111.3
111.5
111.5
111.3

April 14, 1969

A PRIMER

THE U.S. MANNED SPACE FLIGHT PROGRAM

Mercury Gemini Apollo

SATURN HISTORY DOCUMENT
University of Alabama Research Institute
History of Science & Technology Group
Date ---------- Doc. No. --------

CONTENTS

WHY EXPLORE THE MOON?

(Excerpt from statement to Congress March 11, 1969 by Dr. George E. Mueller, NASA Associate Administrator for Manned Space Flight)

Let us look first at why lunar exploration is of great importance to our nation. To the scientific world, there is great interest in the origin and history of the Moon and its relation to the Earth, and to the solar system. Was it formed with the Earth, or captured later? Are there clues to the origin of life? To quote the President's Science Advisory Committee, "Answers to these questions may profoundly affect our views of the evolution of the solar system and its place, as well as man's, in the larger scheme of things."

Many planets have moons, but ours is the largest in relation to its planet. This implies that the two bodies may have been formed in the same manner at the same time. If true, the moon may be a book containing the secret of the earth's first billion years of life. This record is lost on the earth which is subjected to the wear and tear of erosion by atmosphere and water.

Until now natural phenomena that can affect man could be studied only on Earth. Now we believe many things that happen on Earth also happen on the Moon. By comparing similarities and contrasting differences, man may be able to arrive at a greater understanding of the fundamental processes that affect the Earth; for example, the mechanisms that cause earthquakes and volcanic eruptions, and the processes responsible for concentrating ore deposits. The orbits of Apollo 8 and the Lunar Orbiters were disturbed by mass concentrations beneath the circular lunar seas. These may be hugh meteors that struck the Moon with such force that they melted and sank into the interior, or they may be iron deposits.

Another objective of lunar exploration is to learn about man as a space explorer--his capabilities and limitations. Some day man will move on to other planets; the Moon is a training ground.

It is difficult to look far ahead. We don't have the basic information which early lunar landings will furnish and we can only speculate today about the feasibility of the Moon as a base for an observatory or a permanent science station--about exploiting its environment of low gravity and high vacuum--about its potential for natural resources.

-more-

The eventual goal of a lunar base would bring into focus the steps that must precede it, just as Apollo was important in establishing the objectives of Mercury, Gemini, Surveyor, and Orbiter. Critical to future considerations of a lunar base goal is information on the lunar environment, location of natural resources and strategic sites that could serve multiple purposes. A long-range goal like the lunar base would direct technological advances, stimulate public interest, and attain subsidiary objectives with Earth application such as food synthesis, environmental control, and recovery of useful elements from rock.

To summarize the points I have made, through exploring the Moon we hope to make fundamental advances in:

1. Understanding dynamic processes on Earth through direct comparison of the Earth and Moon.

2. Evaluating the natural resources of the Moon and its potential as a base.

3. Extending the potential of man to function as an explorer on another planet.

4. Understanding the solar system and its origin, including clues to the origin of life.

-more-

APOLLO HISTORICAL SUMMARY

Initial planning for a launch vehicle having a payload capability of the Saturn I began in April 1957. In August 1958, studies concluded that a clustered booster of 1.5 million pounds thrust was feasible and the research and development effort was begun. Initial results proved that the engine clustering technique, using existing hardware, could furnish large amounts of thrust.

Rocketdyne, a divison of North American Rockwell Corp., updated the Thor-Jupiter engine, increased its thrust, thus developing the 200,000 pound thrust H-1 engine. Concurrently, from advanced studies, the 1.5 million pound thrust F-1 engine was conceived and subsequently used as the power plant for the even larger boosters.

In October 1958, the Army team moved to develop a high-performance booster for advanced space missions. Tentatively called Juno V and finally designated Saturn, the booster was turned over to NASA in later 1959.

In July 1960, NASA first proposed publicly a post-Mercury program for manned flight and designated it Project Apollo. The Apollo goals envisioned at that time were earth-orbital and circumlunar flights of a three-man spacecraft.

During 1960, Douglas Aircraft Company, Inc. (now McDonnell Douglas) was selected to build the Saturn I second stage (S-IV) and Rocketdyne was chosen to develop the hydrogen fueled J-2 engine for future upper stages of the Saturn vehicles.

On May 25, 1961, President John F. Kennedy proposed to Congress that the United States accelerate its space program, establishing as a national goal a manned lunar landing and return by the end of this decade. In his report to Congress President Kennedy said:

"Now is the time... for this nation to take a clearly leading role in space achievement, which in many ways may hold the key to our future on earth.

"...this is not merely a race. Space is open to us now; and our eagerness to share its meaning is not governed by the efforts of others. We go into space because whatever mankind must undertake, free men must fully share.

"No single space project in this period will be more impressive to mankind or more important for the long-range exploration of space...

"Let it be clear...that I am asking the Congress and the Country to accept a firm commitment to a new course of action, a course which will last for many years and carry very heavy costs... If we are to go only halfway, or reduce our sights in the face of difficulty, in my judgment it would be better not to go at all."

With endorsement by Congress, the national objective of manned lunar exploration created an immediate need for a considerably more powerful booster later designated the Saturn V. Following another six-month study, NASA announced in January 1962 that the Saturn V, using a cluster of five F-1 engines, would generate 7.5 million pounds of thrust, thus providing the liftoff power for the lunar landing program. After announcing that NASA would undertake the task of developing the Saturn V, contracts were awarded to Boeing Company and North American to build the first two stages of the Saturn V.

The second stage has a cluster of five J-2 engines developing a combined thrust of one million pounds. The third stage (S-IVB) and instrument unit were already under development for the smaller Saturn by Douglas Aircraft and IBM, respectively.

Later in 1962, NASA announced it was developing the Saturn IB which combined the first stage of the Saturn I and the top stage of the Saturn V for earth orbital tests of the Apollo spacecraft.

On August 9, 1961, MIT was selected to develop the Apollo spacecraft guidance and navigation system. Three and a half months later, NASA selected North American Rockwell Corp. for the Apollo spacecraft command and service module program.

In mid-July 1962, the National Aeronautics and Space Administration selected the lunar orbital rendezvous mode for the lunar mission. This called for development of a two-man lunar module to be used for landing on the moon and returning to lunar orbit. Grumman Aircraft Engineering Corp. was selected to design and build the lunar module on November 7, 1962.

One year later, the first Apollo command module was flown at White Sands Missile Range in a launch pad abort test. The first high altitude abort was successfully demonstrated on May 13, 1964. Fifteen days later a Saturn I placed the first Apollo command module into orbit from Cape Kennedy.

The first full systems Apollo command module was launched aboard a Saturn IB, and successfully tested the module's reentry heat shield. The February 26, 1966 test was also the first flight of a Saturn IB.

The first phase of the Saturn launch vehicle program was completed in 1965. In ten flights of the Saturn I, ten were successful -- an unprecedented record in rocket development. Much technology was proven in the Saturn I program. The rocket guidance system was developed. The concept of clustered rocket engines was validated and, the program supplied experience in using liquid hydrogen as rocket fuel. Liquid hydrogen provides double the fuel economy of earlier fuels.

The Saturn IB launch vehicle was successfully flown three times in three attempts in 1966 and is considered ready for manned flights. Two of these flights carried spacecraft to space where they satisfactorily completed requirements for Apollo command and service modules in earth orbital operations. The first Apollo lunar module flight and first Apollo/Saturn V flight are planned this fall.

On January 27, 1967, tragedy struck the national space effort when a fire erupted inside an Apollo spacecraft during ground testing at Cape Kennedy, resulting in the deaths of Astronauts Virgil Grissom, Edward White II and Roger Chaffee. After two and a half months of investigation, involving 1,500 people, the Board of Inquiry determined that the most likely cause of the fire was electrical arcing from certain spacecraft wiring. After the Board of Inquiry's report to Congressional committees, the National Aeronautics and Space Administration followed with detailed descriptions of corrective actions, schedule modifications, and cost estimates necessary to move the program toward its objective.

On November 9, 1967, the first flight test of the Apollo/Saturn V space vehicle was successfully accomplished. Designated Apollo 4, the unmanned flight demonstrated performance of the previously unflown first and second Saturn V stages, the restart-in-orbit capability of its third stage, the Apollo spacecraft ability to reenter Earth's atmosphere at lunar mission return speeds, performance of the integrated space vehicle, and the operational readiness of Kennedy Space Center Launch Complex 39. All mission objectives were met following an on-time launching and an 8-hour 37-minute mission. The Saturn V placed a total weight into orbit of over 278,699 pounds after a near perfect countdown. The spacecraft heat shield performed satisfactorily during the 24,800 mile per hour plunge into Earth's atmosphere.

During the January 22-23, 1968 Apollo 5 mission, lunar module systems and structural performance met all objectives, including two firings of both the ascent and descent propulsion systems. The unmanned Lunar Module I was boosted into Earth orbit by a Saturn IB. Post-flight analysis determined the lunar module ready for manned Earth orbital missions.

The April 4, 1968 flight of Apollo 6 was the second unmanned Saturn V mission to demonstrate launch vehicle and spacecraft systems performance. Two problems were experienced with the rocket systems -- vertical oscillations or "POGO" effect in the first stage and rupture of small propellant lines in the upper stages -- in an otherwise, very successful mission.

The precise reentry and splashdown on October 22, 1968 of the 11-day Apollo 7 flight ended what was called a 101 percent successful mission. Manned by Astronauts Walter Schirra, Donn Eisele, and Walt Cunningham, the Apollo 7 performed flawlessly for more than 780 hours in space, including 8 firings of the spacecraft's primary propulsion system and the first live TV from a manned vehicle.

Apollo 8 lifted off precisely on time, December 21, 1968 from the Kennedy Space Center for history's first flight from Earth to another body in the solar system. Apollo 8 performed flawlessly for 147 hours and over a half million miles of space flight which included ten revolutions around the Moon, lunar and Earth photography, and live television broadcasts.

Apollo 9 splashed down in the Atlantic Ocean, northeast of Puerto Rico, at 12:00:53 EST, March 13, 1969, after a 10-day, 6-million mile Earth orbital mission. All major mission objectives were met in the first 5 days of the flight. Apollo 9 was the first all-up manned flight of the Apollo Saturn V space vehicle, first manned flight of the lunar module, first Apollo EVA, and included rendezvous and docking, live television, photographic surveys of Earth, and observation of Pegasus II satellite and Jupiter. This was the fourth Saturn V on-time launch (11:00am EST).

APOLLO LUNAR LANDINGS

Primary objective of the first Apollo lunar landing mission is to prove the Apollo system by achieving a successful Moon landing and safe return to Earth.

During the first landing, plans call for the two astronauts to leave the spacecraft and spend up to three hours on the Moon's surface. During this time they will make observations and photograph the area in the vicinity of the landed spacecraft in addition to collecting the samples and deploying scientific instruments.

The astronauts will perform their tasks in an order of increasing complexity. At each level of activity, scientific and medical data on the expenditure of energy by the astronauts will be obtained. This will ensure adequate monitoring of their ability to perform in the vacuum, extreme temperature and one-sixth gravity of the Moon and will provide important data which will permit the planning of longer and more complex missions for the future.

The scientific experiments, Early Apollo Scientific Experiments Payload (EASEP), are a passive seismometer, a laser ranging retro-reflector and a solar wind composition experiment.

The passive seismometer is a self-contained seismic station with its own Earth-Moon communications link. It is powered by solar cells and may be provided with radioisotope heaters to enable it to survive the extremely cold lunar nights for up to a year. It will provide data on the internal activity of the Moon.

If the Moon is seismically active, information on its structure can be obtained. These data will assist in determining the validity of current concepts about the Moon and its origin and perhaps lead to new concepts. Dr. Gary Latham of Columbia University's Lamont Geological Observatory, Palisades, N.Y., is experimenter.

The laser ranging retro-reflector is a wholly passive experiment consisting of an array of precision optical reflectors which serve as a target for Earth-based laser systems. Data obtained will improve the measurement of Earth-Moon distances and the fluctuation of the Earth's rotation rate.

Measurements of the variations in the gravitational constant "G" also will be improved. The theory of intercontinental drift can be tested by direct measurements from different continents. Dr. Carroll O. Alley of the University of Maryland, College Park, and Dr. Donald Eckhardt of the Air Force Cambridge Research Laboratory, Cambridge, Mass., have experiments of this type under development.

The solar wind composition experiment is designed to entrap the noble gases (Helium, Neon, Argon, Krypton, Xenon) in the solar wind. It consists of a sheet of aluminum foil which is placed across the solar wind. It is retrieved before the astronauts leave the Moon and return to Earth for analysis. The one-pound experiment is developed and funded by the Swiss government. Dr. Johannes Geiss of the University of Berne is experimenter.

On the second, third and fourth lunar landing missions, NASA plans to have the astronauts deploy a full geophysical station or Apollo Lunar Surface Experiments Package (ALSEP) and conduct a detailed field geology investigation. ALSEP instrumentation will provide for passive and active lunar seismic experiments, lunar tri-axis magnetometers, medium and low energy solar wind experiments, suprathermal ion detectors and cold cathode ionization guages.

Lunar surface samples returned to Earth will be thoroughly analyzed by 142 scientists and the data made available to the world scientific community.

ESTIMATED COST OF NASA MANNED LUNAR LANDING PROGRAM
(January 1969)

Apollo Spacecraft	$7,945,000,000
Saturn I Launch Vehicles	767,100,000
Saturn IB Launch Vehicles	1,131,200,000
Saturn V Launch Vehicles	6,871,100,000
Launch Vehicle Engine Development	854,200,000
Mission Support	1,432,300,000
Tracking and Data Acquisition	664,100,000
Ground Facilities	1,830,300,000
Operation of Installations	2,420,600,000
TOTAL	$23,915,900,000

GEMINI	
Spacecraft	797,400,000
Launch Vehicles	409,800,000
Support	76,200,000
TOTAL	$1,283,400,000

MERCURY	
Spacecraft	135,300,000
Launch Vehicles	82,900,000
Operations	49,300,000
Tracking Operations and Equipment	71,900,000
Facilities	53,200,000
	$392,100,000

APOLLO MISSION COSTS
(included in Total Estimated Costs, above)

Apollo 7	$145 million
Apollo 8	310 million
Apollo 9	340 million
Apollo 10 and subsequent lunar missions	350 million

APOLLO PROGRAM FLIGHT SUMMARY

Mission Designation	Mission Dates	Mission Description
Apollo Saturn IB (AS-201)	February 26, 1966	--Unmanned, suborbital, space vehicle development flight, demonstrated space vehicle compatibility and structural integrity; spacecraft heat shield qualification for Earth orbital reentry speeds.
Apollo Saturn IB (AS-203)	July 5, 1966	--Unmanned, orbital, launch vehicle development flight; demonstrated second stage restart and cryogenic propellants storage at zero g conditions. Liquid hydrogen pressure test.
Apollo Saturn IB (AS-202)	August 25, 1966	--Unmanned, suborbital, space vehicle development flight; demonstrated structural integrity and compatibility, spacecraft heat shield performance.
Apollo 4	November 9, 1967	--First Apollo Saturn V flight, unmanned, Earth orbital to 11,234 miles apogee, space vehicle development flight. Demonstrated Saturn V rocket performance and Apollo spacecraft heat shield for lunar mission reentry speeds.
Apollo 5	January 22-23, 1968	--First Apollo lunar module flight on Saturn IB, unmanned, Earth orbital. Demonstrated spacecraft systems performance, ascent and descent stage propulsion firings and restart, and staging.
Apollo 6	April 4, 1968	--Second flight of Saturn V, unmanned, Earth orbital, launch vehicle development flight. Demonstrated Saturn V rocket performance and Apollo spacecraft subsystems and heat shield performance.

-more-

Mission Designation	Mission Dates	Mission Description
Apollo 7	October 11-22, 1968	--First manned Apollo flight, Earth orbital, demonstrated spacecraft, crew and support element performance. Highly successful flight lasting 10 days 20 hours, including 8 major propulsion system firings and first live TV from manned spacecraft.
Apollo 8	December 21-27, 1968	--History's first manned flight from Earth to another body in solar system; included 10 revolutions around the Moon (20-hour period) and safe return to Earth, TV and photography of Moon and Earth by astronauts.
Apollo 9	March 3-13, 1969	--Apollo 9 was the first all-up manned flight of the Apollo Saturn V space vehicle, first manned flight of the lunar module, first Apollo EVA, and included rendezvous and docking, live television, photographic surveys of Earth, and observation of Pegasus II satellite and Jupiter. All mission objectives successfully completed.

-more-

APOLLO APPLICATIONS PROGRAM

The Apollo Applications Program, the National Aeronautics and Space Administration's manned flight program to follow the lunar landing, will consist of long duration Earth orbital missions during which astronauts will carry out scientific, technological and engineering experiments.

The Saturn launch vehicles and spacecraft developed for the Moon exploration program will be modified to provide the capability for crews to remain in Earth orbit for up to 56 days.

The first phase of the Apollo Applications Program will be the Saturn I Workshop missions planned for 1971 and 1972. The workshop, consisting of a modified Saturn upper stage, airlock and docking adapter, will provide living quarters and laboratory area for three men to orbit the Earth. Three visits to the workshop are planned, the first of 28 days duration and two of up to 56 days. Orbital altitude will be about 200 nautical miles.

Scientific, engineering, technological and biomedical experiments are planned to be carried out in the Saturn I Workshop. Included are experiments for the Department of Defense in support of its Manned Orbiting Laboratory Program. Scientific experiments of special interest are multi-band Earth terrain photography and telescopes to observe the activities of the sun unobstructed by the Earth's atmosphere. Much attention will be given to biomedical experiments to investigate how the human body functions in zero gravity over longer periods of time and if any biological changes occur.

The liquid hydrogen fuel tank of a Saturn S-IVB stage will serve as the workshop's crew quarters and major work area. Volume of the tank is 10,000 cubic feet, the size of a large five-room house. Floors and walls of metal grating, wiring and other equipment will be installed inside the tank before launch but will not interfere with the propulsive function of the S-IVB, the second stage of the Saturn IB launch vehicle. An airlock attached to the vehicle stage will contain the power distribution, environmental control and equipment to support the workshop operation. Power will be provided by solar cells arranged on panels attached to the outside of the S-IVB stage. Personal equipment and experiments will be housed in the airlock docking adapter during the launch phase.

The workshop will be launched unmanned. After achieving orbit, the second stage will be purged of residual propellants and the hydrogen tank prepared for pressurization. One day later a second Saturn IB will orbit a crew of three astronauts in an Apollo command and service module.

After a rendezvous maneuver similar to those carried out in the Gemini program, astronauts will dock the spacecraft with the workshop and pressurize the airlock and hydrogen tank. After pressurization is accomplished, the crew will enter the hydrogen tank through tunnels in the docking adapter and airlock and install food and waste management systems, arrange their personal equipment and prepare the experiments.

Plans call for the first crew to remain in orbit four weeks. Before undocking the command module for the Earth return trip, the workshop will be prepared for the next crew visit.

About two months later the second crew will ferry to the workshop in an Apollo spacecraft launched by a Saturn IB. An extensive number of medical experiments are planned for this mission of about 56 days duration. Additional engineering and scientific experiments also will be included.

The third visit to the workshop will require launching of two Saturn IB vehicles. First, the three-man crew will be launched to reactivate the workshop and checkout its systems. A few days later, another Saturn IB will orbit the unmanned Apollo Telescope Mount, mated to the ascent stage of an Apollo lunar module.

The telescope mount will be commanded to rendezvous with the workshop. When it approaches within a few hundred feet of the workshop, the astronauts will dock the vehicle by radio commands into one of the hatches in the docking adapter located at a 90 degree angle to the docked command module-workshop spacecraft.

Through a console in the lunar module cabin the astronauts will visually scan the sun, select areas of interest on which to acquire data and point the instruments accordingly, while continuing to monitor much of the solar disc. Photographic film will be replaced and retrieved through extravehicular activity.

The Saturn I workshop missions will yield a wealth of information on the capability of man to live and work in space, types of equipment best suited for working in space, types of tools needed to maintain and repair space equipment and, very possibly, unforeseen scientific data of great significance.

LUNAR DESCRIPTION

Terrain - Mountainous and crater-pitted, the former rising thousands of feet and the latter ranging from a few inches to 180 miles in diameter. The craters are thought to be formed by the impact of meteorites. The surface is covered with a layer of fine-grained material resembling silt or sand, as well as small rocks.

Environment - No air, no wind, and no moisture. The temperature ranges from 250 degrees in the two-week lunar day to 280 degrees below zero in the two-week lunar night. Gravity is one-sixth that of Earth. Micrometeoroids pelt the Moon (there is no atmosphere to burn them up). Radiation might present a problem during periods of unusual solar activity.

Dark Side - The dark or hidden side of the Moon no longer is a complete mystery. It was first photographed by a Russian craft and since then has been photographed many times, particularly by NASA's Lunar Orbiter spacecraft.

Origin - There is still no agreement among scientists on the origin of the Moon. The three theories: (1) the Moon once was part of Earth and split off into its own orbit, (2) it evolved as a separate body at the same time as Earth, and (3) it formed elsewhere in space and wandered until it was captured by Earth's gravitational field.

Physical Facts

Diameter	2,160 miles (about $\frac{1}{4}$ that of Earth)
Circumference	6,790 miles (about $\frac{1}{4}$ that of Earth)
Distance from Earth	238,857 miles (mean; 221,463 minimum to 252,710 maximum)
Surface temperature	250 (Sun at zenith)-280 (night)
Surface gravity	1/6 that of Earth
Mass	1/100th that of Earth
Volume	1/50th that of Earth
Lunar day and night	14 Earth days each
Mean velocity in orbit	2,287 miles per hour
Escape velocity	1.48 miles per second
Month (period of rotation around Earth)	27 days, 7 hours, 43 minutes

LUNAR SITE SELECTION

The first Americans on the Moon will land in one of five three-by-five-mile landing areas selected by the National Aeronautics and Space Administration's Apollo Site Selection Board.

