and injection ships have a similar capability through the communications satellites.

TYPICAL MISSION COMMUNICATIONS NETWORK



LEGEND
V=Voice
V/D=Voice/Data
HSD-High-Speed Data
WBD=Wideband Data
TTY=Teletype
TV=Television
LIEF=Launch Information Exchange Facility
ALDS=Apollo Launch Data System
C&W=Cable and Wireless
1-Switching Center
2-Relay Station

Note 1
Comsat will be the Prime link

ACN	ASCENSION IS. (NASA STATION)
ACSW	CANBERRA SWITCHING STA.
ANG	ANTIGUA ISLAND
ANT	AFETR SITE ANTIGUA ISLAND
AOCC	AIRCRAFT OPERATIONS CONTROL CENTER
ARIA	APOLLO RANGE INSTRUMENTATION AIRCRAFT
BDA	BERMUDA
CAL	CALIFORNIA (VANDENBERG AFB)
CDSC	COMMUNICATION DISTRIBUTION SWITCHING CENTER
CRO	CARNARVON, AUSTRALIA
CYI	GRAND CANARY ISLAND
ETR	EASTERN TEST RANGE
GBM	GRAND BAHAMA IS.
GDS	GOLDSTONE, CALIFORNIA
GSFC	GODDARD SPACE FLIGHT CENTER
GWM	GUAM
GYM	GUAYMAS, MEXICO
HAW	HAWAII
HSK	HONEYSUCKLE CR. AUST.
HTV	USNS HUNTSVILLE
LLDN	LONDON SWITCHING CENTER
LROB	MADRID, SPAIN SWITCHING CENTER
MAD	MADRID, SPAIN
MER	USNS MERCURY
MCC	MISSION CONTROL CENTER
MIL	MERRITT ISLAND, FLA.
MSFC	MARSHALL SPACE FLIGHT CENTER
PGSW	GUAM SWITCHING CENTER
PHON	HONOLULU SWITCHING STA.
RED	USNS REDSTONE
TAN	TANANARIVE, MALAGASY
TEX	CORPUS CHRISTI, TEXAS
VAN	USNS VANGUARD
WHS	WHITE SANDS, NEW MEXICO
WOM	WOOMERA, AUSTRALIA
WTR	WESTERN TEST RANGE

Fig. 44

APOLLO LAUNCH DATA SYSTEM (ALDS)

The Apollo Launch Data System (ALDS) between KSC and MSC is controlled by MSC and is not routed through GSFC. The ALDS consists of wide-band telemetry, voice coordination circuits, and a high-speed circuit for the Countdown and Status Transmission System (CASTS). In addition, other circuits are provided for launch coordination, tracking data, simulations, public information, television, and recovery.

MSFC SUPPORT FOR LAUNCH AND FLIGHT OPERATIONS

The Marshall Space Flight Center (MSFC), by means of the Launch Information Exchange Facility (LIEF) and the Huntsville Operations Support Center (HOSC), provides real-time support of launch vehicle pre-launch, launch, and flight operations. MSFC also provides support, via LIEF, for post-flight data delivery and evaluation.

In-depth real-time support is provided for pre-launch, launch, and flight operations from HOSC consoles manned by engineers who perform detailed system data monitoring and analysis.

Pre-launch flight wind monitoring analysis and trajectory simulations are jointly performed by MSFC and MSC personnel located at MSFC during the terminal countdown. Beginning at T-24 hours, actual wind data is transmitted periodically from KSC to the HOSC. These measurements are used by the MSFC/MSC wind monitoring team in vehicle flight digital simulations to verify the capability of the vehicle with these winds. In the event of marginal wind conditions, contingency data are provided MSFC in real-time via the Central Instrumentation Facility (CIF). DATA-CORE and trajectory simulations are performed on-line to expedite reporting to KSC.

During the pre-launch period, primary support is directed to KSC. At lift-off primary support transfers from KSC to the MCC. The HOSC engineering consoles provide support as required to the Booster Systems Group for S-IVB/IU orbital operations by monitoring detailed instrumentation for the evaluation of system in-flight and dynamic trends, assisting in the detection and isolation of vehicle malfunctions and providing advisory contact with vehicle design specialists.

ABBREVIATIONS AND ACRONYMS

ac	Alternating Current
AEA	Abort Electronics Assembly
AFB	Air Force Base
AFETR	Air Force Eastern Test Range
AGS	Abort Guidance Subsystem
ALDS	Apollo Launch Data System
AM	Amplitude Modulation
AOT	Alignment Optical Telescope
APS	Auxiliary Propulsion System (S-IVB)
APS	Ascent Propulsion System (LM)
ARIA	Apollo Range Instrumentation Aircraft
ARS	Atmosphere Revitalization Subsystem
AS	Apollo Saturn
AS	Ascent Stage (LM)
ASI	Augmented Spark Igniter
BPC	Boost Protective Cover
BSE	Boost Systems Engineer
CASTS	Countdown and Status Transmission System
CCATS	Communications, Command, and Telemetry System
CCS	Command Communications System
CDP	Command Data Processor (MSFN Site)
CES	Control Electronics Subsystem
CIF	Central Instrumentation Facility
CM	Command Module
COAS	Crewman Optical Alignment Sight
CS	Communications System
CSM	Command Service Module
C/T	Crawler/Transporter
CWEA	Caution and Warning Electronics Assembly
CWG	Constant-Wear Garment
DATA-CORE	CIF Telemetry Conversion System
dc	Direct Current
DEDA	Data Entry and Display Assembly
DOD	Department of Defense
DOS	Department of Supply (Australia)
DPS	Descent Propulsion System (LM)
DS	Descent Stage (LM)
DSEA	Data Storage Electronics Assembly