Each of the five landing areas satisfies criteria in which astronaut safety is the paramount consideration.

The places selected are ellipses around the following central points on the face of the Moon:

Site 1. 34 degrees East; 2 degrees, 40 minutes North.

Site 2. 23 degrees, 37 minutes East; 0 degrees, 45 minutes North.

Site 3. 1 degree, 20 minutes West; 0 degrees, 25 minutes North.

Site 4. 36 degrees, 25 minutes West; 3 degrees, 30 minutes South.

Site 5. 41 degrees, 40 minutes West; 1 degree, 40 minutes North.

The first two sites are in the Sea of Tranquillity, the third is in the Central Bay and the fourth and fifth are in the Ocean of Storms.

The five were selected from eight under study from a choice of 30 original sites. Selection of the five will permit scientists and engineers to concentrate on the fewer areas in preparing data on the specific sites.

The Board studied material obtained by unmanned Lunar Orbiters and soft-landing Surveyor spacecraft. Lunar Orbiter returned high resolution photographs of all the sites and Surveyor provided close-up photos and surface data of the general areas in which they are located.

Following are the criteria considered by the Board:

--Smoothness of area. The sites should have relatively few craters and boulders;

--Approach path. There should be no large hills, high cliffs or deep craters which would cause incorrect altitude signals to the landing radar;

--Propellant. The sites were selected to allow for the expenditure of the least amount of propellant by the lunar module propulsion systems.

-more-

--Recycling during countdown. The sites were selected to allow for the recycling time of the Apollo/Saturn V necessary if the countdown for launch at Kennedy Space Center is delayed;

--Free return. The sites must be within reach of the Apollo spacecraft in the "free-return" trajectory. On the free-return trajectory a spacecraft would coast around the Moon and return safely to Earth without requiring the operation of propulsion systems;

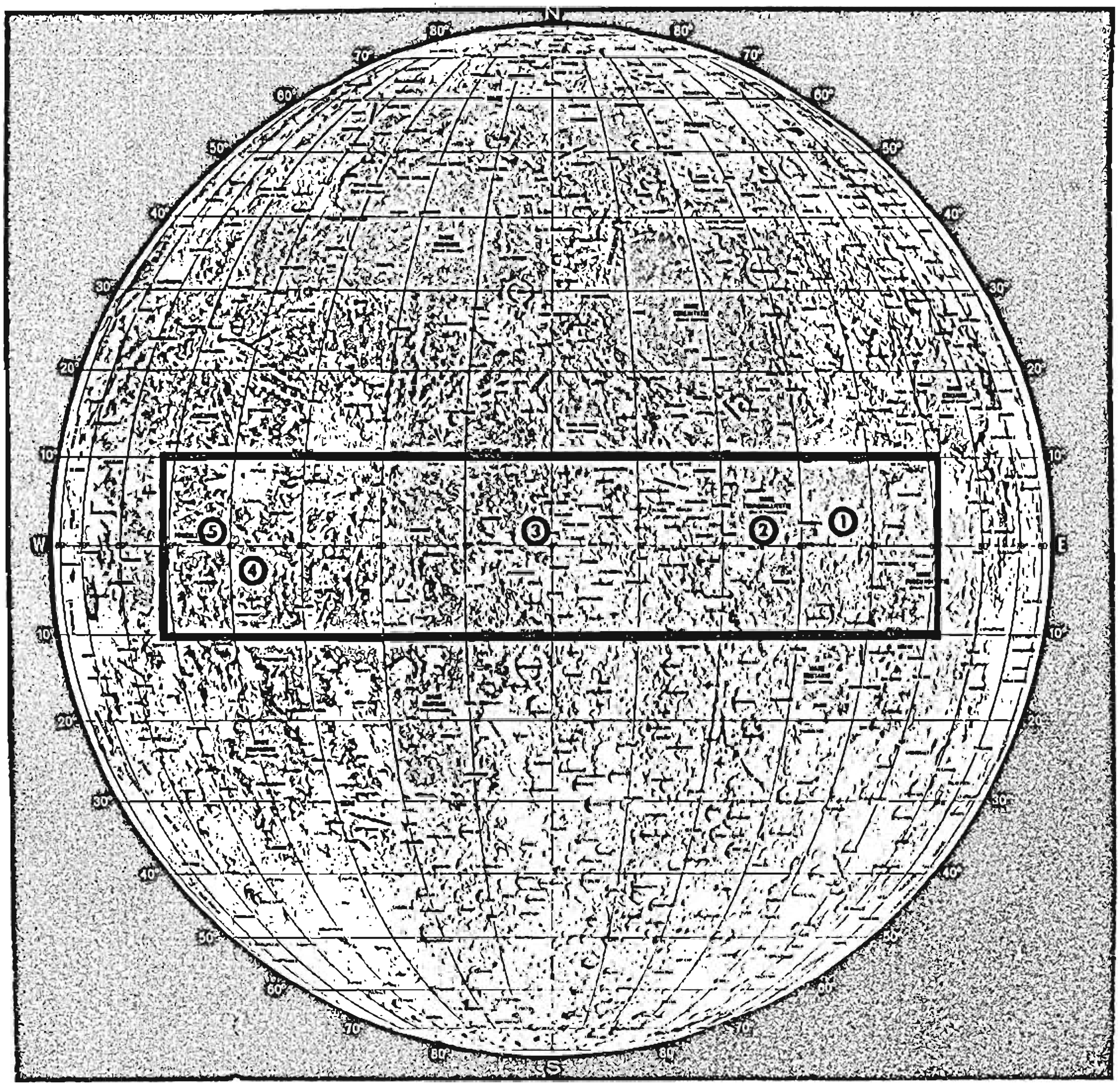
--Lighting. For optimum visibility by the astronauts the sites will have a Sun-angle of 7-20 degrees behind the lunar module as it approaches the landing;

--Slope. The general slope of the landing area and the approach to the landing site must be less than two degrees.

All sites are within the Apollo Zone of Interest--that area of the visible side of the Moon within 45 degrees east and west of the center of the Moon, and five degrees north and south of its equator.

The desired Sun-angle range of 7 to 21 degrees results in a one-day launch opportunity per month for a given site.

Before flight to the Moon, three of the five sites will be chosen for the specific mission. This will make a three-day period each month available for launching the prime Apollo flight.



-more-

APOLLO SPACECRAFT DESCRIPTION

COMMAND AND SERVICE MODULE STRUCTURE, SYSTEMS

The Apollo spacecraft is comprised of a Command module, service module, lunar module, a spacecraft-lunar module adapter (SLA) and a launch escape system. The SLA serves as a mating structure between the instrument unit atop the S-IVB stage of the Saturn V launch vehicle and as a housing for the lunar module.

Launch Escape System (LES)--Propels command module to safety in an aborted launch. It is made up of an open-frame tower structure mounted to the command module by four frangible bolts, and three solid-propellant rocket motors: a 147,000 pound-thrust launch escape system motor, a 2,400-pound-thrust pitch control motor and a 31,500-pound-thrust tower jettison motor. Two canard vanes near the top deploy to turn the command module aerodynamically to an attitude with the heat-shield forward. Attached to the base of the launch escape tower is a boost protective cover composed of glass, cloth and honeycomb, that protects the command module from rocket exhaust gases from the main and the jettison motor. The system is 33 feet tall, four feet in diameter at the base and weighs 8,000 pounds.

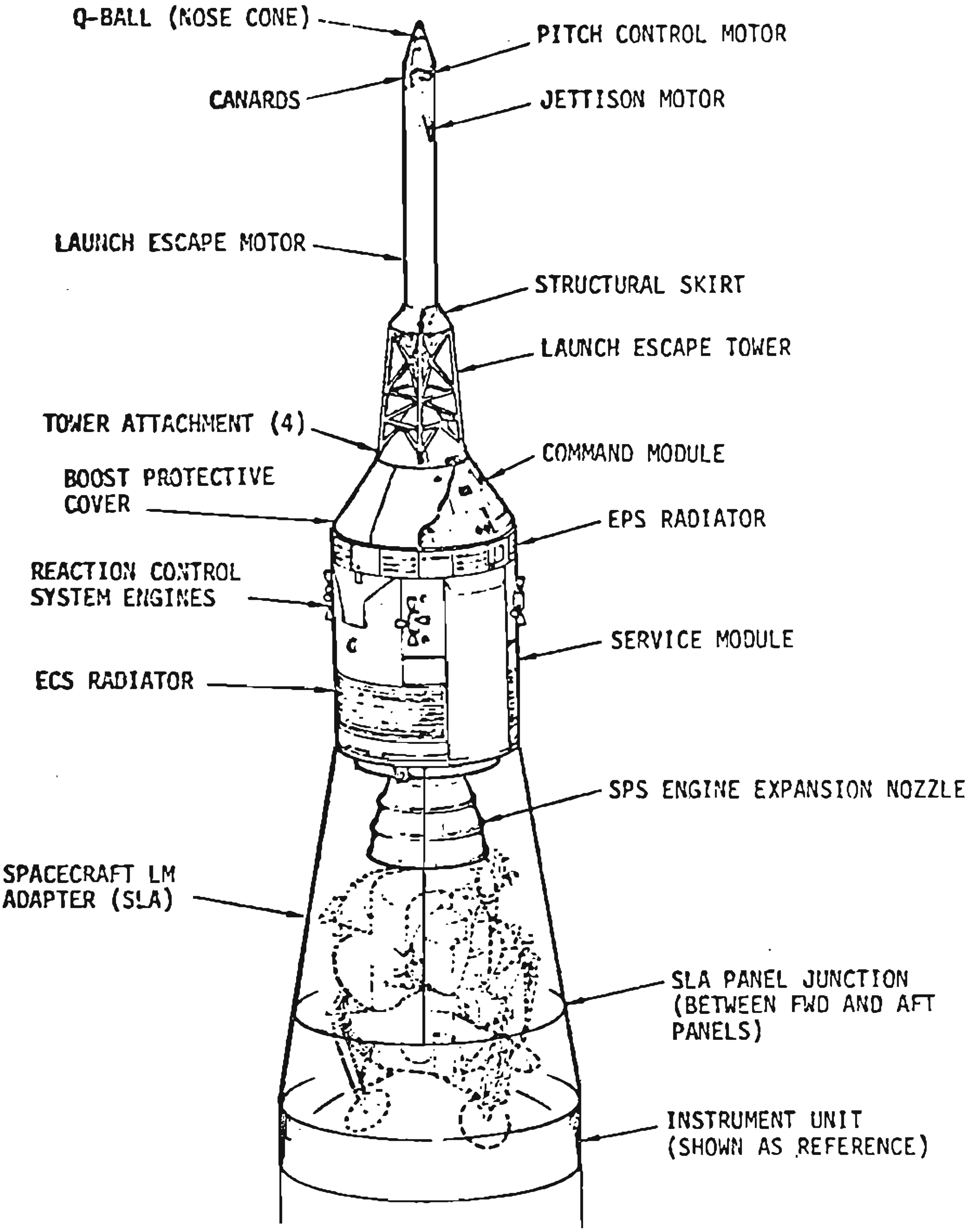
Command Module (CM) Structure--The basic structure of the command module is a pressure vessel encased in heat-shields, cone-shaped 12 feet high, base diameter of 12 feet 10 inches, and launch weight 13,000 pounds with crew.

The command module consists of the forward compartment which contains two negative pitch reaction control engines and components of the Earth landing system; the crew compartment, or inner pressure vessel, containing crew accommodations, controls and displays, and spacecraft systems; and the aft compartment housing ten reaction control engines and propellant tankage.

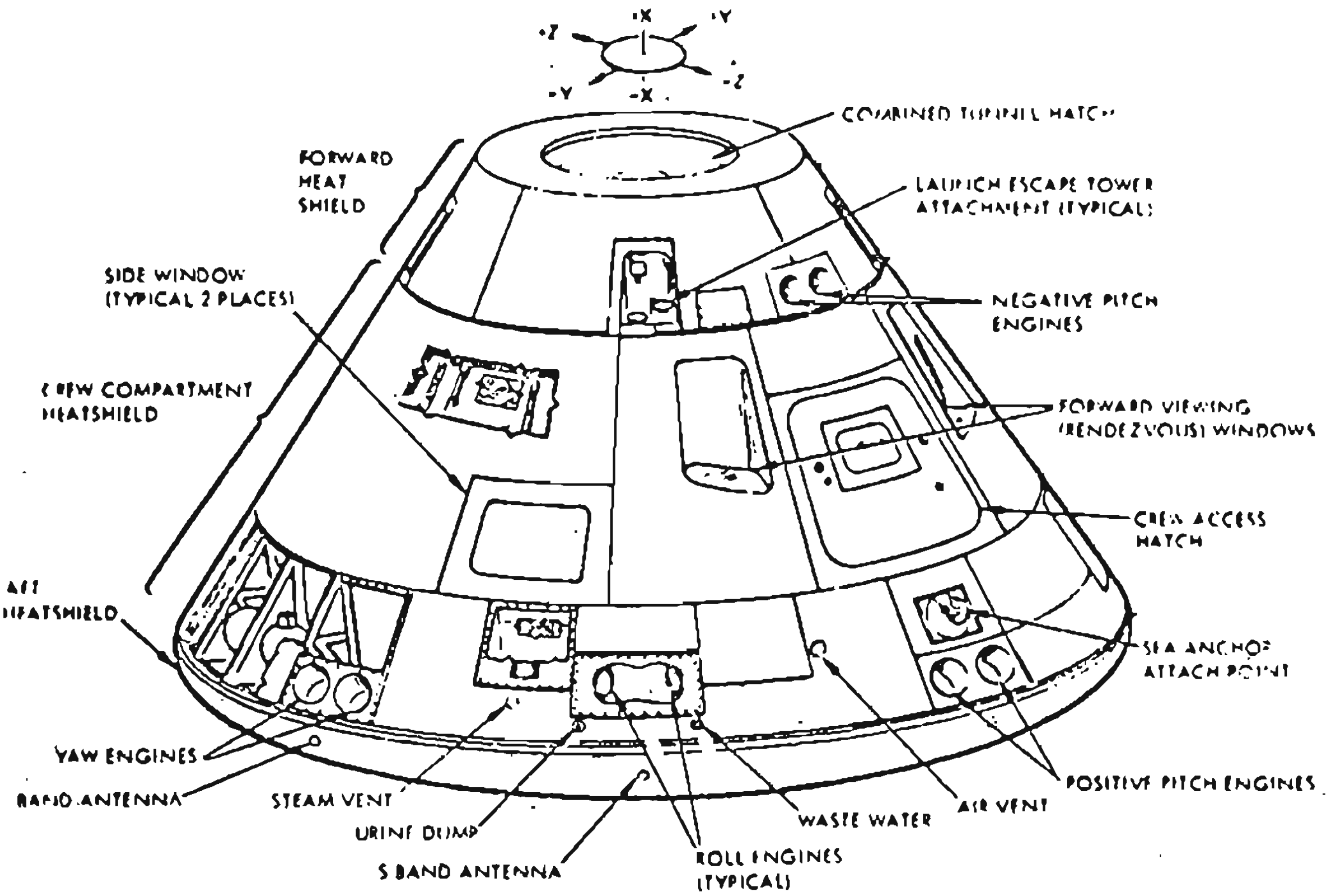
Heat-shields around the three compartments are made of brazed stainless steel honeycomb with an outer layer of phenolic epoxy resin as an ablative material. Heat-shield thickness, varying according to heat loads, ranges from 0.7 inches (at the apex) to 2.7 inches on the aft side.

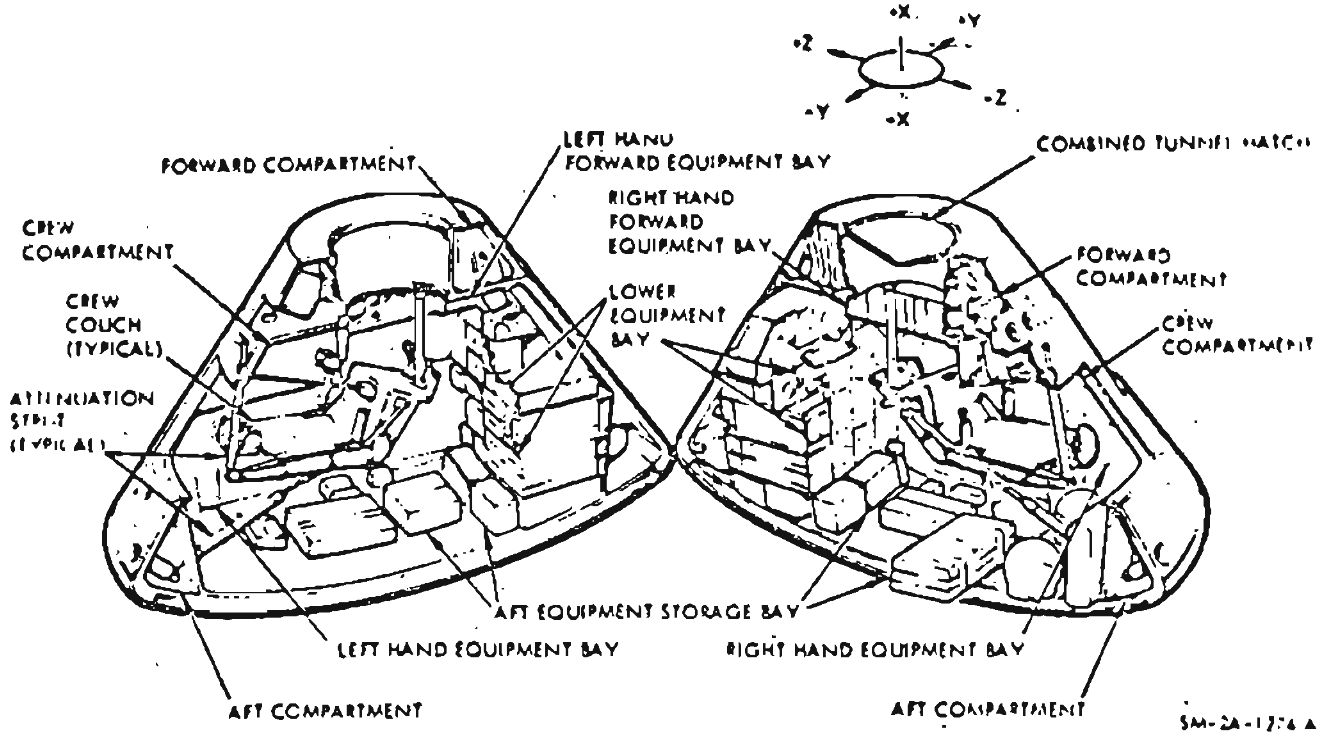
The spacecraft inner structure is of aluminum alloy sheet-aluminum honeycomb bonded sandwich ranging in thickness from 0.25 inches thick at forward access tunnel to 1.5 inches thick at base.

Docking hardware consists of a probe assembly, a folding coupling and impact attenuating device, mounted on the CM tunnel that mates with a conical drogue mounted on the LM docking tunnel. After the docking latches are dogged down following a docking maneuver, both the probe and drogue assemblies are removed from the vehicle tunnels and stowed to allow free crew transfer between the CSM and LM.



SPACECRAFT CONFIGURATION


+X
+Y
+Z
-Z
-Y
-X
COMBINED TUNNEL HATCH
FORWARD HEAT SHIELD
LAUNCH ESCAPE TOWER ATTACHMENT (TYPICAL)
SIDE WINDOW (TYPICAL 2 PLACES)
NEGATIVE PITCH ENGINES
CREW COMPARTMENT HEATSHIELD
FORWARD VIEWING (RENDEZVOUS) WINDOWS
CREW ACCESS HATCH
AFT HEATSHIELD
SEA ANCHOR ATTACH POINT
YAW ENGINES
RADIO ANTENNA
STEAM VENT
URINE DUMP
S BAND ANTENNA
ROLL ENGINES (TYPICAL)
WASTE WATER
AIR VENT
POSITIVE PITCH ENGINES


+X
+Y
+Z
-Z
-Y
-X
FORWARD COMPARTMENT
LEFT HAND FORWARD EQUIPMENT BAY
COMBINED TUNNEL HATCH
CREW COMPARTMENT
RIGHT HAND FORWARD EQUIPMENT BAY
FORWARD COMPARTMENT
CREW COUCH (TYPICAL)
LOWER EQUIPMENT BAY
CREW COMPARTMENT
ATTENUATION STRUT (TYPICAL)
AFT EQUIPMENT STORAGE BAY
LEFT HAND EQUIPMENT BAY
RIGHT HAND EQUIPMENT BAY
AFT COMPARTMENT
AFT COMPARTMENT

SM-2A-1274 A

Service Module (SM) Structure--The service module is a cylinder 12 feet 10 inches in diameter by 22 feet long. For the Apollo 9 mission, it weighed about 51,000 at launch. Aluminum honeycomb panes one inch thick form the outer skin, and milled aluminum radial beams separate the interior into six sections containing service propulsion system and reaction control fuel-oxidizer tankage, fuel cells, cryogenic oxygen and hydrogen, and onboard consumables.

Spacecraft-LM Adapter (SLA) Structure--The spacecraft LM adapter is a truncated cone 28 feet long tapering from 260 inches diameter at the base to 154 inches at the forward end at the service module mating line. Aluminum honeycomb 1.75 inches thick is the stressed-skin structure for the spacecraft adapter. The SLA weighs 4,000 pounds.

CSM Systems

Guidance, Navigation and Control System (GNCS)--Measures and controls spacecraft position, attitude and velocity, calculates trajectory, controls spacecraft propulsion system thrust vector and displays abort data. The Guidance System consists of three subsystems: inertial, made up of an inertial measuring unit and associated power and data components; computer which processes information to or from other components; and optics, including scanning telescope, sextant for celestial and/or landmark spacecraft navigation.