ECS	Environmental Control System
EDS	Emergency Detection System
EDS	Explosive Devices System (LM)
ELS	Earth Landing System
EMS	Entry Monitor System
EMU	Extravehicular Mobility Unit
EPS	Electrical Power System
ETR	Eastern Test Range
EV	Extravehicular
EVA	Extravehicular Activity
FCC	Flight Control Computer (IU, analog)
FDAI	Flight Director Attitude Indicator
FDO	Flight Dynamics Officer
g	Gravity force at sea level (1 g)
GDC	Gyro Display Coupler
GH_2	Gaseous Hydrogen
GN_2	Gaseous Nitrogen
GNCS	Guidance, Navigation, and Control System
GN&CS	Guidance, Navigation, and Control System (LM)
GOX	Gaseous Oxygen
GSE	Ground Support Equipment
GUIDO	Guidance Officer
GSFC	Goddard Space Flight Center
H_2	Hydrogen
HF	High Frequency
HOSC	Huntsville Operations Support Center
HTS	Heat Transport Subsystem (LM)
ICG	In-flight Coverall Garment
IMU	Inertial Measurement Unit
IP	Impact Predictor (at KSC)
IS	Instrumentation System (LM)
IU	Instrument Unit
KSC	Kennedy Space Center
LC	Launch Complex
LCC	Launch Control Center
LCG	Liquid-Cooling Garment
LEA	Launch Escape Assembly
LEB	Lower Equipment Bay
LES	Launch Escape System
LET	Launch Escape Tower
LH	Liquid Hydrogen

LIEF	Launch Information Exchange Facility
LM	Lumar Module
LN_2	Liquid Nitrogen
LOX, LO_2	Liquid Oxygen
LR	Landing Radar
LV	Launch Vehicle
LVDA	Launch Vehicle Data Adapter
LVDC	Launch Vehicle Digital Computer
MCC	Mission Control Center
MILA	Merritt Island Launch Area
ML	Mobile Launcher
MMH	Monomethyl Hydrazine
MOC	Mission Operations Computer
MOCR	Mission Operations Control Room
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
MSFN	Manned Space Flight Network
MSS	Mobile Service Structure
NASCOM	NASA Communications Network
N_2H_4	Hydrazine
N_2O_4	Nitrogen Tetroxide
NPSH	Net Positive Suction Head
O_2	Oxygen
OMR	Operations Management Room
OPS	Oxygen Purge System
OSCPCS	Oxygen Supply and Cabin Pressure Control Subsystem
OSR	Operations Support Room
PCMTEA	Pulse-Code-Modulation and Timing Electronics Assembly
PDS	Propellant Dispersion System
PGA	Pressure Garment Assembly
PGNCS	Primary Guidance Navigation and Control System (LM)
PGNS	Primary Guidance and Navigation Subsystem (LM)
PLSS	Portable Life Support System
PTCR	Pad Terminal Connection Room
PU	Propellant Utilization
RCS	Reaction Control System
RETRO	Direction Opposite to Velocity Vector
RF	Radio Frequency
RIS	Range Instrumentation Ship
RP-1	Rocket Propellant (refined kerosene)
RR	Rendezvous Radar
RTCC	Real Time Computer Complex

SC	Spacecraft
SCS	Stabilization and Control System
SCEA	Signal Conditioning Electronics Assembly
SECS	Sequential Events Control System
SLA	Spacecraft LM Adapter
SM	Service Module
SPS	Service Propulsion System
SSR	Staff Support Room
SV	Space Vehicle
TCA	Thrust Chamber Assembly
TCS	Thermal Conditioning System
TSM	Tail Service Mast
TV	Television
UDMH	Unsymmetrical Dimethylhydrazine
USB	Unified S-band
UHF	Ultra-High Frequency
VAB	Vehicle Assembly Building
VHF	Very High Frequency
WMS	Water Management Subsystem (LM)
WSMR	White Sands Missile Range
WTR	Western Test Range

GPO 871-233

Post Launch
Mission Operation Report
No. M-932-69-09

MEMORANDUM

6 May 1969

To: A/Administrator

From: MA/Apollo Program Director

Subject: Apollo 9 Mission (AS-504) Post Launch Report #1

The Apollo 9 mission was successfully launched from the Kennedy Space Center on Monday, 3 March 1969 and was completed as planned, with recovery of the spacecraft and crew in the Atlantic recovery area on Thursday, 13 March 1969. Initial evaluation of the flight, based upon quick-look data and crew debriefing, indicates that all mission objectives were attained. Further detailed analysis of all data is continuing and appropriate refined results of the mission will be reported in Manned Space Flight Center technical reports.