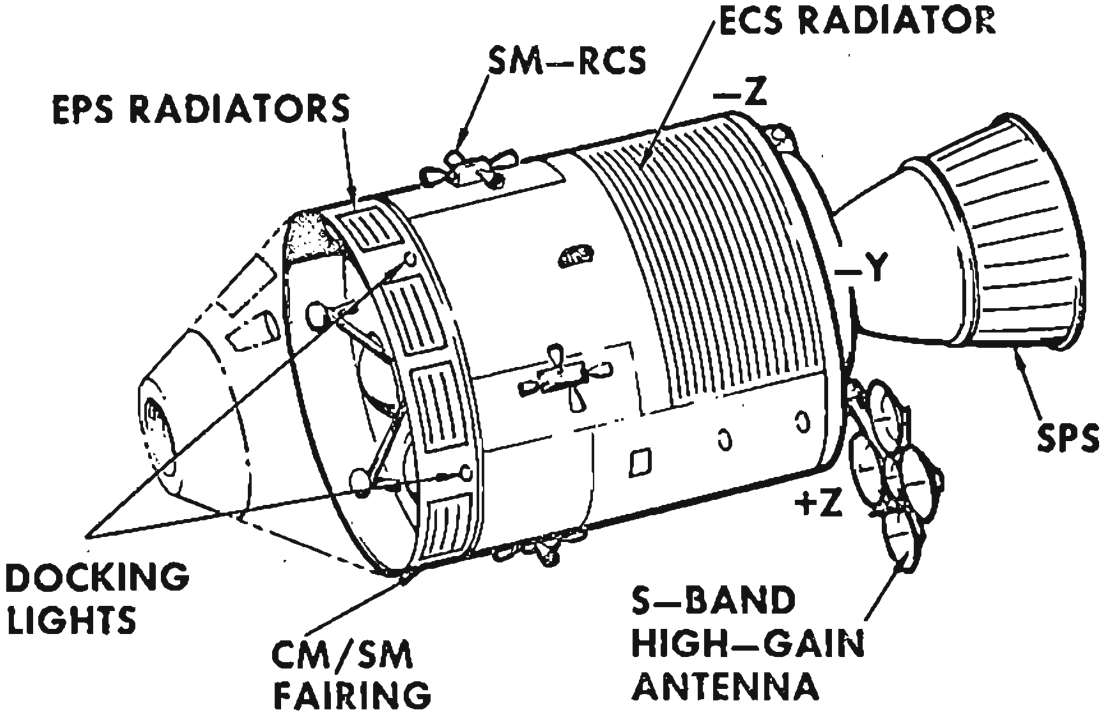
Stabilization and Control System (SCS) --Controls spacecraft rotation, translation and thrust vector and provides displays for crew-initiated maneuvers; backs up the guidance system. It has three subsystems; attitude reference, attitude control and thrust vector control.

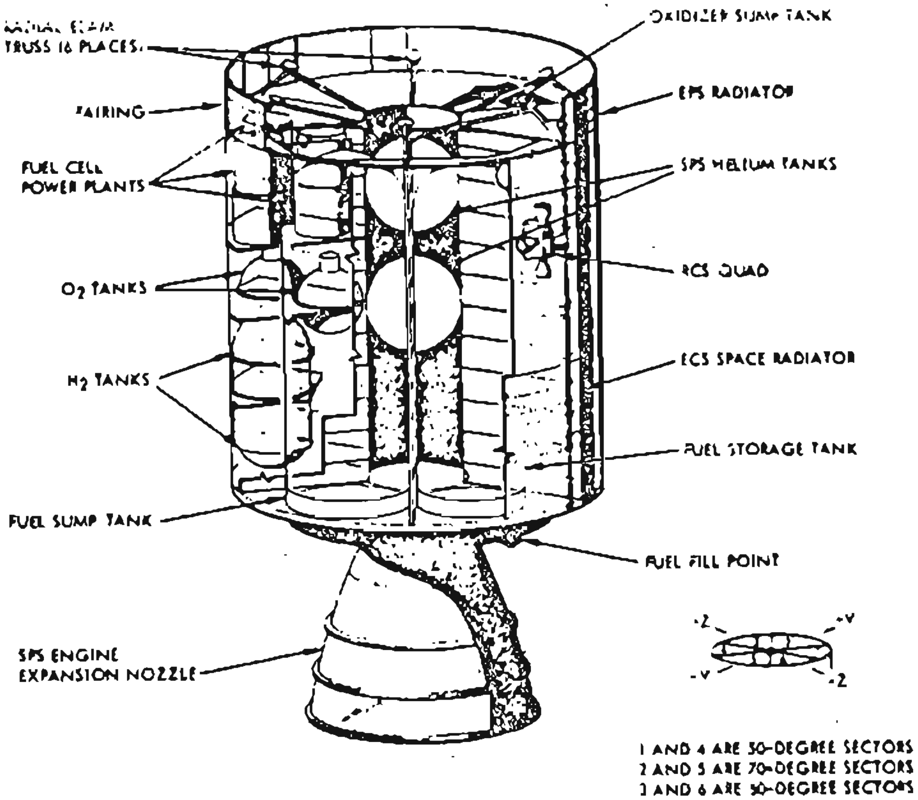
Service Propulsion System (SPS)--Provides thrust for large spacecraft velocity changes through a gimbal-mounted 20,500-pound-thrust hypergolic engine using nitrogen tetroxide oxidizer and a 50-50 mixture of unsymmetrical dimethyl hydrazine and hydrazine fuel. Tankage of this system is in the service module. The system responds to automatic firing commands from the guidance and navigation system or to manual commands from the crew. The engine provides a constant thrust rate. The stabilization and control system gimbals the engine to fire through the spacecraft center of gravity.

Reaction Control System (RCS)--The Command Module and the Service Module each has its own independent system, the CM RCS and the SM RCS respectively. The SM RCS has four identical RCS "quads" mounted around the SM 90 degrees apart. Each quad has four 100 pound-thrust engines, two fuel and two oxidizer tanks and a helium pressurization sphere. The SM RCS provides redundant spacecraft attitude control through cross-coupling logic inputs from the Stabilization and Guidance Systems.

SERVICE MODULE

BLOCK II





Small velocity change maneuvers can also be made with the SM RCS. The CM RCS consists of two independent six-engine subsystems of six 94 pounds-thrust engines each. Both subsystems are activated after separation from the SM: one is used for spacecraft attitude control during entry. The other serves in standby as a backup. Propellants for both CM and SM RCS are monomethyl hydrazine fuel and nitrogen tetroxide oxidizer with helium pressurization. These propellants are hypergolic, i.e., they burn spontaneously when combined without need for an igniter.

Electrical Power System (EPS)--Consists of three, 31-cell Bacon-type hydrogen-oxygen fuel cell power plants in the service module which supply 28-volt DC power, three 28-volt DC zinc-silver oxide main storage batteries in the command module lower equipment bay, and three 115-200-volt 400 hertz three-phase AC inverters powered by the main 28-volt DC bus. The inverters are also located in the lower equipment bay. Cryogenic hydrogen and oxygen react in the fuel cell stacks to provide electrical power, potable water and heat. The command module main batteries can be switched to fire pyrotechnics in an emergency. A battery charger restores selected batteries to full strength as required with power from the fuel cells.

Environmental Control System (ECS)--Controls spacecraft atmosphere, pressure and temperature and manages water. In addition to regulating cabin and suit gas pressure, temperature and humidity, the system removes carbon dioxide, odors and particles, and ventilates the cabin after landing. It collects and stores fuel cell potable water for crew use, supplies water to the glycol evaporators for cooling, and dumps surplus water overboard through the urine dump valve. Proper operating temperature of electronics and electrical equipment is maintained by this system through the use of the cabin heat exchangers, the space radiators and the glycol evaporators.

Telecommunications System--Provides voice, television telemetry and command data and tracking and ranging between the spacecraft and earth, between the command module and the lunar module and between the spacecraft and the extravehicular astronaut. It also provides intercommunications between astronauts. The telecommunications system consists of pulse code modulated telemetry for relaying to Manned Space Flight Network stations data on spacecraft systems and crew condition, VHF/AM voice, and unified S-Band tracking transponder, air-to-ground voice communications, onboard television (not installed on CM 104) and a VHF recovery beacon. Network stations can transmit to the spacecraft such items as updates to the Apollo guidance computer and central timing equipment, and real-time commands for certain onboard functions. More than 300 CSM measurements will be telemetered to the MSFN.

The high-gain steerable S-Band antenna consists of four, 31-inch-diameter parabolic dishes mounted on a folding boom at the aft end of the service module. Nested alongside the service propulsion system engine nozzle until deployment, the antenna swings out at right angles to the spacecraft longitudinal axis, with the boom pointing 52 degrees below the heads-up horizontal. Signals from the ground stations can be tracked either automatically or manually with the antenna's gimballing system. Normal S-Band voice and uplink/downlink communications will be handled by the omni and high-gain antennas.

Sequential System--Interfaces with other spacecraft systems and subsystems to initiate time critical functions during launch, docking maneuvers, pre-orbital aborts and entry portions of a mission. The system also controls routine spacecraft sequencing such as service module separation and deployment of the Earth landing system.

Emergency Detection System (EDS)--Detects and displays to the crew launch vehicle emergency conditions, such as excessive pitch or roll rates or two engines out, and automatically or manually shuts down the booster and activates the launch escape system; functions until the spacecraft is in orbit.

Earth Landing System (ELS)--Includes the drogue and main parachute system as well as post-landing recovery aids. In a normal entry descent, the command module forward heat shield is jettisoned at 24,000 feet, permitting mortar deployment of two reefed 16.5-foot diameter drogue parachutes for orienting and decelerating the spacecraft. After disreef and drogue release, three pilot mortar deployed chutes pull out the three main 83.3-foot diameter parachutes with two-stage reefing to provide gradual inflation in three steps. Two main parachutes out of three can provide a safe landing.

Recovery aids include the uprighting system, swimmer interphone connections, sea dye marker, flashing beacon, VHF recovery beacon and VHF transceiver. The uprighting systems consists of three compressor-inflated bags to upright the spacecraft if it should land in the water apex down (Stable II position).

Caution and Warning System--Monitors spacecraft systems for out-of-tolerance conditions and alerts crew by visual and audible alarms so that crewmen may trouble-shoot the problem.

Controls and Displays--Provide readouts and control functions of all other spacecraft systems in the command and service modules. All controls are designed to be operated by crewmen in pressurized suits. Displays are grouped by system according to the frequency the crew refers to them.

LUNAR MODULE STRUCTURES, SYSTEMS

The lunar module is a two-stage vehicle designed for space operations near and on the Moon. The LM is incapable of reentering the atmosphere and is, in effect, a true spacecraft.

Joined by four explosive bolts and umbilicals, the ascent and descent stages of the LM operate as a unit until staging, when the ascent stage functions as a single spacecraft for rendezvous and docking with the CSM.

Three main sections make up the ascent stage: the crew compartment, midsection and aft equipment bay. Only the crew compartment and midsection can be pressurized (4.8 psig; 337.4 gm/sq cm) as part of the LM cabin; all other sections of the LM are unpressurized. The cabin volume is 235 cubic feet (6.7 cubic meters).

Structurally, the ascent stage has six substructural areas: crew compartment, midsection, aft equipment bay, thrust chamber assembly cluster supports, antenna supports and thermal and micrometeoroid shield.

The cylindrical crew compartment is a semimonocoque structure of machined longerons and fusion-welded aluminum sheet and is 92 inches (2.35 m) in diameter and 42 inches (1.07 m) deep. Two flight stations are equipped with control and display panels, armrests, body restraints, landing aids, two front windows, an overhead docking window and an alignment optical telescope in the center between the two flight stations.

Two triangular front windows and the 32-inch (.81 m) square inward-opening forward hatch are in the crew compartment front face.

External structural beams support the crew compartment and serve to support the lower interstage mounts at their lower ends. Ring-stiffened semimonocoque construction is employed in the midsection, with chem-milled aluminum skin over fusion-welded longerons and stiffeners. Fore-and-aft beams across the top of the midsection join with those running across the top of the cabin to take all ascent stage stress loads and, in effect, isolate the cabin from stresses.

The ascent stage engine compartment is formed by two beams running across the lower midsection deck and mated to the fore and aft bulkheads. Systems located in the midsection include the LM guidance computer, the power and servo assembly, ascent engine propellant tanks, RCS propellant tanks, the environmental control system, and the waste management section.

A tunnel ring atop the ascent stage meshes with the command module latch assemblies. During docking, the ring and clamps are aligned by the LM drogue and the CSM probe.

The docking tunnel extends downward into the midsection 16 inches (40 cm). The tunnel is 32 inches (.81 cm) in diameter and is used for crew transfer between the CSM and LM by crewmen in either pressurized or unpressurized extravehicular mobility units (EMU). The upper hatch on the inboard end of the docking tunnel hinges downward and cannot be opened with the LM pressurized.

A thermal and micrometeoroid shield of multiple layers of mylar and a single thickness of thin aluminum skin encases the entire ascent stage structure.

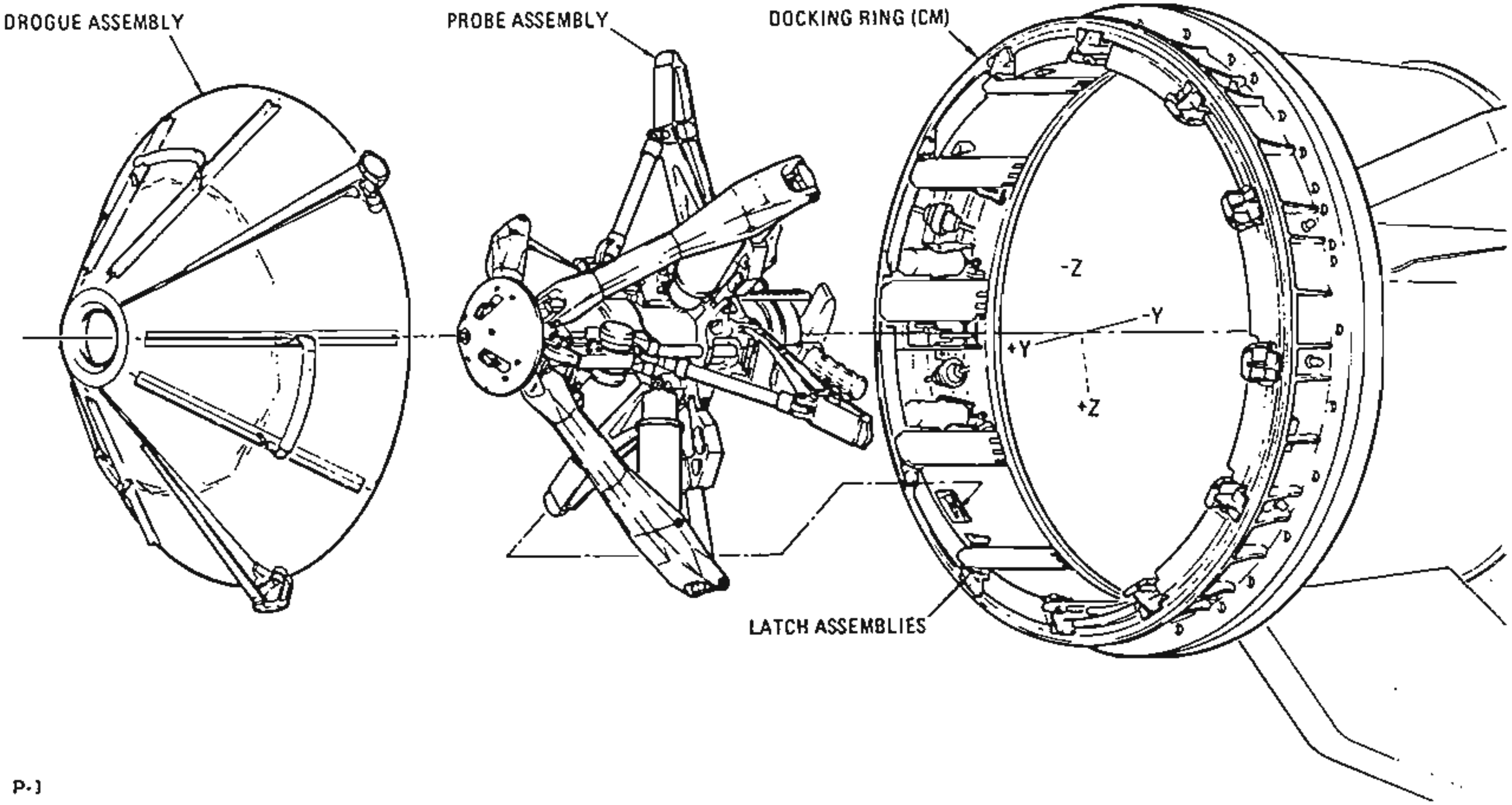
The descent stage consits of a cruciform load-carrying structure of two pairs of parallel beams, upper and lower decks, and enclosure bulkheads -- all of conventional skin-and-stringer aluminum alloy construction. The center compartment houses the descent engine, and descent propellant tanks are housed in the four square bays around the engine.

Four-legged truss outriggers mounted on the ends of each pair of beams serve as SLA attach points and as "knees" for the landing gear main struts.

Triangular bays between the main beams are enclosed into quadrants housing such components as the ECS water tank, helium tanks, descent engine control assembly of the guidance, navigation and control subsystem, ECS gaseous oxygen tank and batteries for the electrical power system. Like the ascent stage, the descent stage is encased in a mylar and aluminum alloy thermal and micrometeoroid shield.

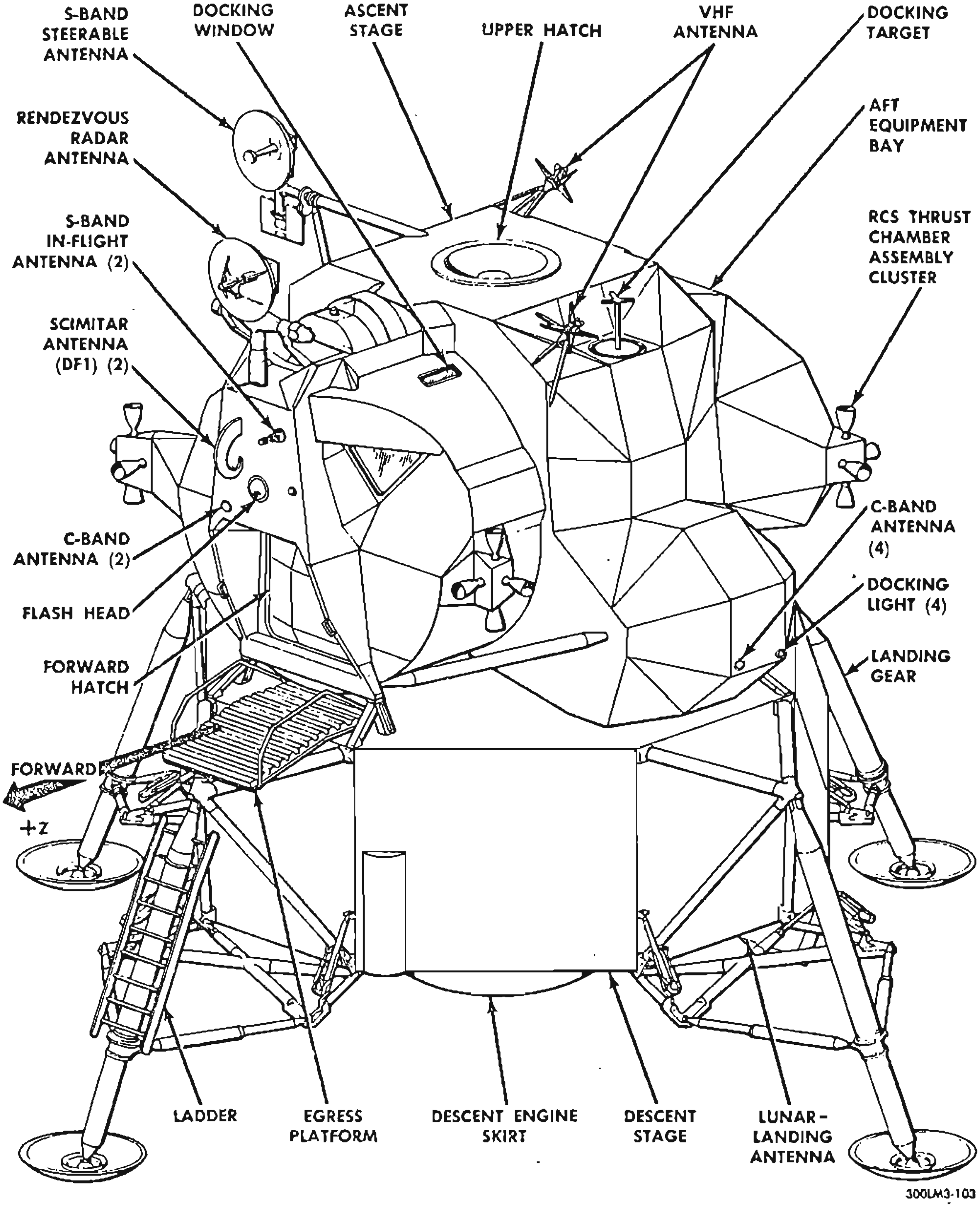
The LM external platform, or "porch," is mounted on the forward outrigger just below the forward hatch. A ladder extends down the forward landing gear strut from the porch for crew lunar surface operations. Foot restraints ("golden slippers") have been attached to the LM-3 porch to assist the lunar module pilot during EVA photography. The restraints face the LM hatch.

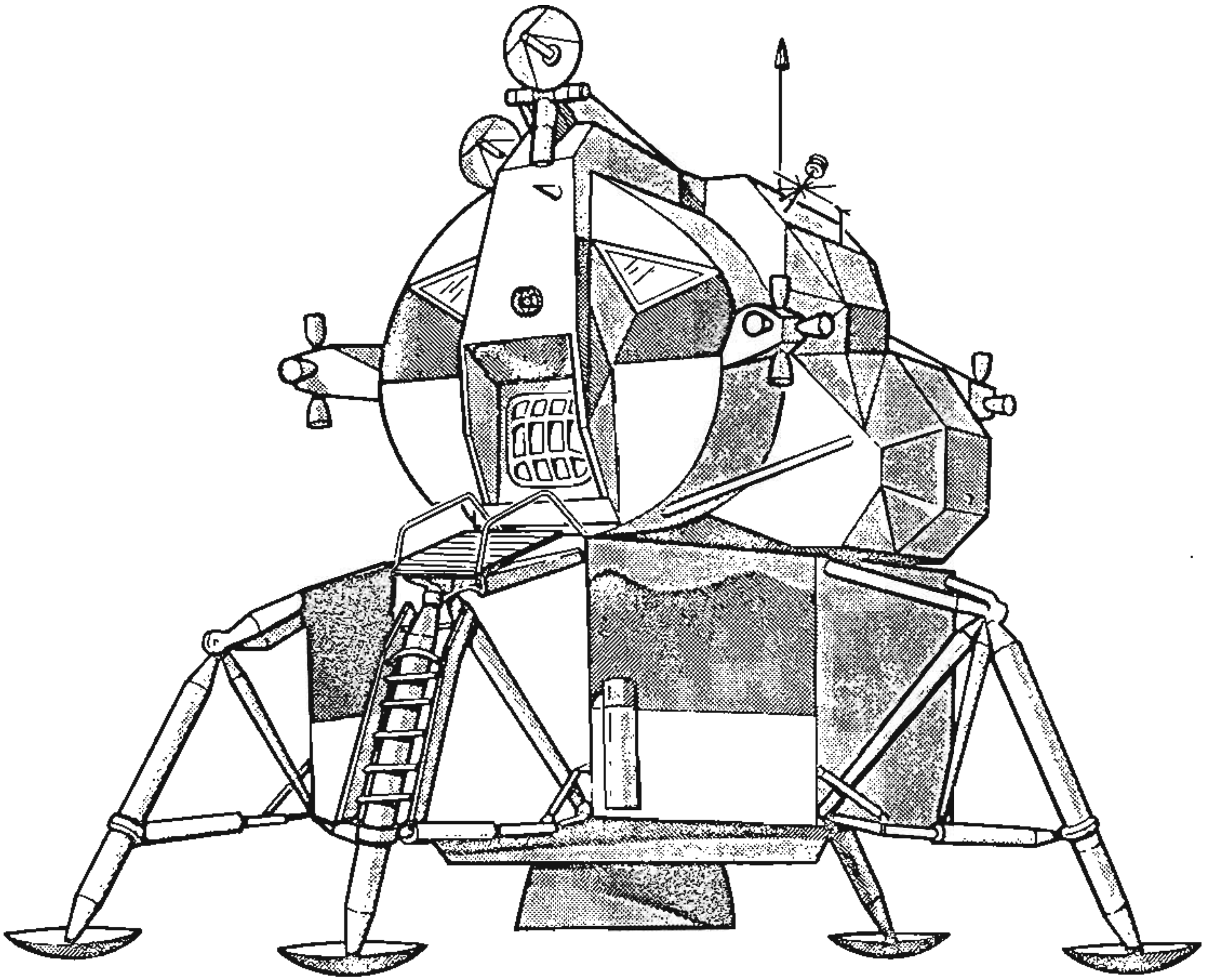
In a retracted position until after the crew mans the LM, the landing gear struts are explosively extended to provide lunar surface landing impact attenuation. The main struts are filled with crushable aluminum honeycomb for absorbing compression loads. Footpads 37 inches (.95 m) in diameter at the end of each landing gear provide vehicle "flotation" on the lunar surface.


DROGUE ASSEMBLY
PROBE ASSEMBLY
DOCKING RING (CM)
-Z
-Y
+Y
+Z
LATCH ASSEMBLIES

P-1

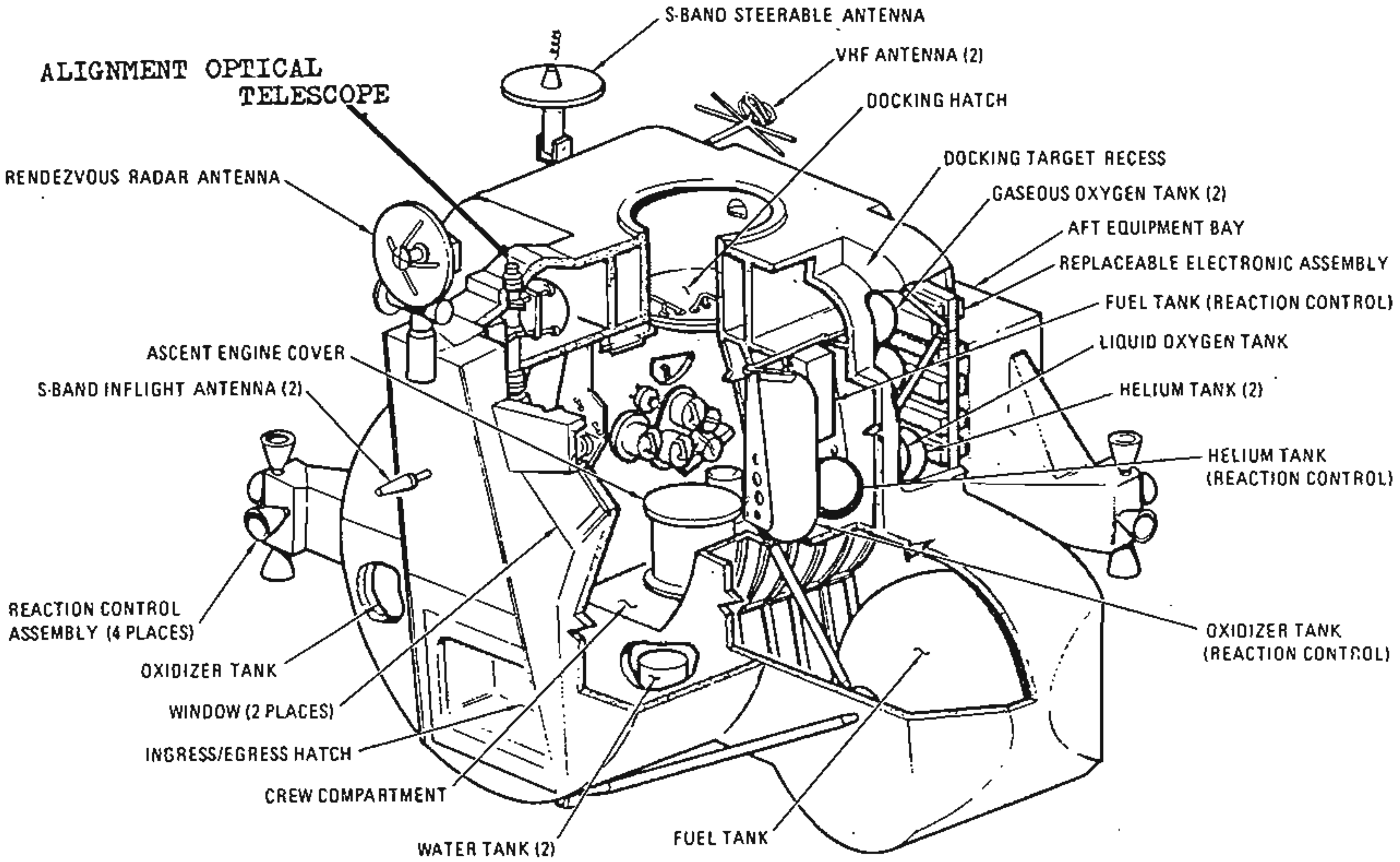
-more-


S-BAND STEERABLE ANTENNA
DOCKING WINDOW
ASCENT STAGE
UPPER HATCH
VHF ANTENNA
DOCKING TARGET
RENDEZVOUS RADAR ANTENNA
AFT EQUIPMENT BAY
S-BAND IN-FLIGHT ANTENNA (2)
RCS THRUST CHAMBER ASSEMBLY CLUSTER
SCIMITAR ANTENNA (DF1) (2)
C-BAND ANTENNA (2)
C-BAND ANTENNA (4)
DOCKING LIGHT (4)
FLASH HEAD
FORWARD HATCH
LANDING GEAR
FORWARD
+Z
LADDER
EGRESS PLATFORM
DESCENT ENGINE SKIRT
DESCENT STAGE
LUNAR-LANDING ANTENNA
300LM3-103



P-73

-more-


S-BAND STEERABLE ANTENNA
VHF ANTENNA (2)
DOCKING HATCH
DOCKING TARGET RECESS
GASEOUS OXYGEN TANK (2)
AFT EQUIPMENT BAY
REPLACEABLE ELECTRONIC ASSEMBLY
FUEL TANK (REACTION CONTROL)
LIQUID OXYGEN TANK
HELIUM TANK (2)
HELIUM TANK (REACTION CONTROL)
OXIDIZER TANK (REACTION CONTROL)
ALIGNMENT OPTICAL TELESCOPE
RENDEZVOUS RADAR ANTENNA
ASCENT ENGINE COVER
S-BAND INFLIGHT ANTENNA (2)
REACTION CONTROL ASSEMBLY (4 PLACES)
OXIDIZER TANK
WINDOW (2 PLACES)
INGRESS/EGRESS HATCH
CREW COMPARTMENT
WATER TANK (2)
FUEL TANK

P-74

-more-

Each pad is fitted with a lunar-surface sensing probe which signal the crew to shut down the descent engine upon contact with the lunar surface.

LM launch weight is 32,400 pounds (14,507.8 kg). The weight breakdown is as follows:

Ascent stage, dry	4,500 lbs.
Descent stage, dry	4,100 lbs.
RCS propellants	600 lbs.
DPS propellants	18,000 lbs.
APS propellants	5,200 lbs.
	34,000 lbs.

LM Spacecraft Systems

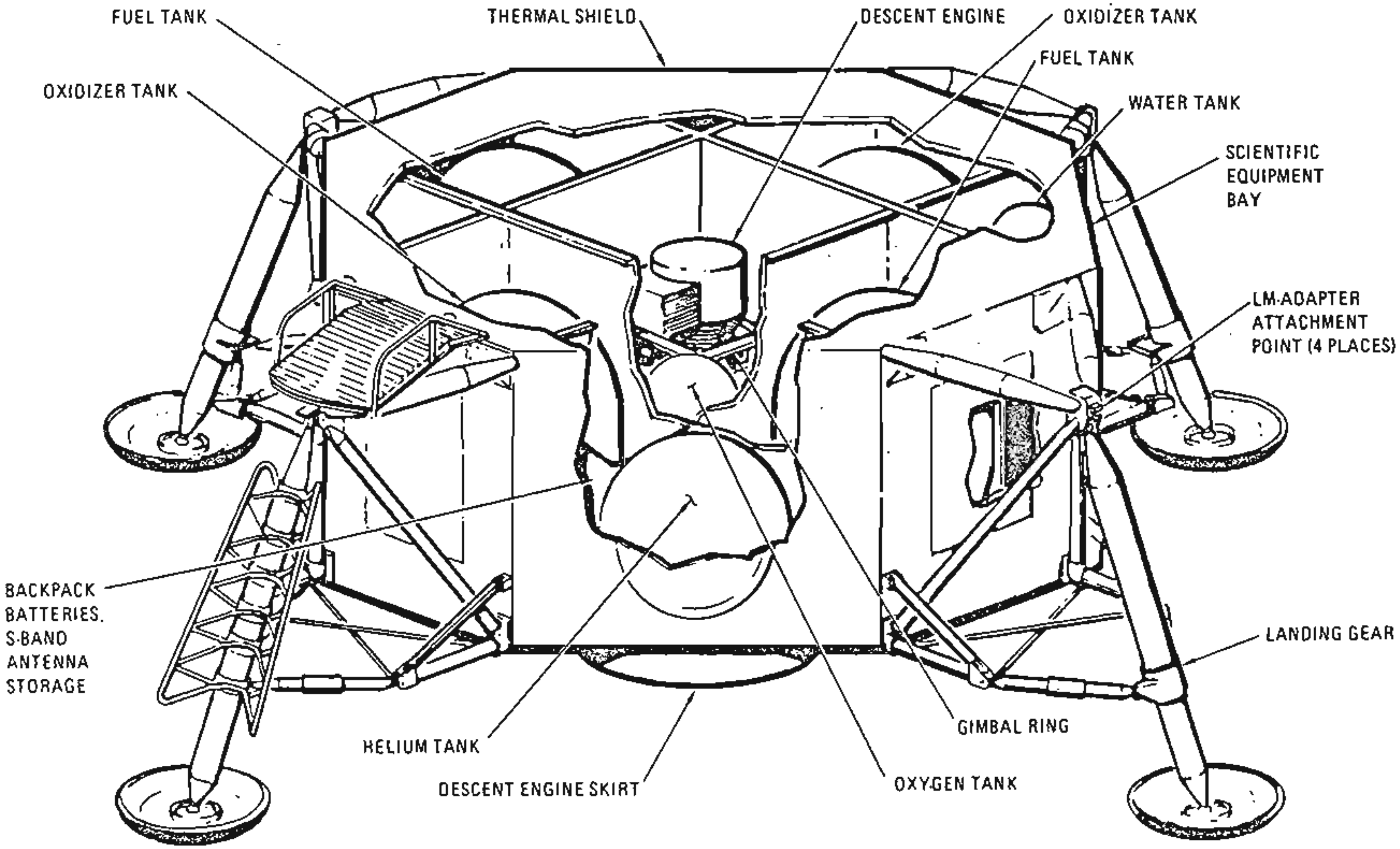
Electrical Power System -- The LM DC electrical system consists of six silver zinc primary batteries -- four in the descent stage and two in the ascent stage, each with its own electrical control assembly (ECA). Power feeders from all primary batteries pass through circuit breakers to energize the LM DC buses, from which 28-volt DC power is distributed through circuit breakers to all LM systems. AC power (117v 400Hz) is supplied by two inverters, either of which can supply spacecraft AC load needs to the AC buses.

Environmental Control System -- Consists of the atmosphere revitalization section, oxygen supply and cabin pressure control section, water management, heat transport section and outlets for oxygen and water servicing of the Portable Life Support System (PLSS).

Components of the atmosphere revitalization section are the suit circuit assembly which cools and ventilates the pressure garments, reduces carbon dioxide levels, removes odors and noxious gases and excessive moisture; the cabin recirculation assembly which ventilates and controls cabin atmosphere temperatures; and the steam flex duct which vents to space steam from the suit circuit water evaporator.

The oxygen supply and cabin pressure section supplies gaseous oxygen to the atmosphere revitalization section for maintaining suit and cabin pressure. The descent stage oxygen supply provides descent phase and lunar stay oxygen needs, and the ascent stage oxygen supply provides oxygen needs for the ascent and rendezvous phase.

-more-


FUEL TANK
THERMAL SHIELD
DESCENT ENGINE
OXIDIZER TANK
FUEL TANK
OXIDIZER TANK
WATER TANK
SCIENTIFIC EQUIPMENT BAY
LM-ADAPTER ATTACHMENT POINT (4 PLACES)
BACKPACK BATTERIES, S-BAND ANTENNA STORAGE
LANDING GEAR
HELIUM TANK
GIMBAL RING
DESCENT ENGINE SKIRT
OXYGEN TANK

P-75

Water for drinking, cooling, firefighting and food preparation and refilling the PLSS cooling water servicing tank is supplied by the water management section. The water is contained in three nitrogen-pressurized bladder-type tanks, one of 367-pound capacity in the descent stage and two of 47.5-pound capacity in the ascent stage.

The heat transport section has primary and secondary water-glycol solution coolant loops. The primary coolant loop circulates water-glycol for temperature control of cabin and suit circuit oxygen and for thermal control of batteries and electronic components mounted on cold plates and rails. If the primary loop becomes inoperative, the secondary loop circulates coolant through the rails and cold plates only. Suit circuit cooling during secondary coolant loop operation is provided by the suit loop water boiler. Waste heat from both loops is vented overboard by water evaporation, or sublimators.

Communication System -- Two S-Band transmitter-receivers, two VHF transmitter-receivers, a UHF command receiver, a signal processing assembly and associated spacecraft antenna make up the LM communications system. The system transmits and receives voice, tracking and ranging data, and transmits telemetry data on 281 measurements and TV signals to the ground. Voice communications between the LM and ground stations is by S-Band, and between the LM and CSM voice is on VHF. In Earth orbital operations such as Apollo 9, VHF voice communications between the LM and the ground are possible. Developmental flight instrumentation (DFI) telemetry data are transmitted to MSFN stations by five VHF transmitters. Two C-Band beacons augment the S-Band system for orbital tracking.

The UHF receiver accepts command signals which are fed to the LM guidance computer for ground updates of maneuvering and navigation programs. The UHF receiver is also used to receive real-time commands which are on LM-3 to arm and fire the ascent propulsion system for the unmanned APS depletion burn. The UHF receiver will be replaced by an S-Band command system on LM-4 and subsequent spacecraft.

The Data Storage Electronics Assembly (DSEA) is a four-channel voice recorder with timing signals with a 10-hour recording capacity which will be brought back into the CSM for return to Earth. DSEA recordings cannot be "dumped" to ground stations.

LM antennas are one 26-inch diameter parabolic S-Band steerable antenna, two S-Band inflight antennas, two VHF inflight antennas, four C-Band antennas, and two UHF/VHF command/DFI scimitar antennas.

Guidance, Navigation and Control System -- Comprised of six sections: primary guidance and navigation section (PGNS), abort guidance section (AGS), radar section, control electronics section (CES), and orbital rate drive electronics for Apollo and LM (ORDEAL).

* The PGNS is an inertial system aided by the alignment optical telescope, an inertial measurement unit, and the rendezvous and landing radars. The system provides inertial reference data for computations, produces inertial alignment reference by feeding optical sighting data into the LM guidance computer, displays position and velocity data, computes LM-CSM rendezvous data from radar inputs, controls attitude and thrust to maintain desired LM trajectory and controls descent engine throttling and gimbaling.

* The AGS is an independent backup system for the PGNS, having its own inertial sensor and computer.

* The radar section is made up of the rendezvous radar which provides and feeds CSM range and range rate, and line-of-sight angles for maneuver computation to the LM guidance computer; the landing radar which provides and feeds altitude and velocity data to the LM guidance computer during lunar landing. On LM-3, the landing radar will be in a self-test mode only. The rendezvous radar has an operating range from 80 feet to 400 nautical miles.

* The CES controls LM attitude and translation about all axes. Also controls by PGNS command the automatic operation of the ascent and descent engines, and the reaction control thrusters. Manual attitude controller and thrust-translation controller commands are also handled by the CES.

* ORDEAL displays on the flight director attitude indicator the computed local vertical in the pitch axis during circular Earth or lunar orbits.

Reaction Control System -- The LM has four RCS engine clusters of four 100-pound (45.4 kg) thrust engines each which use helium-pressurized hypergolic propellants. The oxidizer is nitrogen tetroxide, fuel is Aerozine 50 (50/50 hydrazine and unsymmetrical dimethyl hydrazine). Propellant plumbing, valves and pressurizing components are in two parallel, independent systems, each feeding half the engines in each cluster. Either system is capable of maintaining attitude alone, but if one supply system fails, a propellant crossfeed allows one system to supply all 16 engines. Additionally, interconnect valves permit the RCS system to draw from ascent engine propellant tanks.

The engine clusters are mounted on outriggers 90 degree apart on the ascent stage.

The RCS provides small stabilizing impulses during ascent and descent burns, controls LM attitude during maneuvers, and produces thrust for separation and ascent/descent engine tank ullage. The system may be operated in either pulsed or steady-state modes.

Descent Propulsion System -- Maximum rated thrust of the descent engine is 9,870 pounds (4,380.9 kg) and is throttleable between 1,050 pounds (476.7 kg) and 6,300 pounds (2,860.2 kg). The engine can be gimballed six degrees in any direction for offset center of gravity trimming. Propellants are helium-pressurized Aerozine 50 and nitrogen tetroxide.

Ascent Propulsion System -- The 3,500 pound (1,589 kg) thrust ascent engine is not gimballed and performs at full thrust. The engine remains dormant until after the ascent stage separates from the descent stage. Propellants are the same as are burned in the RCS engines and the descent engine.

Caution and Warning, Controls and Displays -- These two systems have the same function aboard the lunar module as they do aboard the command module. (See CSM systems section.)

Tracking and Docking Lights -- A flashing tracking light (once per second, 20 milliseconds duration) on the front face of the lunar module is an aid for contingency CSM-active rendezvous LM rescue. Visibility ranges from 400 nautical miles through the CSM sextant to 130 miles with the naked eye. Five docking lights analagous to aircraft running lights are mounted on the LM for CSM-active rendezvous: two forward yellow lights, aft white light, port red light and starboard green light. All docking lights have about a 1,000-foot visibility.