Based on the mission performance as described in this report, I am recommending that the Apollo 9 mission be adjudged as having achieved agency preset primary objectives and be considered a success.

Sam C. Phillips

Sam C. Phillips
Lt. General, USAF
Apollo Program Director

APPROVAL:

G. Mueller

George E. Mueller
Associate Administrator for
Manned Space Flight

Report No. M-932-69-09

POST LAUNCH MISSION OPERATION REPORT

APOLLO 9 (AS-504) MISSION

OFFICE OF MANNED SPACE FLIGHT
Prepared by: Apollo Program Office-MAO
FOR INTERNAL USE ONLY

GENERAL

The Apollo 9 (AS-504) mission was the first manned flight involving the Lunar Module. The crew were James A. McDivitt, Commander; David R. Scott, Command Module Pilot; and Russell L. Schweickart, Lunar Module Pilot. Launch had been initially scheduled for 28 February 1969, but was postponed for three days because all three crewmen had virus respiratory infections. The countdown was accomplished without any unscheduled holds and the AS-504 Space Vehicle was successfully launched from Launch Complex 39 at Kennedy Space Center, Florida, on Monday, 3 March 1969. Recovery of the flight crew and Command Module was successfully accomplished on 13 March 1969, for a flight duration of 241 hours 53 seconds.

Initial review of test data indicates that overall performance of the launch vehicle, spacecraft, and flight crew together with ground support and control facilities and personnel was satisfactory, and that all primary mission objectives were accomplished.

NASA OMSF PRIMARY MISSION OBJECTIVES FOR APOLLO 9

PRIMARY OBJECTIVES

- Demonstrate crew/space vehicle/mission support facilities performance during a manned Saturn V mission with CSM and LM.
- Demonstrate LM/crew performance.
- Demonstrate performance of nominal and selected backup Lunar Orbit Rendezvous (LOR) mission activities, including:
    - Transposition, docking, LM withdrawal
    - Intervehicular crew transfer
    - Extravehicular capability
    - SPS and DPS burns
    - LM active rendezvous and docking

CSM/LM consumables assessment.

Sam C. Phillips

Sam C. Phillips
Lt. General, USAF
Apollo Program Director

Date: 14 FEB 69

G E Mueller

George E. Mueller
Associate Administrator for
Manned Space Flight

Date: 17 Feb 1969

RESULTS OF APOLLO 9 MISSION

Based upon a review of the assessed performance of Apollo 9, launched 3 March 1969 and completed 13 March 1969, this mission is adjudged a success in accordance with the objectives stated above.

Sam C. Phillips

Sam C. Phillips
Lt. General, USAF
Apollo Program Director

Date: 30 APRIL 1969

G E Mueller

George E. Mueller
Associate Administrator for
Manned Space Flight

Date: MAY 5 1969

COUNTDOWN

The terminal countdown for Apollo 9 began at T-28 hours at 10:00 p.m. EST, 1 March 1969. The only holds encountered were two planned holds: one at T-16 hours for 3 hours, and one at T-9 hours for 6 hours. The count was resumed for the last time at 2:00 a.m. EST, 3 March 1969, and proceeded to launch at 11:00:00 a.m. EST.

FLIGHT SUMMARY

The Apollo 9 mission was launched from Kennedy Space Center, Florida, at 11:00:00 a.m. EST, 3 March 1969. All launch vehicle stages performed satisfactorily, but burned slightly longer than planned, inserting the S-IVB/spacecraft combination into a nominal orbit of 102.3 by 103.9 nautical miles (NM).

After post-insertion checkout was completed, the Command/Service Module (CSM) was separated from the S-IVB, transposed, and docked with the Lunar Module (LM). The docked spacecraft was separated from the S-IVB at 4:08:05 GET (Ground Elapsed Time). After separation, two unmanned S-IVB burns were performed to place the S-IVB/ Instrument Unit on an earth-escape trajectory. After the third burn, the planned propellant dumps could not be performed.

After spacecraft separation from the launch vehicle, four Service Propulsion System (SPS) firings were made with the CSM/LM docked.

At approximately 43.5 hours GET, the Lunar Module Pilot (LMP) and the Commander (CDR) transferred to the LM. The first manned firing of the LM Descent Propulsion System (DPS) was initiated about 6 hours later. The two crewmen then returned to the Command Module (CM) for the fifth SPS firing.

At approximately 70 hours GET, the LMP and CDR again transferred to the LM for the LMP's 37-minute extravehicular activity (EVA). During this period, the Command Module Pilot (CMP) opened the CM hatch and retrieved thermal samples from the CSM exterior.