LM-3
Rev A
New Page

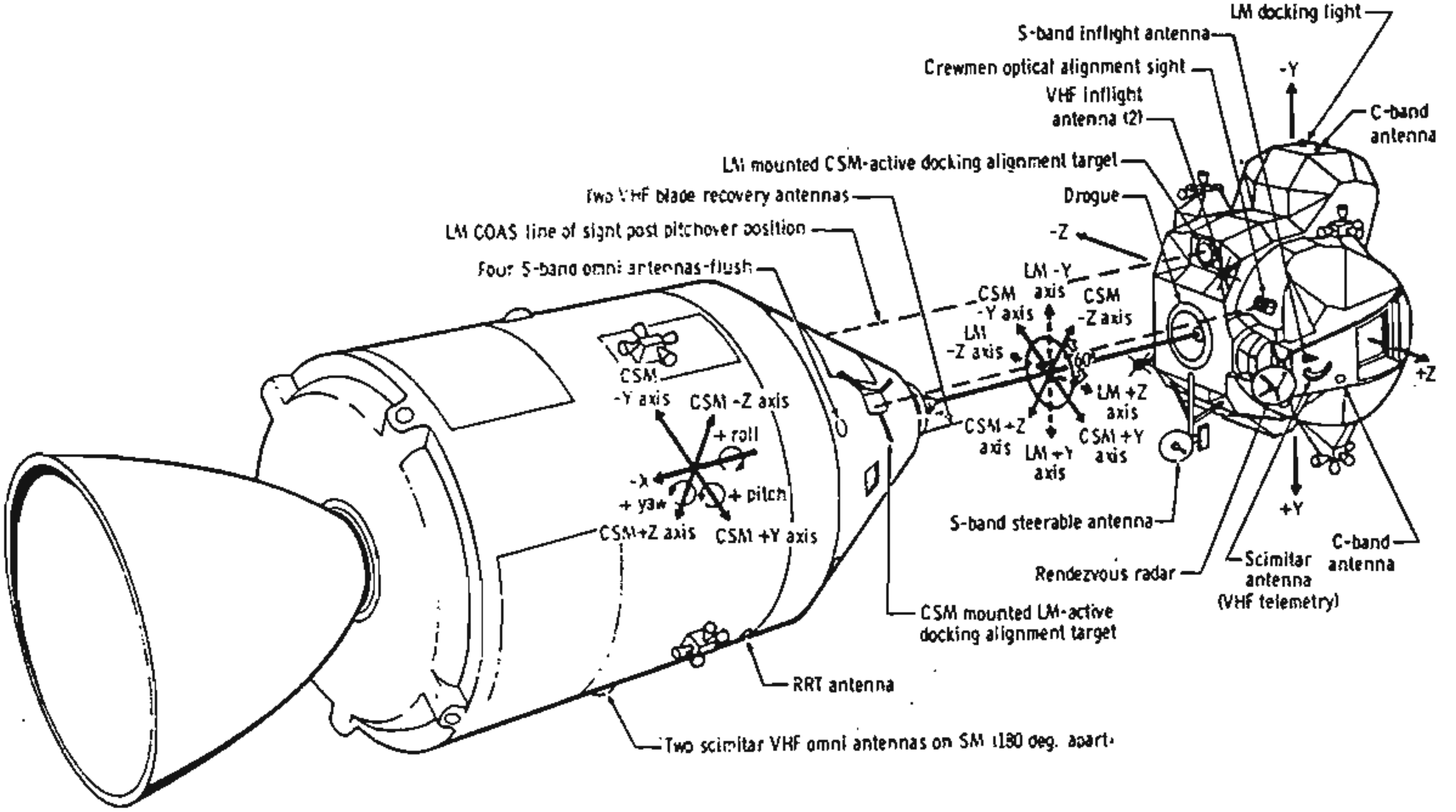
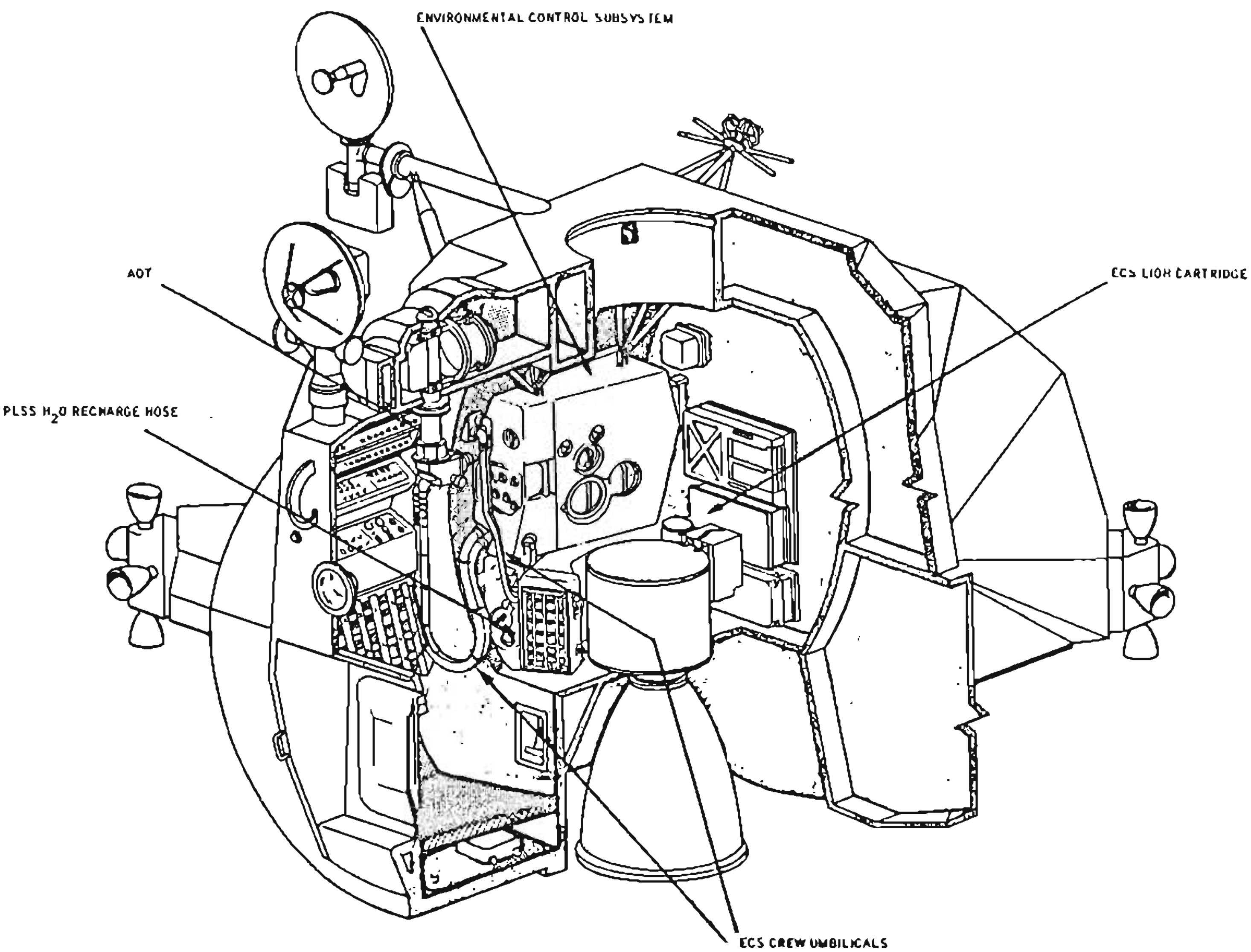
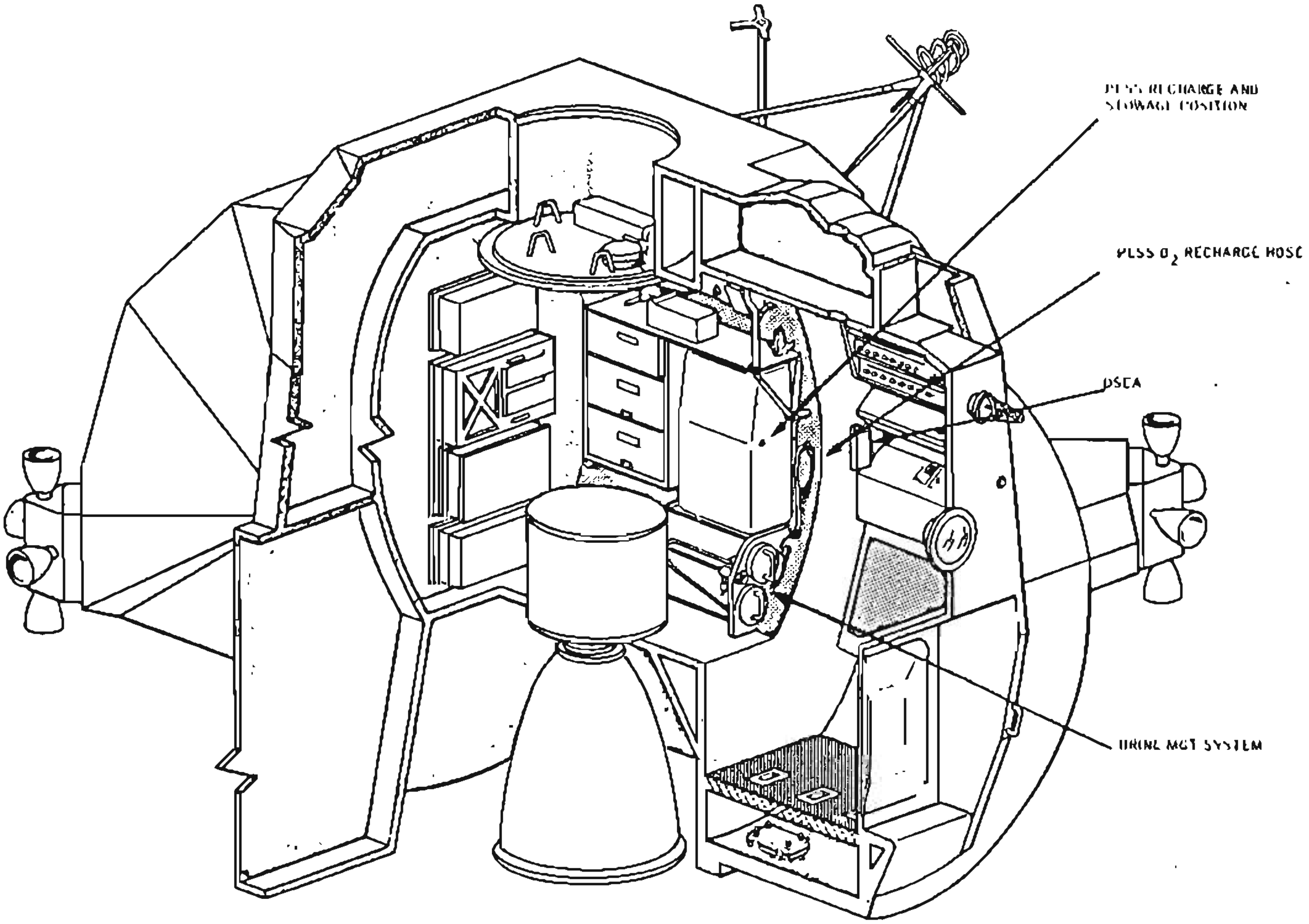


Figure 5-3.2. - LM-CSM antenna locations.

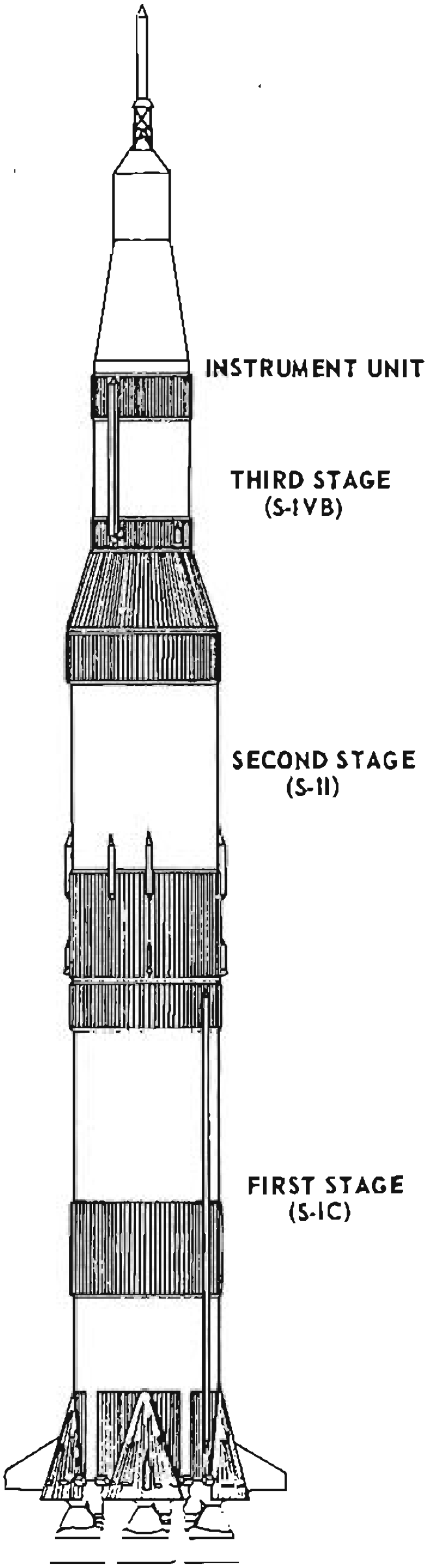


Cutaway of LM cabin interior, left half



Cutaway of LM cabin interior, right half

FACT SHEET, APOLLO/SATURN V SPACE VEHICLE



First Stage (S-IC)

Diameter----------- 33 feet, Height -- 138 feet
Weight------------- 4,881,000 lbs. fueled
303,000 lbs. dry
Engines------------ Five F-1
Propellants-------- Liquid oxygen (334,500 gals.)
RP-1 (Kerosene) - (209,000) gals.)
Thrust------------- 7,700,000 lbs.

Second Stage (S-II)

Diameter----------- 33 feet, Height -- 81.5 feet
Weight------------- 1,037,000 lbs. fueled
95,000 lbs. dry
Engines------------ Five J-2
Propellants-------- Liquid oxygen (83,000 gals.)
Liquid hydrogen (260,000 gals.)
Thrust------------- 1,150,000 lbs.
Interstage--------- 10,305 lbs.

Third Stage (S-IVB)

Diameter----------- 21.7 feet, Height -- 58.3 ft.
Weight------------- 265,000 lbs. fueled
33,600 lbs. dry
Engines------------ One J-2
Propellants-------- Liquid oxygen (20,150 gals.)
Liquid hydrogen (69,500 gals.)
Thrust------------- 225,000 lbs.
Interstage--------- 7,700 lbs.

Instrument Unit

Diameter----------- 21.7 feet, Height -- 3 feet
Weight------------- 4,500 lbs.

NOTE: Weights and measures given above are for the nominal vehicle configuration. The figures may vary slightly due to changes before or during flight to meet changing conditions.

THE SATURN V LAUNCH VEHICLE

The Saturn V, 363 feet tall with the Apollo spacecraft in place, generates enough thrust to place a 125-ton payload into a 105 nm circular Earth orbit or boost a smaller payload to the vicinity of any planet in the solar system. It can boost about 50 tons to lunar orbit. The thrust of the three propulsive stages range from more than 7.7 million pounds for the booster to 230,000 pounds for the third stage at operating altitude. Including the instrument unit, the launch vehicle is 281 feet tall.

First Stage

The first stage (S-IC) was developed jointly by the National Aeronautics and Space Administration's Marshall Space Flight Center, Huntsville, Ala., and the Boeing Co.

The Marshall Center assembled four S-IC stages: a structural test model, a static test version and the first two flight stages. Subsequent flight stages are being assembled by Boeing at the Michoud Assembly Facility in New Orleans. The S-IC stage destined for the Apollo 9 mission was the first flight booster static tested at the NASA-Mississippi Test Facility. That test was made on May 11, 1967. Earlier flight stages were static fired at the NASA-Marshall Center.

The S-IC stage provides first boost of the Saturn V launch vehicle to an altitude of about 37 nautical miles (41.7 statute miles, 67.1 kilometers) and provides acceleration to increase the vehicle's velocity to 9,095 feet per second (2,402 m/sec, 5,385 knots, 6,201 mph). It then separates from the S-II stage and falls to Earth about 361.9 nm (416.9 sm, 667.3 km) downrange.

Normal propellant flow rate to the five F-1 engines is 29,522 pounds per second. Four of the engines are mounted on a ring, each 90 degrees from its neighbor. These four are gimballed to control the rocket's direction of flight. The fifth engine is mounted rigidly in the center.

Second Stage

The second stage (S-II), like the third stage, uses high performance J-2 engines that burn liquid oxygen and liquid hydrogen. The stage's purpose is to provide second stage boost nearly to Earth orbit.

At engine cutoff, the S-II separates from the third stage and, following a ballistic trajectory, plunges into the Atlantic Ocean about 2,412 nm (2,778.6 sm, 4,468 kn) downrange from Cape Kennedy.

Five J-2 engines power the S-II. The four outer engines are equally spaced on a 17.5-foot diameter circle. These four engines may be gimballed through a plus or minus seven-degree square pattern for thrust vector control. Like the first stage, the center (number 5) engine is mounted on the stage centerline and is fixed.

The S-II carries the rocket to an altitude of 103 nm (118.7 sm, 190.9 km) and a distance of some 835 nm (961.9 sm, 1,548 km) downrange. Before burnout, the vehicle will be moving at a speed of 23,000 fps or 13,642 knots (15,708 mph, 25,291 kph, 6,619 m/sec). The J-2 engines will burn six minutes 11 seconds during this powered phase.

The Space Division of North American Rockwell Corp. builds the S-II at Seal Beach, Calif. The cylindrical vehicle is made up of the forward skirt (to which the third stage attaches), the liquid hydrogen tank, the liquid oxygen tank, the thrust structure (on which the engines are mounted) and an interstage section (to which the first stage connects). The propellant tanks are separated by an insulated common bulkhead.

Third Stage

The third stage (S-IVB) was developed by the McDonnell Douglas Astronautics Co. at Huntington Beach, Calif.

The stage, with its single engine, provides propulsion three times during Apollo lunar missions. The first burn occurs immediately after separation from the S-II. It will last long enough (112 seconds) to insert the vehicle and spacecraft into Earth parking orbit. After a thorough checkout of equipment, the third stage re-ignites and burns about six minutes to reach lunar transfer velocity. Approximately 30 minutes after the spacecraft separates from the stage, it will be restarted for the third time to place it into a solar orbit.

Instrument Unit

The Instrument Unit (IU) is a cylinder three feet high and 21 feet 8 inches in diameter. It weighs 4,500 pounds and contains the guidance, navigation and control equipment which will steer the vehicle through its Earth orbits and into the final escape orbit maneuver.

The IU also contains telemetry, communications, tracking and crew safety systems, along with its own supporting electrical power and environmental control systems.

Components making up the "brain" of the Saturn V are mounted on cooling panels fastened to the inside surface of the instrument unit skin. The "cold plates" are part of a system that removes heat by circulating cooled fluid through a heat exchanger that evaporates water from a separate supply into the vacuum of space.

The six major systems of the instrument unit are structural, thermal control, guidance and control, measuring and telemetry, radio frequency and electrical.

The instrument unit provides navigation, guidance and control of the vehicle; measurement of vehicle performance and environment; data transmission with ground stations; radio tracking of the vehicle; checkout and monitoring of vehicle functions; initiation of stage functional sequencing; detection of emergency situations; generation and network distribution of electric power for system operation; and preflight checkout and launch and flight operations.

A path-adaptive guidance scheme is used in the Saturn V instrument unit. A programmed trajectory is used in the initial launch phase with guidance beginning only after the vehicle has left the atmosphere. This is to prevent movements that might cause the vehicle to break apart while attempting to compensate for winds, jet streams and gusts encountered in the atmosphere.

If such air currents displace the vehicle from the optimum trajectory in climb, the vehicle derives a new trajectory. Calculations are made about once each second throughout the flight. The launch vehicle digital computer and launch vehicle data adapter perform the navigation and guidance computations.

The ST-124M inertial platform -- the heart of the navigation, guidance and control system -- provides space-fixed reference coordinates and measures accleration along the three mutually perpendicular axes of the coordinate system.

International Business Machines Corp. is prime contractor for the instrument unit and is the supplier of the guidance signal processor and guidance computer. Major suppliers of instrument unit components are: Electronic Communications, Inc., control computer; Bendix Corp., ST-124M inertial platform; and IBM Federal Systems Division, launch vehicle digital computer and launch vehicle data adapter.

-more-

Propulsion

The 41 rocket engines of the Saturn V have thrust ratings ranging from 72 pounds to more than 1.5 million pounds. Some engines burn liquid propellants, others use solids.

The five F-1 engines in the first stage burn RP-1 (kerosene) and liquid oxygen. Each engine in the first stage develops an average of 1,544,000 pounds of thrust at liftoff, building up to an average of 1,833,900 pounds before cutoff. The cluster of five engines gives the first stage a thrust range from 7.72 million pounds at liftoff to 9,169,560 pounds just before center engine cutoff.

The F-1 engine weighs almost 10 tons, is more than 18 feet high and has a nozzle-exit diameter of nearly 14 feet. The F-1 undergoes static testing for an average 650 seconds in qualifying for the 150-second run during the Saturn V first stage booster phase. This run period, 800 seconds, is still far less than the 2,200 seconds of the engine guarantee period. The engine consumes almost three tons of propellants per second.

The first stage of the Saturn V for this mission has eight other rocket motors. These are the solid-fuel retro-rockets which will slow and separate the stage from the second stage. Each rocket produces a thrust of 87,900 pounds for 0.6 second.

The main propulsion for the second stage is a cluster of five J-2 engines burning liquid hydrogen and liquid oxygen. Each engine develops a mean thrust of more than 205,000 pounds at 5.0:1 mixture ratio (variable from 193,000 to 230,000 in phases of flight), giving the stage a total mean thrust of more than a million pounds.

Designed to operate in the hard vacuum of space, the 3,500-pound J-2 is more efficient than the F-1 because it burns the high-energy fuel hydrogen.

The second stage also has four 21,000-pound-thrust solid fuel rocket engines. These are the ullage rockets mounted on the S-IC/S-II interstage section. These rockets fire to settle liquid propellant in the bottom of the main tanks and help attain a "clean" separation from the first stage. They remain with the interstage when it drops away at second plane separation. Four retrorockets are located in the S-IVB aft interstage (which never separates from the S-II) to separate the S-II from the S-IVB prior to S-IVB ignition.

Eleven rocket engines perform various functions on the third stage. A single J-2 provides the main propulsive force; there are two jettisonable main ullage rockets and eight smaller engines in the two auxiliary propulsion system modules.