At about 89 hours GET, the CDR and LMP returned to the LM for the third time to perform the CSM/LM rendezvous. The LM primary guidance system was used to conduct the rendezvous with backup calculations being made by the CM computer. The phasing and insertion maneuvers were performed using the DPS to set up the rendezvous. The Ascent and Descent Stages were separated, followed by a concentric sequence initiation maneuver using the LM Reaction Control System. The LM Ascent Propulsion System (APS) was fired to establish the constant delta height. The terminal phase of the rendezvous began on time, and the spacecraft were again docked at about 99 hours GET. The Ascent Stage was jettisoned about 2.5 hours later. Shortly after, the APS was fired to propellant depletion. The firing lasted 350 seconds and resulted in an orbit of 3747 by 124.5 NM.

The sixth SPS firing, to lower apogee, was delayed because the +X translation to precede the maneuver was not programmed properly. However, the maneuver was rescheduled and successfully completed in the next revolution.

During the last three days, a seventh SPS firing was made to raise the apogee, and the SO65 Multispectral Photography Experiment and landmark tracking were accomplished.

Unfavorable weather in the planned landing area caused the deorbit maneuver (SPS 8) to be delayed for one revolution. This decision was made the day before splashdown and recovery forces were redeployed. Final parachute descent and splashdown were within sight of the prime recovery ship in the Atlantic Ocean. Splashdown was near the target point of 23 degrees 15 minutes north latitude, 68 degrees west longitude, as determined from the onboard computer solution. The crew were safely aboard the prime recovery ship, USS Guadalcanal, within 1 hour of splashdown.

Table 1 presents a summary of mission events.

TABLE 1

SUMMARY OF MISSION EVENTS

EVENT	TIME (GET) HR: MIN: SEC	
	PLANNED*	ACTUAL
First Motion	00:00:00	00:00:00
Maximum Dynamic Pressure	00:01:21	00:01:26
S-IC Center Engine Cutoff	00:02:14	00:02:14
S-IC Outboard Engine Cutoff	00:02:40	00:02:43
S-IC/S-II Separation	00:02:40	00:02:44
S-II Ignition	00:02:42	00:02:44
Jettison S-II Aft Interstage	00:03:10	00:03:14

* LV events based on MSFC LV Operational Trajectory, dated 31 January 1969.
SC events based on MSC SC Operational Trajectory, Revision 2, 20 February 1969.

Jettison Launch Escape Tower	00:03:16	00:03:18
S-II Engine Cutoff Command	00:08:51	00:08:56
S-II/S-IVB Separation	00:08:52	00:08:57
S-IVB Engine Ignition	00:08:55	00:09:01
S-IVB Engine Cutoff	00:10:49	00:11:05
Parking Orbit Insertion	00:10:59	00:11:15
Separation and Docking Maneuver Initiation	02:33:49	02:41:16
Spacecraft Docking	03:05:00 (Approx)	03:01:59
Spacecraft Final Separation	04:08:57	04:08:06
S-IVB Restart Preparation	04:36:12	04:36:17
S-IVB Reignition (2nd Burn)	04:45:50	04:45:56
S-IVB Second Cutoff Signal	04:46:52	04:46:58
S-IVB Restart Preparations	05:59:35	05:59:41
SPS Burn 1	06:01:40	05:59:01
S-IVB Reignition (3rd Burn)	06:07:13	06:07:19
S-IVB Third Cutoff Signal	06:11:14	06:11:21
Start LOX Dump	06:12:44	Not Accomplished
LOX Dump Cutoff	06:23:54	Not Accomplished
Start LH_2 Dump	06:24:04	Not Accomplished
LH_2 Dump Cutoff	06:42:19	Not Accomplished
SPS Burn 2	22:12:00	22:12:04
SPS Burn 3	25:18:30	25:17:39

SPS Burn 4	28:28:00	28:24:41
Docked DPS Burn	49:42:00	49:41:35
SPS Burn 5	54:25:19	54:26:12
Undocking	92:39:00	92:39:36
CSM/LM Separation	93:07:40	93:02:54
DPS Phasing	93:51:34	93:47:35
DPS Insertion	95:43:22	95:39:08
Concentric Sequence Initiation - LM RCS Burn	96:21:00	96:16:07
Constant Delta Height - APS Burn	97:05:27	96:58:15
Terminal Phase Initiation	98:00:10	97:57:59
CSM/LM Docking	99:13:00 (Approx)	99:02:26
APS Burn to Propellant Depletion	101:58:00	101:53:15
SPS Burn 6	121:58:48	123:25:07
SPS Burn 7	169:47:54	169:39:00
SPS Burn 8 (Deorbit)	**	240:31:15
Entry Interface (400,000 ft)	**	240:44:10
Drogue Chute Deployment (25,000 feet Approx)	**	240:55:08
Splashdown	**	241:00:54

** Premission planned deorbit was changed to permit shift in landing point due to weather and sea conditions in initial planned recovery area. One additional orbit was added.

MISSION PERFORMANCE

The significant portions of the Apollo 9 mission are discussed herein. Space vehicle systems and mission support performance are covered in succeeding sections.

TRAJECTORY

The CSM/LM/IU/S-IVB combination was inserted into earth orbit at 00:11:15 GET after a normal launch phase. The resulting orbital elements and maneuver parameters are given in Table II for all engine firings.

Four SPS maneuvers were performed prior to the first docked DPS firing. Each of the first three SPS maneuvers was made without requiring a +X translation to settle propellants. The fourth SPS maneuver was preceded by an 18-second +X translation made with the Service Module Reaction Control System (SM RCS).

The fifth docked SPS maneuver resulted in the perigee being approximately 5 NM less than planned causing the rendezvous to be initiated 4 minutes earlier. Small cutoff errors of this magnitude were expected, and real-time trajectory planning for both rendezvous and deorbit was conducted to accommodate minor adjustments in the initiation times and velocity increments. Out-of-plane components were added during the flight to certain preplanned maneuvers to provide substantial reduction in spacecraft weight without significantly changing the orbital parameters for subsequent maneuvers.

The trajectory aspects of the rendezvous exercise will be discussed in the rendezvous section.

After the Ascent Stage jettison, a separation maneuver of 3 feet per second (fps) was performed by the SM RCS. The APS engine was then fired to propellant depletion.

The sixth SPS maneuver was delayed one revolution when the accompanying ullage burn did not occur at the proper time, but was completed nominally.

The seventh SPS maneuver was restructured in real time to provide a desired higher burn time and was successfully accomplished.

The deorbit maneuver was made over Hawaii during revolution 152, and CM/SM separation was performed. The CM landed at 241:00:53 GET near 23 degrees 15 minutes north latitude and 68 degrees west longitude.

TABLE II SUMMARY OF MANEUVERS

	BURN TIME (SECONDS)			Δ V (FEET PER SECOND)			RESULTANT ORBIT		
	*Prelaunch PLANNED	Real Time PLANNED	ACTUAL	*Prelaunch PLANNED	Real Time PLANNED	ACTUAL	*Prelaunch PLANNED	Real Time PLANNED	ACTUAL
First Service Propulsion	5.0	4.96	5.2	36.8	36.8	36.6	125.2 X 108.7	128.2 X 110.2	127.6 X 111.3
Second Service Propulsion	111.3	111.2	110.3	849.6	850.6	850.5	190.2 X 109.1	189.8 X 107.7	192.5 X 110.7
Third Service Propulsion	280.0	281.9	279.9	2548.2	2570.7	2567.9	268.2 X 111.3	270.3 X 109.4	274.9 X 112.6
Fourth Service Propulsion	28.1	28.4	27.9	299.4	300.9	300.5	268.7 X 111.4	273.8 X 109.3	275.0 X 112.4
First Descent Propulsion	367.0	370.6	372.0	1734.0	1744.0	1737.5	267.6 X 111.8	269.9 X 109.1	274.6 X 112.1
Fifth Service Propulsion	41.5	43.2	43.3	552.3	575.4	572.5	130.2 X 129.7	129.8 X 129.8	131.0 X 125.9
Ascent Propulsion Firing to Depletion	389.0**	444.9**	362.4	6074.9**	7427.5**	5373.4	4673.3 X 128.9**	6932.3 X 125.9	3760.9 X 126.6
Sixth Service Propulsion	2.4	1.33	1.40	62.7	38.8	33.7	127.9 X 94.6	120.2 X 104.8	123.1 X 108.5
Seventh Service Propulsion	9.9	25.0	24.9	252.8	653.3	650.1	238.7 X 93.9	250.4 X 97.9	253.2 X 100.7
Eighth Service Propulsion	11.7	11.6	11.7	323.3	325.0	322.7	241.8 X -15.1	238.5 X ---	240.0 X -4.7

NOTES: * Prelaunch planned refers to Apollo 9 Spacecraft Operational Trajectory, Revision 2, 20 February 1969.
** APS burn to depletion planned for unattainable apogee value to insure propellant depletion cutoff.

EXTRAVEHICULAR ACTIVITY

Extravehicular activity (EVA), planned for the third day, was reduced from 2 hours 15 minutes to about 1 hour of depressurized LM activity. This change was made because the LMP experienced a minor in-flight illness during the first two days of the mission.

Preparation for EVA began at approximately 71 hours GET. The CDR and the LMP were in the LM and the CMP in the CM. At approximately 73 hours GET, after donning the Portable Life Support System (PLSS) and the Oxygen Purge System (OPS), the LMP egressed through the forward hatch and moved to the external foot restraints on the platform. During this time the CM was depressurized and the side hatch was opened. Thermal sample retrieval was photographically recorded with the sequence cameras. The LMP used the handrails to evaluate body control and transfer techniques. Ingress was completed at about 74 hours GET. Both hatches were then secured and the vehicles repressurized. The PLSS was successfully recharged with oxygen and water.

The lithium hydroxide cartridge from the system was returned to the CM for post-flight metabolic analysis.