MANNED SPACE FLIGHT TRACKING NETWORK

The Manned Space Flight Network (MSFN) has 14 ground stations, four instrumented ships, and eight instrumented aircraft for participation in Apollo missions.

The MSFN is designed to keep in close contact with the spacecraft and astronauts at all times, except for the approximate 45 minutes Apollo is behind the Moon and out of range during the Earth-orbital periods of flight. The network is designed to provide reliable, continuous, and instantaneous communications with the astronauts, launch vehicle and spacecraft from liftoff to splashdown.

As the spacecraft lifts off from Kennedy Space Center, the tracking stations watch it. As the Saturn ascends, voice and data is instantaneously transmitted to Mission Control Center (MCC) in Houston. Data is run through computers at MCC for visual display for flight controllers.

Depending on the launch azimuth, a string of 30-foot diameter antennas around the Earth keep tabs on Apollo and transmit information back to Houston. First, the station at Merritt Island, then it will be Grand Bahama Island, Bermuda, the Vanguard tracking ship, and Canary Island. Later, Carnarvon, Australia, followed by Hawaii, a tracking ship, Guaymas, Mexico, and Corpus Christi, Tex.

For injection into translunar orbit, MCC sends a signal through one of the land stations or one of the three Apollo ships in the Pacific. As the spacecraft heads for the Moon, the engine burn is monitored by the ships and an Apollo/Range Instrumentation Aircraft (A/RIA). The A/RIA provides a relay for the astronauts' voice and data communication with Houston.

As the spacecraft moves away from Earth, first the smaller 30-foot diameter antennas communicate with the spacecraft, then at a spacecraft altitude of 10,000 miles they hand over the tracking function to the larger and more powerful 85-foot antennas. These 85-foot antennas are near Madrid, Spain; Goldstone, Calif.; and Canberra, Australia.

The 85-foot antennas are at 120-degree intervals around Earth so at least one antenna has the Moon in view at all times. As the Earth revolves arom west to east, one station hands over control to the next station as it moves into view of the spacecraft. In this way, a continuous data and communication flow is maintained.

Data is constantly relayed back through the huge antennas and transmitted via the NASA communications network -- a half million miles of land and underseas cables and radio circuits, including those through communications satellites -- to MCC. This data is fed into computers for visual display in Mission Control. For example, a display would show on a large map, the exact position of the spacecraft. Or returning data could indicate a drop in power or some other difficulty which would result in a red light going on to alert a Flight Controller to make a decision and take action.

Returning data flowing through the Earth stations give the necessary information for commanding mid-course maneuvers to keep the Apollo in a proper trajectory for orbiting the Moon. On reaching the vicinity of the Moon the data indicate the amount of burn necessary for the service module engine to place the spacecraft in lunar orbit. And so it goes, continuous tracking and acquisition of data between Earth and Apollo are used to fire the spacecraft's engine to descend to the lunar surface, launch from the Moon, rendezvous and redock, return home and place it on the precise trajectory for reentering the Earth's atmosphere.

As the spacecraft comes toward Earth at about 25,000 miles per hour, it must reenter at the proper angle.

Calculations based on data coming in at the various tracking stations and ships are fed into the computers at MCC where flight controllers make decisions that will provide the returning spacecraft with the necessary information to make accurate reentry. Appropriate MSFN stations, including tracking ships and aircraft repositioned in the Pacific for this event, are on hand to provide support during reentry. An A/RIA aircraft will relay astronaut voice communications to MCC and antennas on reentry ships will follow the spacecraft.

During the journey to the Moon and back, television will be received from the spacecraft at the various 85-foot antennas around the world: Spain, Goldstone, and Australia. Scan converters permit immediate transmission via NASCOM to Mission Control where it is released to TV networks.

NASA Communications Network - Goddard

This network consists of several systems of diversely routed communications channels leased on communications satellites, common carrier systems and high frequency radio facilities where necessary to provide the access links.

The system consists of both narrow and wide-band channels, and some TV channels. Included are a variety of telegraph, voice and data systems (digital and analog) with a wide range of digital data rates. Wide-band systems do not extend overseas. Alternate routes or redundancy are provided for added reliability in critical mission operations.

A primary switching center and intermediate switching and control points are established to provide centralized facility and technical control, and switching operations under direct NASA control. The primary switching center is at Goddard, and intermediate switching centers are located at Canberra, Australia; Madrid, Spain; London, England; Honolulu, Hawaii; Guam; and Cape Kennedy, Fla.

Cape Kennedy is connected directly to the Mission Control Center, Houston, by the communication network's Apollo Launch Data System, a combination of data gathering and transmission systems designed to handle launch data exclusively.

After launch, all network and tracking data are directed to the Mission Control Center, Houston, through Goddard. A high-speed data line (2,400 bits-per-second) connects Cape Kennedy to Goddard, where the transmission rate is increased to 40,800 bits-per-second from there to Houston. Upon orbital insertion, tracking responsibility is transferred between the various stations as the spacecraft circles the Earth.

Two Intelsat commercial communications satellites are used for Apollo. The Atlantic satellite will service the Ascension Island Unified S-Band (USB) station, the Atlantic and Indian Ocean ships and the Canary Island site.

The second Apollo Intelsat communications satellite, over the mid-Pacific, will service the Carnarvon, Australia USB site and the Pacific Ocean ships. All these stations will be able to transmit simultaneously through the satellite to Houston via Brewster Flat, Washington, and the Goddard Space Flight Center.

Network Computers

At fraction-of-a-second intervals, the network's digital data processing systems, with NASA's Manned Spacecraft Center as the focal point, "talk" to each other or to the spacecraft in real time. High-speed computers at the remote site (tracking ships included) issue commands or "up" data on such matters as control of cabin pressure, orbital guidance commands, or "go-no-go" indications to perform certain functions.

In the case of information originating from Houston, the computers refer to their pre-programmed information for validity before transmitting the required data to the capsule.

Such "up" information is communicated by ultra-high-frequency radio at about 1,200 bits-per-second. Communication between remote ground sites, via high-speed communications links, occurs about the same rate. Houston reads information from these ground sites at 2,400 bits-per-second, as well as from remote sites at 100 words-per-minute.

The computer systems perform many other functions, including:

Assuring the quality of the transmission lines by continually exercising data paths.

Verifying accuracy of the messages by repetitive operations.

Constantly updating the flight status.

For "down" data, sensors built into the spacecraft continually sample cabin temperature, pressure, physical information on the astronauts such as heartbeat and respiration, among other items. These data are transmitted to the ground stations at 51.2 kilobits (12,800 binary digits) per second.

At MCC the computers:

Detect and select changes or deviations, compare with their stored programs, and indicate the problem areas or pertinent data to the flight controllers.

Provide displays to mission personnel.

Assemble output data in proper formats.

Log data on magnetic tape for replay.

Provide storage for "on-call" display for the flight controllers.

Keep time.

Fourteen land stations are outfitted with computer systems to relay telemetry and command information between Houston and Apollo spacecraft: Canberra and Carnarvon, Australia; Guam; Kauai, Hawaii; Goldstone, California; Corpus Christi, Texas; Cape Kennedy, Florida; Grand Bahama Island; Bermuda; Madrid; Grand Canary Island; Antigua; Ascension Island; and Guaymas, Mexico.

Network Configuration for Apollo 8

Unified S-Band (USB) Sites:

NASA 30-Foot Antenna Sites

Antigua (ANG)
Ascension Island (ACN)
Bermuda (BDA)
Canary Island (CYI)
Carnarvon (CRO), Australia
Grand Bahama Island (GBM)
Guam (GWM)
Guaymas (GYM), Mexico
Hawaii (HAW)
Merritt Island (MIL), Florida
Corpus Christi (TEX), Texas

NASA 85-Foot Antenna Sites

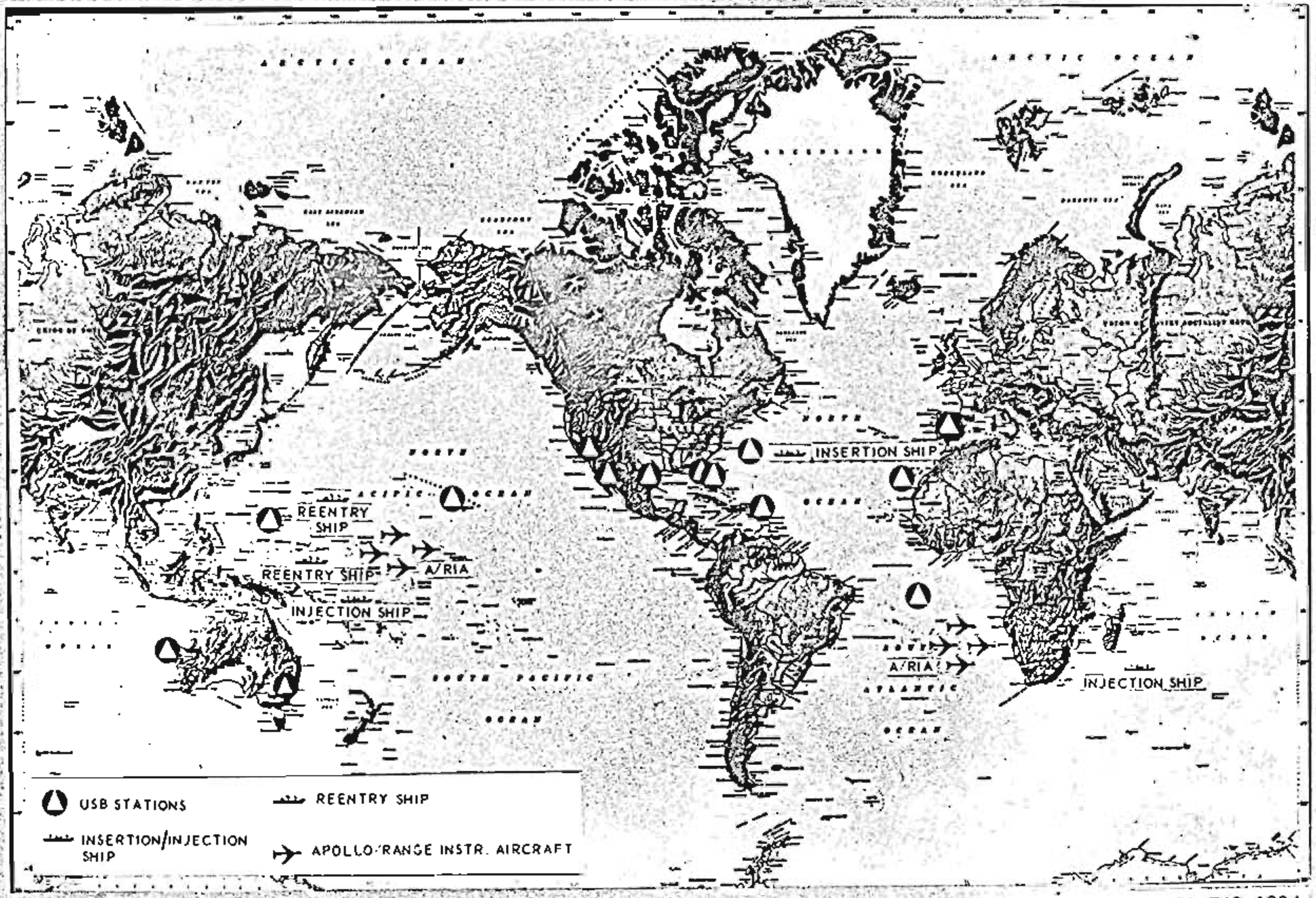
Canberra (CNB), Australia (Prime)
Goldstone (GDS), California (Prime)
Madrid (MAD), Spain (Prime)
*Canberra (DSS-42 Apollo Wing) (Backup)
*Goldstone (DSS-11 Apollo Wing) (Backup)
*Madrid (DSS-61 Apollo Wing) (Backup)

Tananarive (TAN), Malagasy Republic (STADAN station in support role only.)

---

*Wings have been added to JPL Deep Space Network site operations buildings. These wings contain additional Unified S-Band equipment as backup to the Prime sites.

MANNED SPACE FLIGHT NETWORK



NASA T68-1304
1-31-68

-more-

APOLLO FLIGHT CREWS

First Manned Flight (Saturn IB)	Apollo 7
Prime Crew	Commander, Walter M. Schirra, Jr. CM Pilot, Donn F. Eisele LM Pilot, Walter Cunningham
Backup Crew	Commander, Thomas P. Stafford CM Pilot, John W. Young LM Pilot, Eugene A. Cernan
Astronaut Support Team	John L. Swigert, Jr. Ronald E. Evans William R. Pogue
Second Manned Flight (Saturn V)	Apollo 8
Prime Crew	Commander, Frank Borman CM Pilot, James A. Lovell, Jr. LM Pilot, William A. Anders
Backup Crew	Commander, Neil A. Armstrong CM Pilot, Edwin E. Aldrin, Jr. LM Pilot, Fred W. Haise, Jr.
Astronaut Support Team	Thomas F. Mattingly II Gerald P. Carr Vance D. Brand
Third Manned Flight (Saturn V)	Apollo 9
Prime Crew	Commander, James A. McDivitt CM Pilot, David R. Scott LM Pilot, Russell L. Schweickart
Backup Crew	Commander, Charles Conrad, Jr. CM Pilot, Richard F. Gordon LM Pilot, Alan L. Bean
Astronaut Support Team	Edgar D. Mitchell Jack R. Lousma Alfred M. Worden

4th Manned Flight (Saturn V)	Apollo 10
Prime Crew	Commander, Thomas P. Stafford CM Pilot, John W. Young LM Pilot, Eugene A. Cernan
Backup Crew	Commander, L. Gordon Cooper CM Pilot, Donn F. Eisele LM Pilot, Edgar D. Mitchell
Astronaut Support Team	Joe H. Engle James B. Irwin Charles M. Duke, Jr.
5th Manned Flight (Saturn V)	Apollo 11
Prime Crew	Commander, Neil A. Armstrong CM Pilot, Michael Collins LM Pilot, Edwin E. Aldrin
Backup Crew	Commander, James A. Lovell CM Pilot, William A. Anders LM Pilot, Fred W. Haise
Astronaut Support Team	John L. Swigert Ronald E. Evans William P. Pogue
6th Manned Flight (Saturn V)	
Prime Crew	Commander, Charles Conrad Jr. CM Pilot, Richard F. Gordon Jr. LM Pilot, Alan L. Bean
Backup Crew	Commander, David R. Scott CM Pilot, Alfred M. Worden LM Pilot, James B. Irwin
Astronaut Support Team	(Not yet selected 4-10-69)

UNITED STATES MANNED SPACE FLIGHTS

PROJECT MERCURY

DATE	MISSION	REVS.	S/C HRS.			MAN HRS.			CUM. MAN HRS.		
			H	M	S	H	M	S	H	M	S
5/5/61	Mercury-Redstone 3 Freedom 7; Cdr. Shepard	0	0	15	22	0	15	22	0	15	22
7/21/61	Mercury-Redstone 4 Liberty Belle 7; Maj. Grissom	0	0	15	37	0	15	37	0	30	59
2/20/62	Mercury-Atlas 6 Friendship 7; Lt. Col. Glenn	3	4	55	23	4	55	23	5	26	22
5/24/62	Mercury-Atlas 7 Aurora 7; LCdr Carpenter	3	4	56	05	4	56	05	10	22	27
10/3/62	Mercury-Atlas 8 Sigma 7; Cdr. Schirra	6	9	13	11	9	13	11	19	35	38
5/15-16/63	Mercury-Atlas 9 Faith 7; Maj. Cooper	22	34	19	49	34	19	49	53	55	27

PROJECT GEMINI

DATE	MISSION	REVS.	S/C HRS.			MAN HRS.			CUM. MAN HRS.		
			H	M	S	H	M	S	H	M	S
3/23/65	Gemini 3, Molly Brown; Maj. Grissom, LCdr Young	3	4	53	0	9	46	0	63	41	27
6/3-7/65	Gemini 4; Majors McDivitt and White	62	97	56	11	195	52	22	259	33	49
8/21-29/65	Gemini 5; Lt. Colonels Cooper and Conrad	120	190	56	01	381	52	02	641	25	51
12/4-18/65	Gemini 7; Lt.Col. Borman, Cdr. Lovell	206	330	35	13	661	10	26	1302	36	17
12/15-16/65	Gemini 6; Capt. Schirra, Maj. Stafford	16	25	51	24	51	42	48	1354	19	05
3/16/66	Gemini 8; Armstrong, Maj. Scott	7	10	42	06	21	24	12	1375	43	17
6/3-6/66	Gemini 9 (A); Lt. Col. Stafford, LCdr. Cernan	44	72	20	56	144	41	52	1520	25	09
7/18-21/66	Gemini 10; Cdr. Young, Maj. Collins	43	70	46	45	141	33	30	1661	58	39
9/12-15/66	Gemini 11; Cdr. Conrad, LCdr. Gordon	44	71	17	08	142	34	16	1804	32	55
11/11-15/66	Gemini 12; Capt. Lovell, Maj. Aldrin	59	94	34	30	189	09	00	1993	41	55

-more-

PROJECT APOLLO

			S/C HRS.			MAN HRS.			CUM. MAN HRS.		
DATE	MISSION	REVS.	H	M	S	H	M	S	H	M	S
10/11-22/68	Apollo 7; Capt. Schirra, Maj. Eisele, Cunningham	163	260	8	45	780	26	15	2774	8	10
12/21-27/68	Apollo 8; Col. Borman, Capt. Lovell, Maj. Anders	2+10 Lunar	147	00	11	441	00	33	3215	8	43
3/3-13/69	Apollo 9; Col. McDivitt, Col. Scott, Schweickart	151	241	00	53	725	02	39	3456	01	36

-more-

UNITED STATES ASTRONAUTS

ALDRIN, Edwin E., Jr., Air Force Col.
ALLEN, Joseph P., Scientist-Astronaut (PhD)
ANDERS, William A., Air Force Lt. Col.
ARMSTRONG, Neil A., Civilian

BEAN, Alan L., Navy Lt. Comdr.
BORMAN, Frank (NMN) Air Force Colonel
BRAND, Vance DeVoe, Civilian

CARR, Gerald P., Marine Corps Major
CERNAN, Eugene A., Navy Comdr.
CHAPMAN, Philip K., Scientist-Astronaut (ScD)
COLLINS, Michael (NMN) Air Force Lt. Col.
CONRAD, Charles (NMN) Jr., Navy Comdr.
COOPER, L. Gordon, Jr., Air Force Colonel
CUNNINGHAM, R. Walter, Civilian

DUKE, Charles M., Jr., Air Force Major

EISELE, Donn F., Air Force Lt. Col.
ENGLAND, Anthony W., Scientist-Astronaut (PhD)
ENGLE, Joe H., Air Force Major
EVANS, Ronald E., Navy Lt. Comdr.

GARRIOTT, Owen K., Scientist-Astronaut (PhD)
GIBSON, Edward G., Scientist-Astronaut (PhD)
GORDON, Richard F., Jr., Navy Comdr.

HAISE, Fred W., Jr., Civilian
HENIZE, Karl G., Scientist-Astronaut (PhD)
HOLMQUEST, Donald L., Scientist-Astronaut (MD)

IRWIN, James B., Air Force Lt. Col.

KERWIN, Joseph P., Navy Comdr., Scientist-Astronaut (MD)

LENOIR, William B., Scientist-Astronaut (PhD)
LIND, Don L., Civilian (PhD)
LOUSMA, Jack R., Marine Corps Major
LOVELL, James A., Navy Captain

MATTINGLY, Thomas K. II, Navy Lt. Comdr.
McCANDLESS, Bruce (NMN) II, Navy Lt. Comdr.
McDIVITT, James A., Air Force Col.
MICHEL, F. Curtis, Scientist-Astronaut (PhD)
MITCHELL, Edgar D., Navy Comdr.
MUSGRAVE, Franklin S., Scientist-Astronaut (PhD) (MD)

PARKER, Robert A. R., Scientist-Astronaut (PhD)
POGUE, William R., Air Force Major

ROOSA, Stuart A., Air Force Major

SCHIRRA, Walter M., Navy Captain
SCHMITT, Harrison H., Scientist-Astronaut (PhD)
SCHWEICKART, Russell L. Civilian
SCOTT, David R., Air Force Col.
SHEPARD, Alan B., Jr., Navy Captain
SLAYTON, Donald K., Civilian (Dir. of Flight Crew Operations, MSC)
STAFFORD, Thomas P., Air Force Col.
SWIGERT, John L., Jr., Civilian

THORNTON, William E., Scientist-Astronaut (MD)

WEITZ, Paul J., Navy Comdr.
WORDEN, Alfred Merrill, Air Force Major

YOUNG, John W., Navy Comdr.

TOTAL 52

Air Force Officers	15
Navy Officers	14
Marine Corps Officers	2
Civilians	21

There are 15 Doctors, 11 PhD, 1 ScD, 4 MD (one MD is also a PhD and another MD is also a Navy Comdr.)