The repressurization cycles for both vehicles were nominal, and post-EVA procedures were followed without difficulty.

RENDEZVOUS

The CDR and the LMP transferred to the LM on the fifth day for the rendezvous. The rendezvous exercise began on schedule with a 5-fps separation maneuver using the SM RCS.

A phasing maneuver of 90.5 fps was performed with the LM DPS about 2.8 NM from the CSM. Approximately 12 NM above and 27 NM behind the CSM, the DPS was used to impart a 43.1-fps insertion velocity to the LM. At a range of 75 NM from the CSM, the Ascent and Descent Stages of the LM were separated, and a concentric sequence initiation maneuver of 40.0 fps was made with the LM RCS.

Approximately 10 NM below and 78 NM behind the CSM, the constant delta height maneuver was performed with the APS imparting a velocity change of 41.5 fps. The terminal phase began on time with a 22.3-fps LM RCS maneuver.

Braking maneuvers were conducted on schedule, and stationkeeping was maintained at a distance of approximately 100 feet so that photographs could be taken from both vehicles. Docking was successfully completed at about 99 hours GET. Problems were experienced in using the Crewman Optical Alignment Sight (COAS) in both vehicles during docking. The combination of a bright CM, a dimly lighted CM target, and a relatively dim reticle in the alignment sight made LM docking a difficult task.

LM rendezvous navigation and maneuver targeting using both the primary and the backup guidance systems were satisfactory. Radar data were successfully used, both automatically by the primary system and through manual insertion in the About Guidance System, to correct rendezvous state vectors. Maneuver solutions from both onboard systems and from ground computations appeared to correlate closely. The crew selected the primary system solutions for all maneuvers through the first midcourse correction performed after terminal phase initiation.

Rendezvous navigation and mirror-image targeting in the CM were performed satisfactorily; however, loss of the LM tracking light prevented sextant measurements from the CM when both vehicles were in darkness. Preliminary data indicate that CM maneuver calculations for terminal phase initiation were satisfactory.

FLIGHT CREW PERFORMANCE

Crew performance was excellent throughout the mission, and the flight was conducted essentially in accordance with the nominal plan.

Preparation for transfer to the LM required longer than anticipated, primarily because of the time required for the crewmen to don the space suits. The suit supply hoses were a source of interference and also contributed to the longer preparation time. As a result, about 1 hour was added to the preparation time for subsequent transfers.

Visual and photographic inspection of the entire spacecraft was accomplished after rendezvous and before docking.

FLIGHT CREW BIOMEDICAL EVALUATION

The launch was postponed for 72 hours because of symptoms of upper respiratory infections in all three crewmen. Physical examinations 3 hours before launch revealed no infection.

The planned medical operations were conducted as scheduled except that the LMP experienced some nausea and vomiting prior to and following the initial transfer to the LM.

Plans for EVA were modified because of the LMP's illness. The physiological parameters were essentially normal throughout the mission. The LMP's work rate during EVA was on the order of 500 Btu/hr.

FLIGHT CONTROL

Flight control performance was satisfactory in providing operational support for the Apollo 9 mission. Minor spacecraft problems were encountered, but none was such that either the mission operations or the flight plan was significantly altered.

Early in the mission, a caution and warning light on Hydrogen Tank 1 was observed just prior to an automatic cycle of the heaters. This condition persisted and the crew had to be disturbed during a rest period at 81 hours GET to increase the hydrogen tank pressure.

On the third day, the crew were about 1 hour behind the timeline, resulting in cancelling all the planned communications tests except the LM secondary S-band test and the LM two-way relay with television.

On the fourth day, the EVA was abbreviated and the external transfer from the LM to the CM was not performed. The activity was restricted to the LM forward platform because of concern about the LMP's earlier illness and proper readiness for the rendezvous on the following day.

At approximately 78 hours GET, after the tunnel hardware had been installed, a crewman made an unplanned return to the LM to open a circuit breaker. This change shortened the rest period about 30 minutes.

On the fifth day, LM activation was performed approximately 40 minutes early to insure an on-time rendezvous initiation.

The LM VHF telemetry and S-band power amplifier were lost for 6 and 12 hours, respectively, after the APS firing to depletion. These failures were expected because of the lack of cooling. The electrical system capability for this spacecraft was several hours longer than predicted. LM support terminated at 113:42:00 GET.

On the sixth day, the sixth SPS maneuver was delayed by one revolution. The crew reported that the +X translation did not occur. A procedural error was made in loading the CM computer, since the proper SM RCS quads were not selected. The computer was reloaded, and one revolution later, the maneuver was made satisfactorily.

On the eighth day, the seventh SPS maneuver was increased to 25 seconds in duration to permit a test of the Propellant Utilization and Gaging System (PUGS).

RECOVERY

Recovery of the Apollo 9 Command Module and crew was completed in the West Atlantic by the prime recovery ship, USS Guadalcanal. The following table is a list of significant recovery events on 13 March 1969:

EVENT	EST
First VHF contact	11:51 a.m.
First beacon and voice contact	11:57 a.m.
First visual contact	11:59 a.m.
Landing	12:01 p.m.
Swimmers deployed	12:07 p.m.
Flotation collar installed	12:14 p.m.
CM hatch open	12:27 p.m.
First astronaut aboard helicopter	12:39 p.m.
All astronauts in helicopter	12:46 p.m.
Astronauts on deck	12:50 p.m.
CM aboard recovery ship	2:13 p.m.

The CM remained in the stable I flotation attitude. Sea-state conditions were very moderate at the recovery site.

SYSTEMS PERFORMANCE

Engineering data reviewed to date indicate that all mission objectives were attained. Further detailed analysis of all data is continuing and appropriate refined results of systems performance will be reported in MSFC and MSC technical reports. Summaries of the significant anomalies and discrepancies are presented in Tables III, IV, and V.

TABLE III

LAUNCH VEHICLE DISCREPANCY SUMMARY

DESCRIPTION	REMARKS
Oscillations occurred in the S-II center engine chamber pressure and the S-II structure late in the burn. Oscillations have occurred on four flights and five static firings, but only after 320 seconds of S-II burn.	Apparently caused by coupling between the center engine and the stage structure. Fix will be early center engine cutoff at 299 seconds on Apollo 10.
S-IVB APS Module No. 2 helium supply pressure decayed slowly.	Leak in teflon seals upstream of the regulator. Change of seal material to rubber has been approved. Closed.
S-IVB helium regulator lock-up pressure exceeded the redline during countdown, and the helium pneumatic pressure was high throughout the mission.	Internal leakage in regulator caused by wear on poppet. Modified regulator has been tested and installed on S-IVB-505. Redline has been raised from 585 to 630 psi.
S-IVB third burn anomaly: Gas generator pressure spike at start, engine chamber pressure oscillations, loss of engine control pneumatic pressure, abnormal attitude control system oscillations, decrease in engine performance during burn, and inability to dump residual propellants after burn.	Caused by extreme out-of-spec engine start conditions which resulted in excessive engine chamber pressure oscillations and possible gas generator damage, followed by loss of pneumatic system. There is no evidence that the causes of this anomaly are applicable to an in-spec engine start. The flight mission rules allowing restart with recirculation systems inoperative are being revised for Apollo 10.

TABLE IV

COMMAND/SERVICE MODULE DISCREPANCY SUMMARY

DESCRIPTION	REMARKS
Unable to translate the CSM to the left. Propellant isolation valves in two SM RCS quads were found to be closed.	Apparently caused by mechanical shock at CSM/S-IVB separation. The crew will check the valve positions after separation on Apollo 10 and subsequent missions.
Master alarm occurred coincident with hard docking without any accompanying annunciator.	Caused by a sensor transient or a momentary short circuit due to mechanical shock. Also occurred during the CSM 106 docking test.
During the third SPS burn, eight master alarms occurred because of indications of propellant unbalance.	Caused by erroneous readings from the primary probe in the SPS oxidizer tank. The master alarm and warning functions from the PUGS have been deleted on CSM 106 and subsequent spacecraft. Closed.
The scanning telescope mechanism jammed frequently when driven manually, but worked normally in automatic mode.	A pin from a counter drum was found wedged in a split gear. Units on Apollo 10 and subs will be replaced with units that have been inspected. Closed.
Fuel Cell No. 2 condenser outlet temperature exceeded the normal range several times.	The bypass valve that controls coolant temperature operated improperly because of contamination in the glycol. For subsequent missions, Block I valves which are less susceptible to contaminants will be installed and the radiators will be vibrated and flushed 30 to 45 days before launch. Closed.
Automatic control of the pressure in the cryogenic hydrogen tanks was lost and pressure was controlled manually.	Probably caused by an intermittent open circuit in the motor switch control circiut. No hardware change will be made. Closed.
The first two attempts to undock were unsuccessful because the release switch was not held long enough. Before the 2nd docking, the "flag" check showed the capture latches on the probe were not cocked; recycling the switch produced a cocked indication.	The Apollo Operations Handbook has been revised to clarify the procedure for extending the probe. Closed.

TABLE IV (CONTINUED)

DESCRIPTION	REMARKS
CSM would not respond to multiple uplink realtime commands for about 10 hours; only the first command was accepted. The problem was cleared by cycling the up-telemetry command reset switch.	Caused by flight hardware associated with the message-acceptance pulse.
The CM computer failed twice to respond properly to programs entered by DSKY. The ground verified correct loading except for the last entry, which is not monitored.	Probably caused by procedural error in making the last entry on the DSKY. Closed.
The entry monitor system scribe did not continuously cut through the emulsion on the scroll during entry.	Caused by a leak in the scroll assembly which caused hardening of the emulsion. On Apollo 10, the scroll assembly will be leak tested and a sharper stylus will be used. Closed.
After recovery, one docking ring separation charge holder was out of its channel far enough to possibly foul or cut the parachute riser lines during deployment.	A spring has been incorporated to retain the charge holders on CM 106 and subsequent spacecraft. Closed.