JANUARY 1969

NASA ASTRONAUT STATUS

Total selected:	66	
Resigned or Transferred		6
Deceased		8
		14
Total Active Astronauts:	52	

Selection Dates:

		Losses (and Actives)
Group I (7)	April 9, 1959	Carpenter, Glenn, Grissom (Active: Cooper, Schirra, Shepard, Slayton)
Group II (9)	Sept. 17, 1962	See, White (Active: Armstrong, Borman, Conrad, Lovell, McDivitt, Stafford, Young)
Group III (14)	Oct. 8, 1963	Bassett, Chaffee, Freeman Williams (Active: Aldrin, Anders, Bean, Cernan, Collins, Cunningham, Eisele, Gordon, Schweickart, Scott)
*Group IV (6)	June 28, 1965	Graveline (Active: Garriott, Gibson, Kerwin, Michel, Schmitt)
Group V (19)	April 4, 1966	Givens, Bull (Active: Brand, Carr, Duke Engle, Evans, Haise, Irwin, Lind, Lousma, Mattingly, McCandless, Mitchell, Pogue, Roosa, Swigert, Weitz, Worden)

*Scientist-Astronaut

*Group VI (11)	Aug. 4, 1967	O'Leary, Llewellyn (Active: Allen, Chapman, England, Henize, Holmquest, Lenoir, Musgrave, Parker, Thornton)

*Scientist-Astronaut

Details of Losses and Non-Actives:

1. Cdr. M. Scott Carpenter, USN, resigned September 1967 and transferred to U. S. Navy Project Sealab.

2. Col. John H. Glenn, USMC(Ret), resigned 1964 to enter Ohio politics, enter private business; remains NASA consultant.

3. Lt. Col. Virgil I. Grissom, USAF, died in Cape Kennedy Apollo 204 fire January 27, 1967.

4. Elliot M. See, Jr., Civilian, died in T-38 jet crash February 28, 1966, at St. Louis' Lambert Municipal Airport.

5. Lt. Col. Edward H. White II, USAF, died in Cape Kennedy Apollo 204 fire January 27, 1967.

6. Maj. Charles A. Bassett II, USAF, died in T-38 crash with See February 28, 1966, at St. Louis.

7. Lt. Cdr. Roger B. Chaffee, USN, died in Capc Kennedy Apollo 204 fire January 27, 1967.

8. Capt. Theodore C. Freeman, USAF, died in T-38 jet crash at Ellington AFB, Houston, October 31, 1964.

9. Maj. Clifton C. Williams, Jr., USMC, died in T-38 jet crash near Tallahassee, Fla., October 5, 1967.

10. Duane B. Graveline, Civilian Scientist-Astronaut, resigned in 1965.

11. Maj. Edward Givens, Jr., USAF, died in an automobile accident near Houston June 6, 1967.

12. Brian T. O'Leary withdrew April 23, 1968, for personal reasons.

-more-

13. Lt. Cdr. John S. Bull withdrew July 6, 1968, due to pulmonary disease.

14. John A. Llewellyn withdrew August 23, 1968, for personal reasons.

Astronauts Grissom, See, Bassett, Chaffee, Freeman and Williams were buried in Arlington National Cemetery with full military honors (See was a member of the USNR). Astronaut White was buried at USMA; Astronaut Givens was buried in Quanah, Texas, his hometown. Memorial services were held for each astronaut at local churches in the Manned Spacecraft Center, Houston, area.

-more-

THE NATIONAL AERONAUTICS & SPACE ACT OF 1958

The Declaration of Policy and Purpose of the National Aeronautics and Space Act is outlined in Section 102 (a) through (c) of PL 85-568 as follows:

Sec. 102.(a) The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.

(b) The Congress declares that the general welfare and security of the United States require that adequate provision be made for aeronautical and space activities. The Congress further declares that such activities shall be the responsibility of, and shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operation, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of, and shall be directed by, the Department of Defense; and that determination as to which such agency has responsibility for and direction of any such activity shall be made by the President in conformity with section 201 (e).

-more-

(c) The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

(1) The expansion of human knowledge of phenomena in the atmosphere and space;

(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;

(4) The establishment of long-range studies of the potential benefits to be gained from the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;

-more-

(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; and

(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment.

-more-

APOLLO PROGRAM MANAGEMENT

Direction of the Apollo Program, the United States' effort to land men on the Moon and return them safely to Earth before 1970, is the responsibility of the Office of Manned Space Flight (OMSF), National Aeronautics and Space Administration, Washington, D.C. Dr. George E. Mueller is Associate Administrator for Manned Space Flight.

NASA Manned Spacecraft Center (MSC), Houston, is responsible for development of the Apollo spacecraft, flight crew training and flight control. Dr. Robert R. Gilruth is Center Director.

NASA Marshall Space Flight Center (MSFC), Huntsville, Ala., is responsible for development of the Saturn launch vehicles. Dr. Wernher von Braun is Center Director.

NASA John F. Kennedy Space Center (KSC), Fla., is responsible for Apollo/Saturn launch operations. Dr. Kurt H. Debus is Center Director.

NASA Goddard Space Flight Center (GSFC), Greenbelt, Md., manages the Manned Space Flight Network under the direction of the NASA Office of Tracking and Data Acquisition (OTDA). Gerald M. Truszynski is Associate Administrator for Tracking and Data Acquisition. Dr. John F. Clark is Director of GSFC.

Apollo/Saturn Officials

NASA Headquarters

Lt. Gen. Sam C. Phillips, (USAF)	Apollo Program Director, OMSF
George H. Hage	Apollo Program Deputy Director, Mission Director, OMSF
Chester M. Lee	Assistant Mission Director, OMSF
Col. Thomas H. McMullen (USAF)	Assistant Mission Director, OMSF
Maj. Gen. James W. Humphreys, Jr.	Director of Space Medicine, OMSF
Norman Pozinsky	Director, Network Support Implementation Div., OTDA

-more-

Manned Spacecraft Center

George M. Low	Manager, Apollo Spacecraft Program
Kenneth S. Kleinknecht	Manager, Command and Service Modules
Brig. Gen. C. H. Bolender (USAF)	Manager, Lunar Module
Donald K. Slayton	Director of Flight Crew Operations
Christopher C. Kraft, Jr.	Director of Flight Operations
Charles A. Berry	Director of Medical Research and Operations

Marshall Space Flight Center

Maj. Gen. Edmund F. O'Connor	Director of Industrial Operations
Dr. F. A. Speer	Director of Mission Operations
Lee B. James	Manager, Saturn V Program Office
William D. Brown	Manager, Engine Program Office

Kennedy Space Center

Miles Ross	Deputy Director, Center Operations
Rear Adm. Roderick O. Middleton (USN)	Manager, Apollo Program Office
Rocco A. Petrone	Director, Launch Operations

Walter J. Kapryan	Deputy Director, Launch Operations
Dr. Hans F. Gruene	Director, Launch Vehicle Operations
John J. Williams	Director, Spacecraft Operations
Paul C. Donnelly	Launch Operations Manager

Goddard Space Flight Center

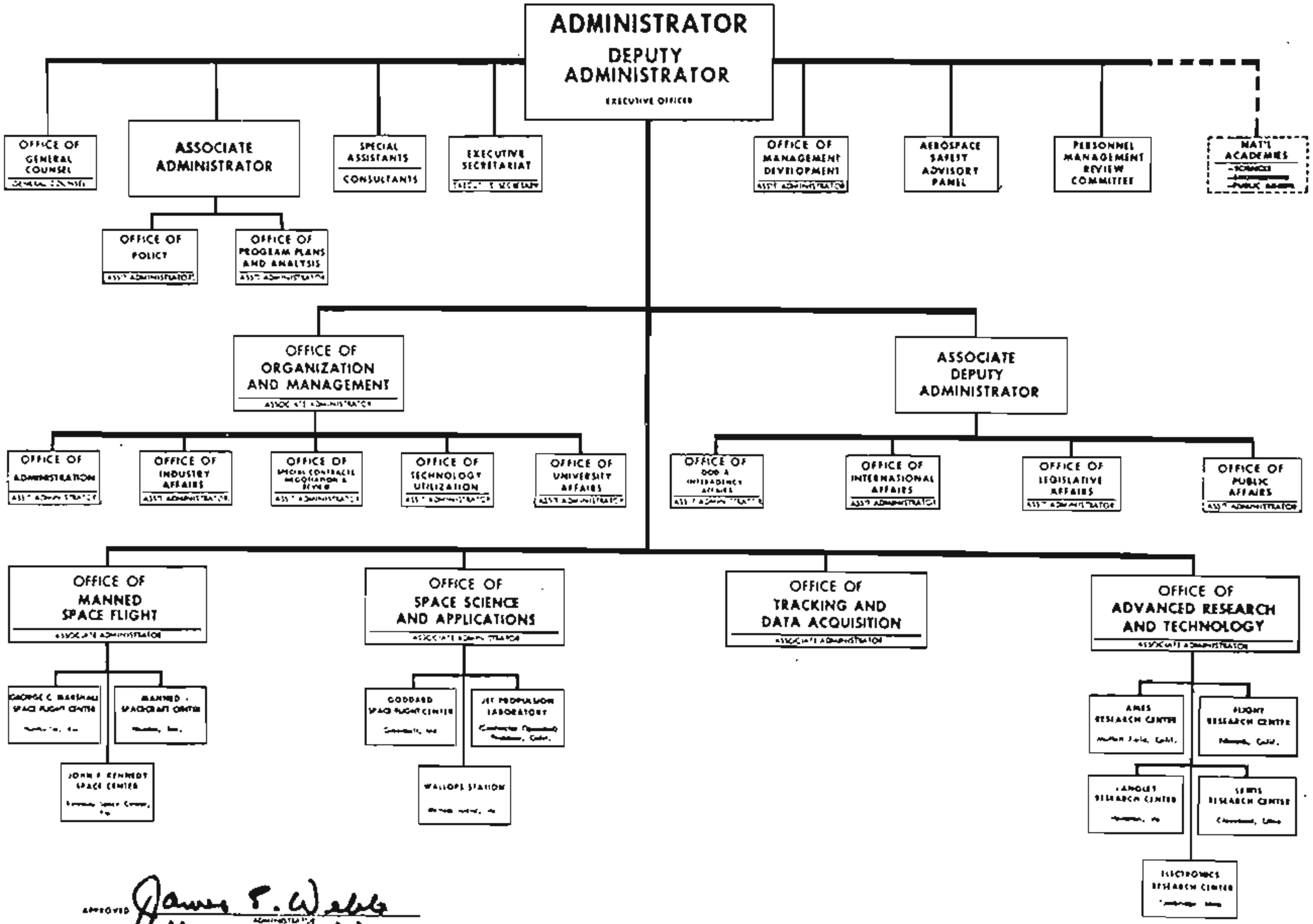
Ozro M. Covington	Assistant Director for Manned Space Flight Tracking
Henry F. Thompson	Deputy Assistant Director for Manned Space Flight Support
H. William Wood	Chief, Manned Flight Operations Div.
Tecwyn Roberts	Chief, Manned Flight Engineering Div.

Major Apollo/Saturn V Contractors

Contractor	Item
Bellcomm Washington, D.C.	Apollo Systems Engineering
The Boeing Co. Washington, D.C.	Technical Integration and Evaluation
General Electric-Apollo Support Dept., Daytona Beach, Fla.	Apollo Checkout and Reliability
North American Rockwell Corp. Space Div., Downey, Calif.	Spacecraft Command and Service Modules
Grumman Aircraft Engineering Corp., Bethpage, N.Y.	Lunar Module
Massachusetts Institute of Technology, Cambridge, Mass.	Guidance & Navigation (Technical Management)
General Motors Corp., AC Electronics Div., Milwaukee	Guidance & Navigation (Manufacturing)
TRW Systems Inc. Redondo Beach, Calif.	Trajectory Analysis
Avco Corp., Space Systems Div., Lowell, Mass.	Heat Shield Ablative Material
North American Rockwell Corp. Rocketdyne Div., Canoga Park, Calif.	J-2 Engines, F-1 Engines
The Boeing Co. New Orleans	First Stages (SIC) of Saturn V Flight Vehicles, Saturn V Systems Engineering and Integration Ground Support Equipment
North American Rockwell Corp. Space Div. Seal Beach, Calif.	Development and Production of Saturn V Second Stage (S-II)
McDonnell Douglas Astronautics Co. Huntington Beach, Calif.	Development and Production of Saturn V Third Stage (S-IVB)

International Business Machines Federal Systems Div. Huntsville, Ala.	Instrument Unit (Prime Contractor)
Bendix Corp. Navigation and Control Div. Teterboro, N. J.	Guidance Components for Instrument Unit (Including ST-124M Stabilized Platform)
Trans World Airlines, Inc.	Installation Support, KSC
Federal Electric Corp.	Communications and Instrumentation Support, KSC
Bendix Field Engineering Corp.	Launch Operations/Complex Support, KSC
Catalytic-Dow	Facilities Engineering and Modifications, KSC
ILC Industries Dover, Del.	Space Suits
Radio Corp. of America Van Nuys, Calif.	110A Computer - Saturn Checkout
Sanders Associates Nashua, N. H.	Operational Display Systems Saturn
Brown Engineering Huntsville, Ala.	Discrete Controls
Ingalls Iron Works Birmingham, Ala.	Mobile Launchers (structural work)
Smith/Ernst (Joint Venture) Tampa, Fla. Washington, D.C.	Electrical Mechanical Portion of MLs
Power Shovel, Inc. Marion, Ohio	Crawler-Transporter
Hayes International Birmingham, Ala.	Mobile Launcher Service Arms
United Aircraft Corp. Hamilton Standard Div. Windsor Locks, Conn.	Portable Life Support System for EVA
Bendix	ALSEP

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



APPROVED James E. Webb
ADMINISTRATOR

EFFECTIVE May 1, 1968
(Supersedes chart dated December 15, 1967)

-more-

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546
TELS. WO 2-4155
WO 3-6925

PUBLIC AFFAIRS DIRECTORY

NASA HEADQUARTERS

Washington, D. C.
20546

OFFICE OF PUBLIC AFFAIRS

NAME & TITLE	OFFICE PHONE	HOME PHONE
Julian Scheer Assistant Administrator	Area Code 202 963 - 5302	Area Code 703 347 - 3816
William L. Green Deputy Assistant Administrator	Area Code 202 962 - 2368	Area Code 703 280 - 1736
Richard T. Mittauer Public Affairs Officer	Area Code 202 962 - 0666	Area Code 703 836 - 2366
Alfred P. Alibrando Public Affairs Officer, OMSF	Area Code 202 962 - 0666	Area Code 202 337 - 1793
William J. O'Donnell Assistant Public Affairs Officer, OMSF	Area Code 202 962 - 0666	Area Code 703 JA 4 - 3665
Howard Allaway Public Affairs Officer	Area Code 202 962 - 0666	Area Code 202 347 - 8497
William W. Pomeroy Public Affairs Officer, OART	Area Code 202 962 - 3865	Area Code 703 931 - 7869
Donald L. Zylstra Public Affairs Officer, OSSA	Area Code 202 962 - 1176	Area Code 301 ST 9 - 6308

PUBLIC INFORMATION

NAME & TITLE	OFFICE PHONE	HOME PHONE
O. B. Lloyd, Jr. Director	Area Code 202 962 - 1736	Area Code 301 439 - 2564
Walter A. Pennino Deputy Director	Area Code 202 962 - 1737	Area Code 703 938 - 2495

Ralph Gibson News Chief	Area Code 202 963 - 6925	Area Code 301 530 - 4234
Miles Waggoner Feature Editor	Area Code 202 963 - 6925	Area Code 301 248 - 5495
John Kley Media Services, Query Desk	Area Code 202 962 - 4155	Area Code 301 292 - 2162
Barbara Selby Clearances, Accreditation	Area Code 202 962 - 4155	Area Code 301 864 - 0136
Joseph A. Stein Safety, University Affairs	Area Code 202 963 - 6925	Area Code 301 493 - 5975
Joseph McRoberts Backup for OSSA	Area Code 202 962 - 1176	Area Code 703 548 - 7151
Richard Friedman International Affairs	Area Code 202 962 - 1338	Area Code 202 333 - 8990
Mary Fitzpatrick Technology Utilization	Area Code 202 962 - 7387	Area Code 202 638 - 5494
Jack Keany Backup for OART	Area Code 202 962 - 3865	Area Code 301 647 - 6414
Kenneth Atchison Backup for OMSF	Area Code 202 962 - 0666	Area Code 301 292 - 3141
Louise Dick Backup for OMSF	Area Code 202 963 - 6927	Area Code 202 337 - 2822
Les Gaver Chief, Audio-Visual	Area Code 202 962 - 1721	Area Code 301 384 - 6125
William Taub Deputy Chief, Audio-Visual; Senior NASA Photographer	Area Code 202 962 - 1721	Area Code 301 262 - 9289
Ralph Gesell Audio-Visual Specialist	Area Code 202 962 - 1721	Area Code 301 871 - 7366
Walter Hering Audio-Visual Specialist	Area Code 202 962 - 1721	Area Code 301 577 - 1531
Joseph Headlee TV & Radio Assistant	Area Code 202 963 - 4086	Area Code 703 451 - 3023
James Cast Audio-Visual Specialist	Area Code 202 963 - 4086	Area Code 301 894 - 7832
Clayton Edwards TV & Radio Production	Area Code 202 962 - 2795	Area Code 703 538 - 4960

-more-

AMES RESEARCH CENTER

Moffett Field, California
94036

NAME & TITLE	OFFICE PHONE	HOME PHONE
Bradford A. Evans Public Affairs Officer	Area Code 415 961 - 1111 Ext. 2671	Area Code 415 948 - 2084

ELECTRONICS RESEARCH CENTER

575 Technology Square
Cambridge, Massachusetts
02139

NAME & TITLE	OFFICE PHONE	HOME PHONE
Edward Martin Public Affairs Officer	Area Code 617 494 - 2227	Area Code 617 GR 9 - 3637

FLIGHT RESEARCH CENTER

Post Office Box 273
Edwards, California
93523

NAME & TITLE	OFFICE PHONE	HOME PHONE
Ralph B. Jackson Public Affairs Officer	Area Code 805 258 - 3311 Ext. 221	Area Code 805 WH 2 - 5427

GODDARD INSTITUTE FOR SPACE STUDIES

2880 Broadway
New York, New York
10025

NAME & TITLE	OFFICE PHONE	HOME PHONE
Nicholas Panagakos Public Information Officer	Area Code 212 UN 6 - 3600 Ext. 262 & 263	Area Code 212 YU 2 - 5057

GODDARD SPACE FLIGHT CENTER

Greenbelt, Maryland
20771

NAME & TITLE	OFFICE PHONE	HOME PHONE
Edward Mason Chief, Office of Public Affairs	Area Code 301 982 - 6255 or 4955	Area Code 301 643 - 6240

-more-

JET PROPULSION LABORATORY

4800 Oak Grove Drive
Pasadena, California
91103

NAME & TITLE	OFFICE PHONE	HOME PHONE
Frank J. Colella Manager, Office of Public Information	Area Code 213 354 - 5011	Area Code 213 790 - 1652

JOHN F. KENNEDY SPACE CENTER, NASA

Kennedy Space Center, Florida
32899

NAME & TITLE	OFFICE PHONE	HOME PHONE
Gordon L. Harris Chief of Public Affairs	Area Code 305 867 - 2201	Area Code 305 783 - 1682
Arnold I. Richard Assistant for Programs	Area Code 305 867 - 2363	Area Code 305 632 - 8494
John W. King Deputy Chief of Public Affairs Acting Chief of Public Information Branch	Area Code 305 867 - 2468	Area Code 305 783 - 7272
Gatha F. Cottee Public Information Branch	Area Code 305 867 - 2468	Area Code 305 254 - 3424
Edward K. Harrison Public Information Branch	Area Code 305 867 - 2468	Area Code 305 632 - 0187
Charles T. Hollinshead Public Information Branch	Area Code 305 867 - 2468	Area Code 305 671 - 5104

JOHN F. KENNEDY SPACE CENTER, NASA

Unmanned Launch Operations
Western Test Range
P. O. Box 425
Lompoc, California
93438

NAME & TITLE	OFFICE PHONE	HOME PHONE
Walter Dundon Public Affairs Officer	Area Code 805 866 - 1611 Ext. 52015	Area Code 805 RE 5 - 1754

LANGLEY RESEARCH CENTER

Hampton, Virginia
23365

NAME & TITLE	OFFICE PHONE	HOME PHONE
H. Lee Dickinson Public Affairs Officer	Area Code 703 827 - 3966	Area Code 703 723 - 2021

-more-

LEWIS RESEARCH CENTER

21000 Brookpark Road
Cleveland, Ohio
44135

NAME & TITLE	OFFICE PHONE	HOME PHONE
Hugh W. Harris Chief, Public Information	Area Code 216 433 - 4000 Ext. 415, 438, 782	Area Code 216 932 - 3966

MANNED SPACECRAFT CENTER

Houston, Texas
77058

NAME & TITLE	OFFICE PHONE	HOME PHONE
Paul Haney Public Affairs Officer	Area Code 713 HU 3 - 3671	Area Code 713 HU 8 - 0706
Howard Gibbons Deputy Public Affairs Officer	Area Code 713 HU 3 - 4341	Area Code 713 HU 8 - 3861
Roy A. Alford Executive Assistant to the Public Affairs Officer	Area Code 713 HU 3 - 3671	Area Code 713 932 - 2857
Charles J. Bauer Administrative Assistant	Area Code 713 HU 3 - 3671	Area Code 713 WA 3 - 5139
John E. McLeaish Chief, Public Information	Area Code 713 HU 3 - 5111	Area Code 713 GR 1 - 3210
John E. Riley Information Specialist	Area Code 713 HU 3 - 5111	Area Code 713 GR 1 - 0624

MARSHALL SPACE FLIGHT CENTER

Huntsville, Alabama
35812

NAME & TITLE	OFFICE PHONE	HOME PHONE
Bart J. Slattery, Jr. Chief of Public Affairs	Area Code 205 453 - 0031	Area Code 205 881 - 4123
Foster A. Haley Deputy Chief of Public Affairs	Area Code 205 453 - 0032	Area Code 205 536 - 1909
Irene Shafer Administrative Officer	Area Code 205 453 - 0033	Area Code 205 355 - 2749
Joseph M. Jones Chief, Media Branch	Area Code 205 453 - 0034	Area Code 205 852 - 8847

-more-

(Marshall Space Flight Center)
MICHOUD ASSEMBLY FACILITY

P. O. Box 29300
New Orleans, Louisiana
70129

NAME & TITLE	OFFICE PHONE	HOME PHONE
William M. Bailey Chief, Business Management Office	Area Code 504 255 - 2605	Area Code 504 643 - 0244

(Marshall Space Flight Center)
MISSISSIPPI TEST FACILITY

Bay St. Louis, Mississippi
39520

NAME & TITLE	OFFICE PHONE	HOME PHONE
Mack Herring Public Affairs Officer	Area Code 601 688 - 3341	Area Code 601 863 - 0862

NASA PASADENA OFFICE

4800 Oak Grove Drive
Pasadena, California
91103

NAME & TITLE	OFFICE PHONE	HOME PHONE
Stan A. Miller Chief, Public Affairs Division	Area Code 213 354 - 6486	Area Code 213 888 - 1887

NUCLEAR ROCKET DEVELOPMENT STATION

P. O. Box 1
Jackass Flats, Nevada
89023

NAME & TITLE	OFFICE PHONE	HOME PHONE
Elizabeth McDevitt Public Information Office	Area Code 702 986 - 5723	Area Code 702 385 - 3695

(Las Vegas, Nev.: Area Code 702, 734 - 3011, Ext. 3591)

WALLOPS STATION

Wallops Island, Virginia
23337

NAME & TITLE	OFFICE PHONE	HOME PHONE
Joseph E. Robbins Public Information Officer	Area Code 703 824 - 3411 Ext. 248	Area Code 703 787 - 3836

John F. Kennedy Space Center

KENNEDY SPACE CENTER, FLORIDA

The John F. Kennedy Space Center comprises two federal installations which form the major launch base for the national space program. One is operated by the National Aeronautics and Space Administration and the other by the Department of Defense.

The NASA facility occupies 88,000 acres on Merritt Island, Florida. It extends 35 miles in a north-south direction, bounded on the east by the Atlantic Ocean and on the west by the Indian River. This is the site of the national Spaceport from which United States astronauts will journey to the moon and back.

Adjacent to the NASA installation is the Cape Kennedy Air Force Station, a Department of Defense facility managed by the United States Air Force. Launch complexes constructed and operated by NASA for manned and unmanned space exploration missions are located at the Cape. Other complexes are utilized by the Army, Air Force and Navy for the launch of defense weapons systems and space vehicles.

The Cape Kennedy Air Force Station is Station Number 1 of the Eastern Test Range which includes United States-owned tracking stations on islands stretching southeastward 10,000 miles to the Indian Ocean. These stations are instrumented with electronic and optical systems for tracking and obtaining in-flight operation data on both NASA and military vehicles and spacecraft.

Approximately 35,000 persons are employed in the launch programs at the two installations. Most work for aerospace companies that are members of the goverment-industry team which assembles, tests, prepares and launches rockets of varying sizes designed for specific space exploration tasks.

While Department of Defense activities at the Kennedy Space Center are concerned primarily with the development of weapons systems, NASA is engaged in the peaceful exploration of space.

Following the establishment of NASA on October 1, 1958, various government organizations previously engaged in launch operations at Cape Canaveral (now Cape Kennedy) were consolidated under the direction of the NASA Launch Operations Center, later renamed the John F. Kennedy Space Center, NASA. With the activation of the national Spaceport, the NASA Center moved to the present Merritt Island location.

Since the United States' first satellite was launched in 1958, a fixed launch concept has been employed in all major NASA programs. This concept requires assembly, integration and final checkout of the space vehicle at the launch pad. The method has proved satisfactory in programs to date. The size and complexity of the Apollo/Saturn V rocket, however, prompted evolution of the new mobile launch concept.

This concept consists of assembly, integration, and checkout of a space vehicle in the protected environment of a building. Then the flight ready vehicle is transported to the launch site. There, following final servicing and propellant loading, the vehicle is launched.

One of the major benefits realized in the mobile launch concept is a substantial reduction in the time a launch pad and supporting facilities are engaged in preparation for a mission. Manned Mercury and Gemini flights, for instance, required pad times of several months. For Apollo missions, the mobile launch concept can eventually reduce pad time to about 13 days.

The Kennedy Space Center's Launch Complex 39 provides the facilities to implement the mobile concept in support of the Apollo program.

The hub of operations at Launch Complex 39 is the Vehicle Assembly Building or VAB, as it is popularly known. Approximately 52 stories high and containing 129,482,000 cubic feet of interior space, it is the world's largest building. Assembly of the 363-foot-tall Apollo/Saturn V space vehicles take place inside the VAB.

The building contains two operational areas: a low bay area 210 feet high and a high bay area 525 feet high. The low bay houses eight preparation and checkout cells for the second and third stages of the rocket. The high bay contains four vertical bays for assembly, integration and checkout of the launch vehicle and spacecraft.

Located southeast of the VAB and connected to it is the Launch Control Center. This four-story structure is the electronic brain of Launch Complex 39. It contains four control and firing rooms, one for each corresponding high bay in the VAB. Each firing room is equipped to checkout and launch a space vehicle independently of the others.

-more-

Apollo/Saturn V space vehicles are assembled inside the high bays of the VAB on structures known as Mobile Launchers. The base of each structure is a two-story platform which houses computer systems, digitally controlled equipment for propellant loading, hydraulic test sets, propellant and pneumatic lines, electrical power systems and water systems. At one end of the platform is a 380-foot steel tower that provides support for nine swing arms (for direct access to the space vehicle), 17 work platforms and distribution equipment for propellant, pneumatic, electrical and instrumentation system. Mounted at the top of the tower is a 25-ton hammerhead crane. There are three Mobile Launchers at the Spaceport. Each stands 445 feet tall and weighs approximately 12,000,000 pounds.

Transportation, the key to the mobile launch concept, is provided by two tracked vehicles known as Transporters. Each vehicle is 131 feet long, 114 feet wide and weighs about 6,000,000 pounds. These units transfer the Mobile Launchers into the VAB to serve as assembly platforms for the space vehicles. After assembly and checkout of a space vehicle, a Transporter reenters the VAB, raises the Mobile Launcher with the assembled rocket, then transfers them three and one-half miles to a launch pad.

During the trip to the launch pad, the Transporter travels over a specially constructed roadbed 130 feet wide and divided by a 50-foot median strip. The roadbed is approximately eight feet thick and can support loads up to 18,000,000 pounds, the combined weight of the Transporter, Mobile Launcher and Apollo/Saturn V space vehicle.

Two launch sites are located at Complex 39. Each site is an irregular eight-sided polygon measuring 3,000 feet across. The major elements of the launch sites include storage tanks for rocket propellants, gas compressor facilities, electrical and communications systems, associated umbilical connections, the launch pads and various supporting equipment.

The launch pads, occupying the center of each launch site, are reinforced concrete hardstands measuring 390 feet by 325 feet. At the surface of each pad are six mount mechanisms to secure the Mobile Launcher with the flight ready space vehicle. Surface height of the pads is 48 feet, sufficient distance for the rocket's engine nozzles to rest above a 1,300,000-pound flame deflector.

Located near the launch sites is a 402-foot steel truss tower known as the Mobile Service Structure. After the Transporter has deposited the Mobile Launcher and space vehicle on the launch pad, it returns to the service structure parking area, picks up the Mobile Service Structure and deposits it on four mounted pedestals on the launch pad adjacent to the Mobile Launcher and vehicle. Weighing more than 9,800,000 pounds, the Mobile Service Structure provides 360-degree access to the rocket for final launch preparations at the pad. The Mobile Service Structure is returned to its parking area by the Transporter before launch.

Launch Complex 39 contains a barge terminal facility, consisting of an access canal, a turning basin, dock, barge slips and a materials handling area. The access canal is provided for marine barge vessels which deliver launch vehicle stages and related components as well as other types of heavy equipment. The canal runs eastward to the Banana River, which in turn leads to the Atlantic Ocean via Port Canaveral.

Five miles south of the launch area are the Headquarters of the Kennedy Space Center, NASA, and administrative, engineering and spacecraft preparation buildings. Apollo astronauts complete their preflight training in this area, employing simulators which duplicate the conditions they will encounter in space. The area also contains warehouses, medical facilities and other supporting elements.

Cape Kennedy, is a prime launching site for the nation's missile and space programs. Located approximately two miles east of the Kennedy Space Center's Merritt Island facilities, the Cape takes in a 27-square-mile area which was mostly uninhabited scrubland prior to 1950. It is bordered by the Atlantic Ocean on the east and the Banana River on the west.

Along the southern edge of the Cape is a deep water port to service the Eastern Test Range's fleet of tracking ships, Navy ships and nuclear submarines used in the Navy's Polaris missile development program. Within the Cape's boundaries are complete assembly and launch facilities for ballistic missiles and space vehicles, storage and dispersing stations for rocket fuels, and a landing strip for delivery of rocket stages, spacecraft, and other hardware from the manufacturer to the launch sites.

-more-

The Cape was activated by the Department of Defense as a missile test center in May 1949 and assigned to the Air Force for management. The first rocket launches from the Cape occurred July 24, 1950. Since then, all branches of the military have utilized the Cape's facilities for the development of defense weapons systems.

With the orderly growth of the national space program and its emphasis on the peaceful exploration of space, NASA has become a prime user of the Cape and Eastern Test Range. NASA's major launch organization, the Kennedy Space Center, operates and maintains launch facilities on the Cape to conduct manned and unmanned space launches.

The largest of these facilities are Launch Complexes 34 and 37 which were designed for the first and second generation Saturn rockets. Complex 34 became operational in October 1961 with the launch of the first Saturn I vehicle. Complex 37 was activated shortly afterward. At the completion of the Saturn I program, both launch complexes were modified to accommodate the more powerful uprated Saturn I rocket which is capable of placing the three-man Apollo spacecraft or the lunar module into earth orbit. Manned Apollo flights from these complexes will enable astronauts to practice rendezvous and docking techniques vital to the success of the forthcoming manned lunar landing.

Complexes 36A and 36B are the second largest launch complexes on the Cape and were designed for the Centaur vehicle, the first United States rocket to employ liquid hydrogen as a fuel. Centaur, launched by an Atlas booster stage, has successfully powered unmanned Surveyor spacecraft to landings on the moon. These sophisticated robots are exploring the lunar surface and environment in detail preliminary to manned landings.

Complexes 12 and 13 are utilized by NASA for Atlas/Agena rockets which launched Ranger and Lunar Orbiter spacecraft on photographic missions to the moon and Mariner spacecraft on flyby missions to the planets Mars and Venus. Other launches originating from these complexes include orbiting geophysical and astronomical observatories and advanced technological satellites.

The busiest launch site on Cape Kennedy is Launch Complex 17, home of the versatile Delta rocket which has orbited more than half of NASA's unmanned satellites. These include Echo, Relay, Telstar, Syncom and Early Bird communications satellites; the TIROS and ESSA weather reconnaissance series; and scientific satellites such as Explorer, Pioneer, Interplanetary Monitoring Platform, Geodetic Explorer and Orbiting Solar Observatory.

Several launch complexes on Cape Kennedy though no longer in active service, are historically significant. Complex 26, now the Air Force Space Museum, was the launch site for the first United States satellite, Explorer I. Complexes 5 and 6 were the launch sites for the early Mercury suborbital flights, the nation's first manned space missions. Originating from Complex 14 were the manned earth-orbiting missions of the Mercury program. This launch site was also used for the Gemini/Atlas-Agena target vehicles of the Gemini program. The successful Gemini manned space flight series originated from Complex 19.

Also located on the Cape are launch and test facilities for the Navy's Polaris and Poseidon missiles and the Air Force's Minuteman II ICBM. In addition, the Air Force operates and maintains a Titan III-C Integrate-Transfer complex located adjacent to the Cape on man-made islands in the Banana River.

Manned Spacecraft Center

HOUSTON, TEXAS

The Manned Spacecraft Center, one of the newest and largest research and development facilities of the National Aeronautics and Space Administration, serves as a focal point for this Nation's manned space flight program. The facilities that exist at the Manned Spacecraft Center (MSC), about 25 miles from the center of downtown Houston, Texas, form a national resource for accomplishing a five-fold job:

- Developing the technology required for manned spacecraft in present and future programs
- Managing the efforts of industry in the detailed design, development, and fabrication of spacecraft for on-going programs
- Selecting and training the astronauts for NASA's *manned space flights*
- Exercising control over the NASA manned space flights from the time of launch until a landing is accomplished
- Managing the medical, scientific, and engineering experiments that are conducted during manned space flights.

In all of this effort MSC is assisted and supported by other NASA Centers, by various other civilian government agencies, the Department of Defense, industry, many universities, and many other nations in the free world.

MSC and its predecessor, Space Task Group, have successfully completed the Mercury and Gemini programs which gave the United States its first experiences with man's capabilities in space flight and the opportunity to develop many of the operational techniques upon which the Apollo lunar landing program depends.

The Mercury program, which included two suborbital and four orbital manned missions, was operationally completed May 15-16, 1963, when the "Faith 7" spacecraft touched down in the Pacific Ocean.

The Gemini program included ten manned flights utilizing a two-man spacecraft. The first manned Gemini flight was made March 23, 1965, and the tenth and final manned mission, that of Gemini XII, flown November 11-15, 1966. It achieved the objectives of further investigating man's capabilities of performance in the weightless environs of space, proving the feasibility of rendezvous and docking of two vehicles in space, determining the ability of man to function in space while outside his spacecraft, and performing many scientific experiments.

The Apollo program was established to develop the industrial, technological, and management capabilities required to make the United States preeminent in this new age of technology, and able to carry out the national aim of exploring space for the benefit of all mankind. A specific objective of the program is a manned landing on the moon and safe return to earth within the decade.

In the Apollo program three men will follow a translunar trajectory to orbit the moon. Two of the men will enter the lunar module and descend to the surface of the moon to perform limited exploration and secure samples of the lunar surface. They will then ascend in the lunar module to rendezvous with the mother craft and return to earth.

All MSC activities are carried out under the supervision of the Center Director, six functional directors, and program office managers. The functional directors are: Director of Engineering and Development; Director of Flight Crew Operations; Director of Medical Research and Operations; Director of Science and Applications; Director of Flight Operations; and the Director of Administration.

The two program offices now active are: Apollo Spacecraft Program Office; and the Apollo Applications Program Office. All manned space flights are controlled from liftoff through recovery from the Mission Control Center at MSC. This facility includes several major electronic subsystems—communications, displays, simulation and training, and computers. It contains two mission control rooms and can support both a manned flight and a simulated flight simultaneously.

-more-

Other major facilities in the 1620-acre complex at MSC are:

- The Space Environment Simulation Laboratory tests spacecraft under simulated space environmental conditions. The laboratory has two space simulator chambers. Chamber A is 120 feet high and 65 feet in diameter and Chamber B is 43 feet high and 35 feet in diameter. Possible temperature extremes range from plus 260 degrees to minus 280 degrees Fahrenheit.
- The Flight Acceleration Facility contains a centrifuge and its chamber area. The centrifuge's gondola is 12 feet in diameter and weighs 8000 pounds with three occupants and instrumentation. This load may be whirled at the end of its 50-foot arm at 20 g's continuously or up to 30 g's for short duration.
- An Anechoic Chamber Test Facility in which spacecraft communications systems are tested in an echo-free environment.

Manned Spacecraft Center is the site of the Lunar Receiving Laboratory which will be the initial distribution point for lunar rock samples to the scientific community. One hundred and ten scientists have been named to examine the lunar material brought back by the first Apollo astronauts to land on the moon. Preliminary biological, geological, and chemical analysis will be performed in this laboratory during a quarantine period. This facility will also serve as a quarantine area for astronauts returning from the lunar mission. The National Academy of Sciences recommended the latter procedure to NASA.

As stated previously, one of the major management responsibilities of the Manned Spacecraft Center is that of selecting and training flight crew members. The development of a pool of trained flight crew members has been constant since 1959, and the number of astronauts and scientist-astronauts has increased as additional programs have been assigned. All astronauts are given thorough training in a wide variety of subjects to keep them abreast of the rapidly changing developments in space oriented hardware and operations. This training ranges from formal classroom work to jungle, water, desert, and Arctic survival—from practicing getting out of a spacecraft to the practice of removal of experiment packages in a simulated weightless condition. In addition, when crews are named for a specific flight they engage in full-time preparation for such a mission. This includes spending hundreds of hours in flight simulators.

With Mercury and Gemini completed emphasis at Manned Spacecraft Center is now being placed on the Apollo and the Apollo Applications programs. Apollo Applications has been designated as the follow-on program to Apollo; and MSC will have an important role to play in program planning, in supplying the crew members, and in controlling the flights from its Mission Control Center.

The Science and Applications Directorate of MSC provides a point of contact for scientists throughout the country interested in taking part in the manned space flight program. Its chief areas of responsibility include:

- Lunar science programs;
- Earth resources programs;
- Meteorology investigations using manned spacecraft;
- Providing environmental data to support spacecraft and mission design in space physics investigations;
- Conceiving, developing, and integrating experimental instrumentation and equipment for science and applications program;
- Providing design data and real-time mission information on radiation, micrometeorites and lunar surface conditions for manned missions.

In the earth resources applications areas, Manned Spacecraft Center will assess a variety of flight systems and data acquisition approaches to aid in pollution studies, in oceanography work, and in more accurate geological and geographical mapping. It will study potential benefits to be derived from manned space application programs, such as more effective determination of world crop status and better assessment of the world's water supply. Much of this applications work will be done in cooperation with other NASA Centers and government agencies.

Marshall Space Flight Center

HUNTSVILLE, ALABAMA

Development of large launch vehicles such as Saturn V and spacecraft for deep space and near-earth missions and studies of future space exploration projects are the prime responsibilities of the Marshall Space Flight Center. Named for General George C. Marshall, the Center is National Aeronautics and Space Administration's largest installation.

The joint responsibility of its more than 7,000 employees is the development of large rockets, and the development of spacecraft such as the Orbital Workshop which can sustain astronauts on missions of up to 58 days. Marshall Center scientists and engineers have designed many of this country's rockets, including the Redstone, Jupiter, Saturn I, Uprated Saturn I and Saturn V. They are presently laying the groundwork for the Apollo Applications Program which will use the Apollo elements for other manned missions in earth orbit. The future program will exploit the investment in the Apollo program by applying its wide range of capabilities to a number of other potential missions. The Orbital Workshop is a part of this effort.

A CHANGING ROLE

Marshall earlier had the capability of developing and manufacturing launch vehicles almost entirely within its own facility. This work was done in several major laboratories and manufacturing facilities. To maintain its role in the ever-expanding space exploration picture, the Marshall Center organization has adjusted to a changing role. While the Center still maintains its strength in the technical expertise of the space team built up in its major laboratories over the years, management has taken into account the fact that its space assignments are now too big to be handled in-house. As a result, to a much larger extent than before, work on the Saturn rockets and other missions is performed by industry through a series of prime contracts.

The two major organizational elements of the Marshall Center are Research and Development Operations and Industrial Operations.

Industrial Operations' program offices serve as management centers to administer contracts to private industrial firms who assist with Marshall Center missions. These offices must see that all the various components and stages are built to specifications and will work together when assembled into complete vehicles.

It is the responsibility of Research and Development Operations to insure that the Marshall Center remains expert in the basic aspects of space technology. Industrial Operations provides the capability of managing the efforts of industry.

OTHER FACILITIES

Industrial Operations also directs two government-owned facilities that extend the manufacturing and testing capability of the Marshall Center: Michoud Assembly Facility in New Orleans, Louisiana, and Mississippi Test Facility located in Hancock County, Mississippi. Although located in separate states, the two installations are only about 45 water miles apart. Both are linked with the Marshall Center by water routes traveling over the Mississippi, Ohio and Tennessee rivers.

Michoud is the production site for rocket first stages for the Uprated Saturn I and the Saturn V. Michoud's manufacturing building is one of the largest single-floor buildings in the country, covering almost 43 acres. It is 15 miles east of downtown New Orleans and located on the intracoastal water route.

Mississippi Test Facility provides the rocket-testing stands, test control and support units, laboratories, and an industrial complex capable of acceptance testing both the first and second stages of the Saturn V. The central test area of 13,427 acres is surrounded by a sound buffer zone (128,526 acres). Through a series of canals, the large rocket stages can be lifted directly from barges onto the test stands at the Mississippi site.

Industrial Operations presently has five program offices. These are:

1. Saturn I and Uprated Saturn I
2. Saturn V
3. Engine Program Office
4. Mission Operations
5. Saturn/Apollo Applications

Industrial Operations has a group of staff offices that include:

1. The Contracts Office
2. Facilities Projects Office
3. Project Logistics Office
4. Resources Management Office

RESEARCH AND DEVELOPMENT OPERATIONS

Eight major laboratories in Research and Development Operations perform the basic functions of design, development, fabrication and testing of launch vehicles and payloads. Research and Development Operations also provides in depth technical support to contractor operations.

R&D Operations has four offices and eight laboratories. The four offices are:

Advanced Systems Office—Advanced space technology for future space flight systems.

Technical Systems Office—Overall systems engineering in support of Saturn program.

Experiments Office—Development and management of in-house experiment activities.

Operations Management Office—Resources management and the coordination of technical support to Industrial Operations.

The eight laboratories are:

Aero-Astrodynamics—Rocket shape and design, aerodynamic flow and stability, trajectories, flight evaluation and performance.

Astrionics—Guidance, control, and communications, power supplies, electrical networks, telemetering equipment.

Computation—Computation, simulation, and data reduction in related space fields.

Manufacturing Engineering—Large structures fabricated and assembled. Prototype boosters, space vehicles produced.

Propulsion and Vehicle Engineering—Structures, mechanics, propulsion vehicle systems, systems integration, and materials.

Quality and Reliability Assurance—Performance of space vehicles is assured through checkout before and after test firings.

Research Projects—Scientific research of new concepts in specified fields and studies of possible future programs.

Test—Experimental and developmental testing programs of launch vehicles, components, and other systems.

PHYSICAL DESCRIPTION

Marshall Center consists of about 1,800 acres within the 40,000 acre Redstone Arsenal located just southwest of Huntsville in north-central Alabama. Total estimated value of real estate holdings and government property is more than $300 million. The Center consists of more than 270 structures and buildings with floor space totaling about four million square feet.

-end-