TABLE V

LUNAR MODULE DISCREPANCY SUMMARY

DESCRIPTION	REMARKS
During the first 30 seconds of the 1st DPS burn, the supercritical helium regulator manifold pressure dropped to 180 psia and then recovered to a normal 240 psia. An anomalous pressure rise also occurred during prelaunch servicing.	Flow was probably blocked momentarily by freezing of air or other contaminants in the supercritical helium tank heat exchanger. Servicing equipment and procedures have been revised. Closed.
The DPS supercritical helium tank pressure began decaying at the end of the 1st DPS burn at a rate indicating a 0.1 lb/hr leak.	Possible leak upstream of the solenoid latch valve. The LM-4 flight configuration will be checked to assure adequate strength margins for thermal, vibration, and squib valve firing shock. The squib valve braze joints will also be tested.
The oxygen purge system light did not come on during a self-test prior to rendezvous, after being erratic earlier.	Failure of the main power switch actuator mechanism, which has been redesigned for Apollo 10 and subs. Closed.
The LMP's push-to-talk switches on the umbilical and on the attitude controller were inoperative after about 89 hours GET. LMP used the VOX mode for remainder of LM operations.	Probably caused by a discontinuity (broken wire) in the common wire to the push-to-talk switches which are in parallel. Closed.
The abort guidance system (AGS) warning light remained on continuously in standby and operating modes during period five. The AGS operated nominally throughout the mission.	Probably a malfunction of the caution and warning circuitry, but the failure mode cannot be identified because the AGS parameters are not displayed or telemetered. Closed.
The DPS engine was rough for a few seconds at 27% throttle during the second DPS burn.	Caused by helium trapped in the propellant lines during the previous SPS burns, which has no detrimental effect on the system. Closed.
The tracking light failed during ascent/descent staging.	Probably caused by a failure in the pulse forming network. Mission simulations are being run on the LM-4 light.

TABLE V (CONTINUED

DESCRIPTION	REMARKS
The Crewman Optical Alignment Sight (COAS) reticle was difficult to see during rendezvous.	Background light washed out the reticle image. On LM-4 and subsequent LM's, the light filter will be replaced with a diffuser lens and a detachable filter assembly will be provided. Closed.
At the start of the APS burn to depletion, the helium pressure to the propellant tanks regulated at 177 psia instead of the expected 185 psia. At 290 seconds, the pressure increased from 176 to 180 psia.	Possible failure modes will be simulated on a regulator and the behavior of the regulated pressure will be determined. The presently identified types of failure that can cause a downward shift in regulation pressure produce no detrimental effects in DPS operation.
The Data Entry and Display Assembly operator error light remained on, and multiple depression of the "Clear" button was required to extinguish the light.	Probably caused by failure of contacts to close on one of the two switches in the "Clear" pushbutton. Closed.
When the forward hatch was opened for EVA, it tended to bind at the top and it also would not stay open.	A thermal blanket which interfered with the hatch will be retained with tape on LM-4. The door stop is being studied for possible improvement.

MISSION SUPPORT

LAUNCH COMPLEX

No major problems occurred during the terminal countdown. Launch damage to the pad was minimal and ground system performance was as expected.

NETWORK

Overall mission support by the Mission Control Center and the Manned Space Flight Network was considered satisfactory throughout the mission. Mission Control Center hardware, communications, and computer systems experienced very few problems with no major data losses. Network telemetry, tracking, and command support were satisfactory. The few failures which were experienced had minimal impact on Mission Control Center operations. Carnarvon was the only site which had persistent support problems in that the command and telemetry computers experienced outages.

HF communications reception during some periods was marginal at several sites; however, the requirement for HF communications was kept at a minimum by using satellite communications systems when possible. Although several minor communications outages were experienced, no significant data losses were experienced. A number of significant problems were experienced with air-to-ground communications primarily because of ground procedural errors.

The most significant anomalies and discrepancies are presented in Table VI.

TABLE VI

MISSION SUPPORT DISCREPANCY SUMMARY

DESCRIPTION	REMARKS
During the fourth revolution, over Guaymas, air-to-ground voice was lost for approximately 6 minutes.	Caused by a procedural error at the Mission Control Center, which had been improperly configured for the transmissions.
During extravehicular activity, air-to-ground transmissions to the spacecraft were lost from Guaymas, Texas, Merrit Island, Bermuda, and USNS Vanguard stations. Downlink voice was remoted to the Mission Control Center nominally during the same period.	The loss of uplink capability was caused by a combination of the stations being configured to uplink S-band only (rather than S-band and VHF simultaneously) and the spacecraft crew having the S-band volume fully decreased as planned. The problem was further complicated by the inability to transmit VHF voice from Bermuda because of a simultaneous transmission on that frequency from the LM and a suppression of the VHF uplink by the continuously keyed Portable Life Support System.
Air-to-ground communications were lost for approximately 3 minutes over Texas during revolution 119.	Caused by a patching error at Texas.